Learning dynamics in social dilemmas

Macy, M.W.; Flache, A.

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

[Link to publication in University of Groningen/UMCG research database](#)

L

L1 Learning Process

► Language Acquisition and Development

L1-L2 Facilitation/Inhibition

► Cross-Linguistic Influence and Transfer of Learning

L2 Acquisition

► Second Language Learning

La Fixité Du Milieu Intérieur or Stability of the Internal Environment

► Physiological Homeostasis and Learning

Laboratory Learning

Cecilia Ka Yuk Chan
Centre for the Enhancement of Teaching and Learning, University of Hong Kong, Hong Kong, China

Synonyms

Experiment; Experiential education; Hands-on learning; Practical learning

Definition

Laboratory learning is learning that takes place in a space where students can observe, practice, and experiment with objects, materials, phenomena, and ideas either individually or in groups. This learning is not confined within a physical laboratory space, but can also occur in various forms of space such as the e-learning management system and computer-simulated virtual laboratories.

Within the laboratory, learning may occur in many ways, often through observing a case or phenomena, performing hands-on practical trainings, or conducting experiments. The primary aim of arranging laboratory learning for students is to develop the practical competence often within their area of specialization. Laboratory learning provides opportunities for students to relate and reinforce the theoretical concepts taught in class. It also targets a range of learning outcomes including experiential learning process that cannot be developed explicitly through lectures and tutorials. Students learn by doing, and then drawing meaning and understanding from these experiences. Contrary to lectures where students are often only passive participants, laboratory learning allows students to be actively engaged in their learning. The importance of direct experience with objects, materials, and phenomena is that this allows students to build true understanding that is functional and develop the ability to inquire actively. Effective laboratory sessions can achieve many desirable outcomes, including increasing students' interests in their academic discipline, discouraging rote learning, and motivating students to participate in the process of investigation and inquiry, thereby leading to the development of higher-level cognitive skills.

Most laboratory learning is assessed as formative assessment. For the usual settings such as conducting experiments, students are normally given the experimental objective, design and procedures, and are asked to carry out the experiment by following the given instructions carefully. Depending on the task, they may be asked to work individually or in groups. During the laboratory session, teachers and demonstrators

would offer assistance and support to the students, providing feedback and suggestions. The objectives of the experiment usually involve students testing or applying the hypotheses, collecting data and taking measurements accurately in the experimental tasks, analyzing and interpreting the results, and also summarizing and evaluating the experiment. Often as part of the formative assessment, students are asked to write a report after performing the experimental procedures. Such reports may include objectives, description of the experiment including method used, results, discussions, and conclusions. In addition, teachers may assess students on the actual experiment during the laboratory hours on their practical skills and their understanding of the laboratory experiments through direct observations or oral questioning. Of course, students may also be assessed on the end product and the results of the experiment. These are common assessment methods for laboratory learning.

Theoretical Background

The idea of learning from experiences and observation in education to enrich students with solid experience to objects and concepts can be traced back to as early as the eighteenth century. Pestalozzi (1746–1827), an educational reformer who opposed the ideas of corporal punishment and rote memorization for instructional purposes, recognized the importance of learning through activity and through objects. In the 1860s, Pestalozzi's ideas of using objects in education were spread to America. This movement influenced many science committees in America, which repeatedly stressed the importance of practical experiences to students. According to the National Education Association in 1893, "the study of books is well enough and undoubtedly important, but the study of things and of phenomena by direct contact must not be neglected."

Laboratory learning before the 1950s was largely based on confirmation of concepts, delivery of knowledge, and procedural routines, without broadening the capability and knowledge inquiry of students. Active learning were further advocated by the American education reformer – John Dewey (1859–1952) – in his progressive education movement "*learn by doing*" approach. By 1970s, all major science degree programs had included laboratory learning as part of their curriculum. Laboratory learning was initially designed and developed only for science-related education; it has

however gradually developed to other disciplines such as arts, social science, and medicine as educators recognize the benefits of laboratory learning. Laboratory learning is particularly common in engineering and science-related disciplines. In fact, laboratory learning is a mandatory curriculum criterion for scientific program such as engineering to achieve its academic accreditation status with the recognized professional body.

Historically, the primary aim of laboratory learning for students was to develop the practical competence within their area of specialization in order to make sense of the theoretical concepts taught in class. However, by the twentieth century, laboratory learning was no longer merely aimed at practical competence, but has shifted to other educational outcomes such as communication skills, collaboration, problem solving, and creative thinking. These learning outcomes constitute an important part in the research cycle for scientific inquiries, which provides the empirical basis for the establishment and refinement of theories and indications for making predictions. It causes students to rely on evidence generated from their own practical experiments instead of relying on information provided solely by teachers and textbooks. It ensures that students do not only learn the body of scientific knowledge, but also the processes in which it has been developed. Several researchers like Shulman and Tamir (1973) developed various objectives for laboratory pedagogy. These objectives included transforming laboratory learning as the core of the science learning process rather than just a pure confirmation step, establishing students' higher level of cognitive skills like problem solving, creative thinking, inquiry skills, and appreciation of the scientific theories and models. The promotion of communication, positive attitude toward the discipline, and the need to foster deep learning were also established. These objectives have since been the fundamental goals of laboratory learning.

Important Scientific Research and Open Questions

Laboratory learning is an important element of meaningful and holistic learning. While there seems to be general consensus that laboratory sessions are indeed necessary, most studies on science education seem to focus on curriculum design, new in-class or laboratory

learning activities, and technologies. Laboratory curriculum design and its learning outcomes tend to be excluded from educators' interests (Feisel Lyle and Rosa 2005). Hofstein and Lunetta (2003) have reported two critical reviews on laboratory activities in science education, featuring the role of laboratory work and the effectiveness of pedagogies used in laboratory learning. The most frequent problem arose is that the learning outcomes of the laboratory activities is often not necessarily understood by students and teachers, and there appears to be a mismatch between students' perceptions and the intended learning outcomes. Insufficient laboratory hours, poor assessment, and experiment design – not aligned with the learning outcomes of laboratory learning, overloading students to recall learning materials, and blindly follow the "recipe" style laboratory manual – are all factors that inhibit laboratory learning. Such distinction was ambiguous during the early 1980s, as research at that time failed to develop relationships between experiences in the laboratory and student learning, as well as how the laboratory methodologies or strategies are related and interacted to achieve the learning outcomes. Moreover, these investigations often omitted or underestimated the importance of teachers' perspectives and attitudes towards laboratory sessions, interaction among student-to-student and student-to-teachers, student behavior, generic skill acquisition, and higher order intellectual development. By incorporating the inquiry learning theory into laboratory work, students are able to propose ideas, discuss, explain, and justify assertions upon evidence determined from the experimental process, hence there can be a true and authentic reflection of student's critical thinking logic and problem solving abilities. Sufficient time and opportunities for metacognitive activities during lab session are also essential. This allows students to rethink, give feedback, and elaborate on one's learning, increase interaction among students, thus well-designed experiment protocol would indeed account for the success of the lab session. Moreover, the interactive experience students gained in labs by working in small groups promotes cooperative learning as students are collectively engaged to collaborate in inquiry. This promotes and creates a community of learners which will be future experts themselves.

With the recent advances technologies, a new mode of laboratory known as "Virtual Laboratory" has begun to revolutionize science education. Some of the "used to be" physical laboratory elements have been adapted into computerized laboratory environment, ranging from simple pre-lab, to computer simulated laboratory, and to the more advanced 3-dimensional visualization models. This development has generated some attention and discussion on the fundamental learning outcomes of laboratory and ultimately, an interest in the changes within the learning experiences of students in laboratory learning (Chan and Fok 2009). Virtual laboratory can be defined as an environment for experiments which is conducted or controlled partly or wholly through computer operation, simulation, and/or animation locally or remotely via the internet. With regards to computer animation type of virtual laboratory, the experiment is often a graphical model of the actual experiment. This type of virtual laboratory does not include physical hardware, but allows the user to observe the process and the end product by way of animation. Some systems allow users to control the process and the end product using some controllable variables of the experiment in the software. The computer simulation type of virtual laboratory usually contains some physical instruments and hardware. The simulation may be the data acquisition part and/or the components. The computer operation type of virtual laboratory is often the actual physical laboratory with the actual components in a confined space that a user can remotely access through a computer. This has the advantages of accessing the laboratory that maybe restricted due to safety, time, and distances issues. At Carnegie Mellon, students can assess and conduct actual experiments in the EEE virtual laboratory remotely using a personal computer. The system also has a live-video capability so students can observe the experiment as if they were physically there. The technology greatly enhances the flexibility of laboratory education.

An effective computer laboratory environment is not possible unless proper interaction exists among students, teachers, and resources. In recent years, studies on students' perception on the effectiveness of laboratory learning were reported. An on-going exploratory case study by Chan and Fok (2009) on the effectiveness of virtual laboratories in electrical and electronic engineering (EEE) at a research intensive university was reported. The report indicated that virtual laboratories were generally well received by

L

students; however, responses indicated that students perceived traditional labs as more easy to operate and easy to understand. Given the above attitudes, students' responses concerning whether virtual laboratories could substitute traditional laboratories to provide a comparable learning experience are understandable. Newby and Marcoulides (2008) reported that students in a *cohesive* group in an open-ended approach laboratory class integrated with appropriate technology had found the laboratory environment particularly desirable. However, such optimized environment is highly dependent on various factors such as university strategic policy, resource availability, teacher's initiative, and laboratory design, as well as student's cohesiveness. With the uniqueness of laboratory learning, there is no single recipe for an optimal laboratory learning environment whether it is physical laboratory or computer laboratory, although one can still establish criteria to evaluate its effectiveness in teaching and learning. More research efforts would be needed to accommodate the differences among the skill levels, cultures, talents, aptitudes of the students and teachers, as well as the suitability of the laboratory environment and strives to achieve a balance of knowledge delivery and student experience. Though Dewey's philosophy has long been realized, it still stays true that "if knowledge comes from the impressions made upon us by natural objects, it is impossible to procure knowledge without the use of objects which impress the mind" (Dewey 1916/2009).

Cross-References

▶ Constructivist Learning
▶ Evaluation of Student Progress in Learning
▶ High Performance Learning Spaces
▶ Inquiry Learning
▶ Metacognition

References

Chan, C. K. Y., & Fok, W. W. T. (2009). Evaluating the learning experiences in virtual laboratory training in electrical and electronic engineering through student perceptions - a case study in the University of Hong Kong, engineering education. *The Journal of the Higher Education Academy Engineering Subject Centre, 4*(2), 70–75.

Dewey, J. (1916). *Democracy and education.* New York: Macmillan.

Dewey, J. (2009). Education as engineering. *Journal of Curriculum Studies, 41*, 1–5.

Feisel Lyle, D., & Rosa, A. J. (2005). The role of the laboratory in undergraduate engineering education. *Journal of Engineering Education, 2005*, 121–130.

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28–54.

Julieta, N., & Enrique, S. L. (2006). Intelligent virtual laboratory and project-oriented learning for teaching mobile robotics. *International Journal of Engineering Education., 22*(4), 743–757.

Newby, M., & Marcoulides, L. D. (2008). Examining student outcomes in university computer laborary environments. Issues for educational management. *International Journal of Educational Management, 22*(5), 371–385.

Shulman, L. D., & Tamir, P. (1973). Research on teaching the natural sciences. In R. M. W. Travers (Ed.), *Second handbook of research on teaching* (pp. 1098–1140). Chicago: Rand Mc Nally.

Ladygina-Kohts N. (1890–1963)

Zoya A. Zorina
Department of Biology, Lomonosov Moscow State University, Moscow, Russia

Life Dates

Ladygina-Kohts, Nadezda Nikolaevna, was born on 6 (18).05.1889 in the city of Penza, Russia. Her father worked as a teacher of music in a college, her mother had no education. Nevertheless, Nadezda had an excellent education derived in a gymnasium. In 1917, she graduated with honors from Moscow Higher Lady's Courses and maintained her degree work at Moscow State University. She was a remarkable, beautiful woman with a brilliant scientific mind. Her scientific interests were defined very early, and an interest to the Charles Darwin theory of evolution was one of the main things. A while after, she cast her lot with her husband, Alexander F. Kohts (1880–1964) and dedicated her entire life to Darwin Museum (Moscow) created by him.

A. Kohts was a famous Russian zoologist closely adhered to the theory of evolution. In 1907, he had founded in Moscow a museum based on his private zoological collections illustrating the main principles of Darwin's theory of evolution, the reason why later on it was named after Darwin. It was the first and only one in Russia museum of natural history. For her entire life, Ladygina-Kohts assisted in expanding the museum

collections and invested much of her energy to the scientific and educational activities carried out by the Darwin museum. She is the author of the world's first museum exposition devoted to the evolution of behavior. It is, after all, much for her credit that Darwin museum became very popular in Russia (400,000 visitors every year) and has grown to obtain international recognition. In 1911, she founded Zoopsychology department at the Darwin museum aimed at studying the evolution of animal cognition. Most of her experimental data were obtained there.

In 1941 she defended a doctoral thesis. From 1945, she worked also as a senior researcher at the Institute of Philosophy of USSR Academy of Science, while in the 1950s, she was also a lecturer at Department of Philosophy of Moscow State University.

Many famous Russian psychologists were nurtured by her ideas and studies (K.E. Fabri, S.L. Novoselova, L.A. Paramonova, M.A. Deryagina, G.G. Philippova, M.L. Butovskaya, D.B. Bogoyavlenskaya, V.S. Mukhina et al.); some of them would continue her scientific work.

From the very start of her research, she had been publishing books and papers not only in Russian but also in other European languages. In 1910s she has visited several European biological institutes and museums of natural history. It helped her keep in touch with a number of foreign colleagues (J.S. Huxley, E. Claparède, J. Dembovsky, and many others), who had visited later her laboratory in the Darwin museum to know more about her investigations. Within long years she kept in touch with the famous American primatologist R. Yerkes. Their correspondence of many years is stored in the Darwin Museum. In 1930s, he visited twice her laboratory.

Ladygina-Kohts is widely recognized as one of founders of Russian zoopsychology. Most of her works were ahead of their time, and some are still quite up-to-date to exert a profound influence on the development of modern comparative psychology, primatology, anthropology, human ethology and cognitive science. She published more than ten monographs and several dozens of articles contributing to different aspects of great apes' behavior and cognition to give the evidence of their demonstrating a premise of human intelligence.

Ladygina-Kohts was awarded Honored Scientist (1953), Lenin Order and medals. She died in Moscow on 03.09.1963 (Novoselova 1997).

Contribution(s) to the Field of Learning

The contribution made by Ladygina-Kohts to the study of animal learning and cognition stemmed from her experiments with an infant chimpanzee, Jony. In 1913–1916, at an age between 1.5–4 years, he lived in Kohts' family, like an adopted child, and was a subject of regular observations and experiments (Fig. 1). That was, perhaps, the first systematic study of behavior and mentality of great apes, which made it possible to describe their instincts, external expression of emotions, and mimic, locomotion and manipulation patterns as well as the ways they display their emotions, play and acquire their habits. It was, moreover, a developmental study following the ontogenesis of the most important behavioral traits.

Apart from thousands of the diary pages, the results of this work were recorded in hundreds of sketches and photographs illustrating virtually every detail of Jony's behavior. They were complemented by investigations on Jony's memory and his cognitive and learning abilities. It was shown that the chimpanzee is capable not only of learning but also of abstraction and concept formation. Thus, Ladygina-Kohts was the first scientist to prove experimentally that animals can master elementary reasoning. These results were summarized in the first Ladygina-Kohts's monograph (1923, in Russian) entitled "Poznavatel'naya deyatel'nost shimpanze" ("Chimpanzee Cognition").

Almost 10 years after Jony's death, a son, Roody (1925–2008), was born in her family. His early behavior was studied and described as thoroughly as it had been with the infant chimpanzee (Fig. 2). Thus, it was an unbiased and definite answer to the question about how far the distance between man and ape is. This comparative work became the base for a capital monograph (1935, 2011, in Russian) under the title "Ditya shimpanze I ditya cheloveka v ikh instinktakh, emotsiyakh, igrakh, privychkakh I vyrazitel'nykh dvizheniyakh" ("Infant Chimpanzee and Human Child in their instincts, emotions, games, habits and expressive gestures"). The second volume of this issue includes 160 plots, every containing a selection of photographs showing the similarities and dissimilarities between a human child and a infant chimpanzee in various form of their behavior and psychological traits.

"Infant Chimpanzee and Human Child …" is a milestone book in comparative psychology. It would

Ladygina-Kohts N. (1890–1963). Fig. 1 (a) Ladygina-Kohts and chimpanzee Jony (the photo was made in 1915) on a frontispiece of her book "Poznavatel'naya deyatel'nost shimpanze, 1923". (Reprinted with permission of the State Darwin Museum). (b) Ladygina-Kohts and Robert Yerkes (a famous American psychologist, he is rightmost in the picture) in the State Darwin Museum, 1930. (Reprinted with permission of the State Darwin Museum)

be no *overstatement* to say that Ladygina-Kohts pioneered in the studies concerning numerous aspects of the chimpanzee behavior and intelligence. She was the first one who described and compared several important psychological traits:

- Mirror-self-recognition: she compared the reaction demonstrated by human and anthropoid babies to their own images appearing in a mirror, and revealed that both under four years cannot recognize himself in the mirror, the fact entirely supported by recent data.
- Picture-making: she discovered, again for the first time, that the chimpanzee will readily draw or paint;
- Using the indicating gesture by infant chimpanzee;
- She also described the elements of theory of mind, social cognition and Machiavellian intelligence that this species possesses, which, according to recent studies, are characteristic features of the great ape cognition;
- Her attempt to analyze how humans and anthropoids communicate was the earliest in science, too.

It promoted a detailed comparison of human and anthropoid ontogenesis in terms of behavior and intelligence as well as an unbiased description of the features they have in common and those distinguishing them. An example of such comparison was summed up in an extensive table where 51 behavior traits were analyzed, each entry split into patterns typical for only one species and those shared by both. The author concluded with the idea that, despite many external similarities in behavior, "... in the final analysis we can see the creatures diverge. Ultimately, it appears clear that the more vital features are compared the oftener we see a chimpanzee ahead of a human; whereas the subtler and loftier psychological matters are drawn into our analysis the more often a chimpanzee will be behind" (Ladygina-Kohts 2002, p. 395).

Drawing the bottom line under this enormous work of hers, Ladygina-Kohts emphasized, that in humans, we can discover the distinguishing features never found in the chimpanzee. The most important are the presence of articulated speech and the ability to produce distinct words. Nevertheless, in spite of many

Ladygina-Kohts N. (1890–1963). Fig. 2 Ladygina-Kohts with young chimpanzee Jony (the photo was made in 1914–1915) and her son Roody (the photo was made in 1925) on a frontispiece of her book "Ditya shimpanze i ditya cheloveka …". (Ladygina-Kohts, 1935. Reprinted with permission of the State Darwin Museum)

behavioral similarities between humans and great apes, revealed in her own experiments, she always highlighted the idea that great ape "not only isn't 'almost human' as he usually is called, but also he is 'by no means human'" (Ladygina-Kohts 2002, p. 393).

In conclusion Ladygina-Kohts noted that she plans to compare the entire psychic structures of the infant chimpanzee and human child, and it would be possible to determine their relation more accurately. She worked on third volume of her research "Chimpanzee's Abilities to Distinguish Shapes, Size, Quantity, to

Counting, Analysis and Synthesis", but this volume was never been published and the manuscript was not found yet.

This book had made its author internationally famous and was translated into English, with F. de Waal and A. & B. Gardner's prefaces (Ladygina-Kohts 2002). The data collected in this book are still up-to-date. They have lately been confirmed and expanded in a variety of modern research (see Parr et al. 2002; Zorina 2008 for details).

A great success of Ladygina-Kohts's large-scaled research is not in small part due to the general approach and particular methods she developed in zoopsychology. Authentic and finely elaborated, they have become an integral part of modern science. Just one example is her "matching-to-sample" training method (Fig. 3), the modern versions of which are still in all-over-the-world use when studying a widest range of tests on animal cognition. She also introduced the tradition of adopting anthropoid babies to scientist families (cross-fostering) to systematically study their psyche and behavior. This approach was followed by a number of psychologists in the 1930–1950s, while in 1970–1990s it was found of especial value in studying language-trained chimpanzees. These experiments expanded and developed the data on the comparative behavioral ontogenesis of human and anthropoid infants obtained by Ladygina-Kohts and suggested the ability of great apes to master human language on the level of a 2–2.5 year's old human child.

All her life, Ladygina-Kohts was adhered to the comparative approach, which she used systematically in her every research. Not to mention her primate studies, she was always careful when applying this method working with all other animals. In 1920s, she initiated comparative studies of different behavioral features, such as color perception, using dogs, young wolves, and 10 species of parrots. She also studied some cognitive abilities (e.g., the ability to "count") in several species of birds and mammals (dogs, parrots, macaques, ravens, etc.). In 1950s, she studied tool-using and tool-making in chimpanzee Paris and proved them signs of reasoning (1959, "Orudiinaya i Constructivnaya Deyatel'nost' Vysshikh Primatov" (in Russian); "Tool-using and Tool-constructing in Great Apes").

Studying the elements of reasoning that she had discovered in chimpanzee infants, had become the key

Ladygina-Kohts N. (1890–1963). Fig. 3 Ladygina-Kohts in the Laboratory of Zoopsychology of the State Darwin Museum: chimpanzee Jony responding during matching-to-sample test (1915). (Reprinted with permission of the State Darwin Museum)

problem in Ladygina-Kohts's scientific activity. She explored the problem, using different experimental models (such as tool-using, tool-making, numerical competence), and with different species (dogs, parrots, macaques), thus concluded that animal elementary reasoning can be considered a biological precondition of human intelligence.

In her publications, she argued systematically in favor of the concept that animals do have many types of elementary reasoning that should be considered as biological preconditions of human intelligence. Her entire concept of intelligence evolution was presented in two monograph (in Russian) entitled "Razvitie psykhiki v processe evolucii organizmov" (1959, "Development of psyche in the process of organisms's evolution") and "Predposylki chelovecheskogo myshlenia" (1965, "The preconditions of human intelligence").

Cross-References

▶ Abstract Concept Learning in Animals
▶ Linguistic and Cognitive Capacities of Apes
▶ Self-Esteem and Learning
▶ The Matching to Sample Experimental Paradigm
▶ Theory of Mind in Animals
▶ Tool Use and Problem Solving in Animals

References

Ladygina-Kohts, N. N. (2002). *Infant chimpanzee and human child. A classic 1935 comparative study of ape emotions and intelligence.* Oxford: Oxford University Press.

Novoselova, S. L. (1997). Ladygina-Kohts N.N. – gordost' russkoi nauki (in Russian. "Ladygina-Kohts N.N. – Pride of Russian Science"). In V. V. Rubzov & M. G. Yaroshevsky (Eds.), *Prominent psychologists of Moscow* (pp. 251–285). Moscow.

Parr, L. A., Preuscholt, S., & de Waal, F. B. M. (2002). Afterword: research on facial emotion in chimpanzees, 75 years since Kohts. In N. N. Ladygina-Kohts (Ed.), *Infant chimpanzee and human child: A classic 1935 comparative study of ape emotions and intelligence* (pp. 411–452). Oxford: Oxford University Press.

Zorina, Z. A. (2008). At the origins of comparative psychology and human ethology: works of N.N. Ladygina-Kohts. *Herald of the NGU Series: Psychology, 2*, 10–27. in Russian.

Language

▶ Communication Theory
▶ Verbal Behavior and Learning

Language/Discourse Comprehension and Understanding

Jesse R. Sparks
School of Education and Social Policy, Northwestern University, Evanston, IL, USA

Synonyms

Discourse processing; Reading comprehension; Text comprehension

Definition

Discourse comprehension involves building meaning from extended segments of language, such as novels, news articles, conversations, textbooks, and other everyday materials. Successfully comprehending larger units of text and discourse requires making inferences to connect ideas both within and across local and global discourse contexts. Establishing such connections relies on the integration of information from prior discourse contents, as well as from prior knowledge, in order to build a coherent memory representation for the events and concepts the text describes. Following successful comprehension, the resultant discourse representation can be retrieved, updated, manipulated, and applied in order to answer questions and solve problems.

Theoretical Background

Traditional psycholinguistic research has primarily investigated language comprehension at the level of words and sentences (Traxler and Gernsbacher 2006). Sentence comprehension is considered a relatively "deconstructionist" activity, requiring several constituent processes, such as identifying letters and sounds, binding those segments into words and clauses, and parsing the sentence into a meaningful description of some event, which can potentially be maintained in memory. Understanding ▶ discourse, however, requires much more than processing a series of individual sentences.

Investigations of discourse comprehension have emphasized the critical role of *discourse context* in building meaning from extended linguistic input, and have tried to characterize the various psychological processes involved in discourse experiences (Gerrig 1993; Graesser et al. 2003). This entry discusses theory and research in text comprehension specifically; readers interested in comprehension of conversation are referred to work by Clark (Clark 1996; Clark and Carlson 1992; Clark and Haviland 1977).

Historically, research in discourse processing has examined the factors that influence comprehension and memory for text. *Text content* has considerable impact on readers' comprehension. Prior work suggests that language serves as a set of processing cues or instructions that guide construction of memory for discourse (Gernsbacher 1990; Givón 1992). These cues indicate which aspects of the text are important to remember. By influencing what readers attend to, linguistic cues directly impact the contents of memory. Readers might rely on several types of linguistic cues during processing. *Lexical cues* help to establish coherence among discourse elements. Connectives such as "because," "however," and "not" signal conceptual and logical relations among ideas and arguments (Sanders and Noordman 2000). In addition, anaphors highlight important concepts from prior text that should remain in reader focus (Dell et al. 1983). *Structural cues* are features of the organization of information within the discourse that emphasize particular elements. Syntax reveals the subject or object of events (Gernsbacher and Hargreaves 1988), or distinguishes presumably familiar concepts from new information (Haviland and Clark 1974). Other organizational features, such as titles or topic headings, can enhance readers' understanding of relationships among sentences and concepts (Bransford and Johnson 1972). Headings enhance both readers' memory for content and their subjective reports of comprehension. *Genre-based cues* are macro-level structural features that suggest the type of information contained in a text, the format or presentation of that content, or the material's intended purpose. Genre knowledge guides readers' expectations for text content, thereby influencing processing and subsequent recall (Wolfe 2005; Zwaan 1994). Narrative, expository, and procedural texts each have distinct features that influence understanding (Bovair and Kieras 1996; Goldman and Bisanz 2002; Mandler and Johnson 1977).

Reader characteristics also serve as critical influences on comprehension and memory. Researchers typically

address these characteristics by examining how particular ► individual differences impact processing (e.g., ► working memory capacity; Just and Carpenter 1992). Many individual variables affect successful text comprehension. The most critical variable, *prior knowledge*, includes information recently activated in short term memory (e.g., previously mentioned text concepts), as well as the personal experiences, facts, ideas, and understandings stored in long term memory. Both the quantity and quality of a reader's prior knowledge affect comprehension (Kendeou et al. 2003). In particular, the amount of one's knowledge, as well as the accuracy, flexibility, and coherence of that knowledge base, both affect understanding. Prior knowledge is crucial for disambiguating concepts, making predictions, and inferring unstated connections among ideas. Researchers have argued that prior knowledge can be applied both spontaneously and strategically during processing (Long and Lea 2005; van den Broek et al. 2005). *Language ability* consists of the various processing abilities readers possess; this can include vocabulary, oral language skills, and reading skills, which consist of both basic level (e.g., decoding and fluency) and higher-order processes (e.g., the ability to make inferences). Each of these factors can influence understanding; for example, children's oral language and decoding skills independently predict story comprehension (Kendeou et al. 2009). *Goals for reading* also affect comprehension by influencing readers' strategies, for example, by directing their attention to goal-relevant information (McCrudden et al. 2010). Readers' goals can also impact the effort they expend during comprehension. Readers engage in more integrative, effortful processing when reading for study than when reading for leisure (van den Broek et al. 2001).

Models of discourse processing have attempted to describe when and how linguistic input and prior knowledge influence moment-by-moment processing during reading experiences. Notably, text content and reader characteristics often have interactive, rather than independent, effects on comprehension (Kintsch et al. 1996; O'Reilly and McNamara 2007; Long and De Ley 2000). In order to address the relative contributions of these factors, researchers have developed theories regarding the role of knowledge activation during reading. Such theories attempt to describe how text input activates information in memory, and how those activations impact subsequent comprehension (Kintsch 1998; Rapp and van den Broek 2005).

Two prominent theoretical approaches have followed from this work. The *memory-based* or *resonance* view suggests that linguistic input automatically and quickly activates any information in memory that matches that input semantically or phonologically (Myers and O'Brien 1998). For example, reading "apple" might activate concepts of fruits, personal computers, or the similar-sounding "grapple." Through resonance, multiple concepts are activated simultaneously, but only some of these concepts receive sufficient activation for retrieval. This broad-based activation is passive and unrestricted, occurring without strategic input (Gerrig and McKoon 1988; O'Brien et al. 1998). Resonance is also consistent with existing models of memory (Collins and Loftus 1975), since it relies on general cognitive processes such as ► priming (Meyer and Schvaneveldt 1971) and does not require mechanisms that are specific to discourse. Evidence suggests that resonance alone helps readers maintain both local and global connections among discourse concepts (Albrecht and O'Brien 1993).

In contrast, proponents of the *constructionist* view argue that knowledge activation results from an effortful memory search, driven by a reader's goals for a given reading experience (Graesser et al. 1994). Readers engage in a strategic "search after meaning" (cf. Bartlett 1932), only activating concepts that are relevant for understanding discourse content. Constructionist accounts argue that readers use prior knowledge selectively, generating ► inferences that explain *why* actions and events are described in the text.

Despite the polarity of these views, recent accounts of discourse processing have reconciled the two approaches into a dynamic view of comprehension (van den Broek et al. 2005), in which memory-based and constructionist processes interact in a stage-like manner, with initial broad-based activation followed by strategic memory search. Computational models of comprehension such as the Construction-Integration model (Kintsch 1988), the Collaborative Activation-Based Production System (Goldman and Varma 1995), and the Landscape Model (van den Broek et al. 1999) have demonstrated that cascaded sequences of memory-based and constructionist processes best characterize human comprehension performance, relative to non-integrated simulations. Such models

suggest that both memory-based and constructionist processes interactively affect comprehension.

In addition to detailing the processes involved in comprehension, researchers have examined how reader characteristics and text content influence readers' memory for discourse. Investigations of memory products have considered the nature of ► mental representations for discourse. The prevailing theory of text representation is the *tripartite model* (van Dijk and Kintsch 1983). According to this model, readers construct multi-leveled memory representations, with different information encoded at each level. The most basic level is the *surface* representation, which encodes the exact wording of phrases and sentences (i.e., the text's surface form) without representing any meaning associated with the words. Without continued rehearsal, surface text is quickly displaced from memory (Bransford et al. 1972). The *textbase* or *propositional* representation contains the meanings underlying language. This includes understanding the specific ideas conveyed by the discourse; thus, textbase representations are critical for comprehension and recall (Kintsch and van Dijk 1978). However, the textbase only contains information that is explicitly stated in the text.

The level of representation that has been the focus of most discourse comprehension research is the *mental* or *situation model* (Johnson-Laird 1983; van Dijk and Kintsch 1983). Situation models encode a representation of situations described by, but not explicitly stated within, the text; this includes any inferences readers generate. Inferences allow readers to make connections among different text elements, which facilitates construction of coherent memory of what the text is about (Kintsch 1988). Reader inferences are critical components of situation models. Accordingly, inferences have received considerable attention in research. Past work has examined the types of inferences readers generate, as well as the conditions under which readers construct particular inferences (Singer 1994; McKoon and Ratcliff 1992). Situation models may contain information about a character's appearance, authors' and characters' ironic intentions (Kreuz and Glucksberg 1989), or the spatial configuration of objects, all of which require inferences. Situation models encode text events according to their continuity along (at least) five dimensions: time, space, causality, protagonists, and intentions (Zwaan et al. 1995; Zwaan and Radvansky 1998). These dimensions interactively influence memory for discourse (Rapp and Taylor 2004).

Many researchers have argued that construction of a coherent situation model is tantamount to successful text comprehension (Graesser et al. 1997; van Dijk and Kintsch 1983). Thus, studying how readers construct coherent memory for text information is fundamental to understanding issues of discourse comprehension.

Important Scientific Research and Open Questions

A current trend in discourse processing research involves examining influences on comprehension outside of the traditionally studied reader and text variables. For example, readers' propensity to monitor their understanding (Thiede et al. 2010), their reliance on credible and non-credible information sources (Sparks and Rapp 2011), and affective influences on comprehension (Komeda et al. 2009) have each been the focus of recent investigations. Some researchers have argued that theories of discourse comprehension must be able to account for these types of processes, which constitute our naturalistic comprehension experiences (e.g., Gerrig 1993).

To date, most research in discourse comprehension has been concerned with individual readers processing a single text. How readers interact with and build meaning from multiple, related texts remains an important issue (Goldman 2004). Consider that the Internet affords individuals the opportunity to read multiple, varied, conflicting accounts of current events (Rouet 2006), or that history students must integrate across multiple texts to understand a historical incident (Wineburg 2001). Explaining such everyday experiences requires closer examination of multiple text comprehension and its implications for learning and memory.

Another important issue for text comprehension research involves investigating how readers revise what they know to reflect information gained from a discourse (i.e., updating). Research on updating has examined the types of texts, reader variables, and task instructions that make revision more likely. Readers often rely on information mentioned early in a text, even when that information is discounted or contradicted; this can disrupt comprehension (Johnson and Seifert 1994; O'Brien et al. 2010). Memory

updating is facilitated by texts that contain causal explanations for why outdated information is no longer valid, or by instructions asking readers to track unfolding text events (Rapp and Kendeou 2007). These findings are consistent with work addressing the utility of refutation texts in educational setting (Guzzetti et al. 1993). Additional research is necessary to determine which types of refutations effectively encourage updating, given particular types of text content and particular kinds of readers.

Cross-References

► Discourse
► Discourse Processes and Learning
► Learning from Text
► Literacy and Learning
► Mental Models in Discourse Processing
► Role of Prior Knowledge in Learning Processes
► Text Relevance

References

Albrecht, J. E., & O'Brien, E. J. (1993). Updating a mental model: Maintaining both local and global coherence. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 19*, 1061–1069.

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, England: Cambridge University Press.

Bovair, S., & Kieras, D. E. (1996). Toward a model of acquiring procedures from text. In R. Barr, M. L. Kamil, & P. B. Mosenthal (Eds.), *Handbook of reading research* (Vol. 2). Mahwah, NJ: Erlbaum.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11*, 717–726.

Bransford, J. D., Barclay, J. R., & Franks, J. J. (1972). Sentence memory: A constructive versus interpretive approach. *Cognitive Psychology, 3*, 193–209.

Clark, H. H. (1996). *Using language*. Cambridge: Cambridge University Press.

Clark, H. H., & Carlson, T. B. (1992). Hearers and speech acts. In H. H. Clark (Ed.), *Arenas of language use* (pp. 205–247). Chicago: University of Chicago Press and CSLI.

Clark, H. H., & Haviland, S. E. (1977). Comprehension and the given-new contract. In R. Freedle (Ed.), *Discourse production and comprehension*. Hillsdale, NJ: Lawrence Erlbaum.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*, 407–428.

Dell, G. S., McKoon, G., & Ratcliff, R. (1983). The activation of antecedent information during the processing of anaphoric reference in reading. *Journal of Verbal Learning and Verbal Behavior, 22*, 121–132.

Gernsbacher, M. A., & Hargreaves, D. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory and Language, 27*, 699–717.

Gernsbacher, M. A. (1990). *Language comprehension as structure building*. Hillsdale, NJ: Erlbaum.

Gerrig, R. J. (1993). *Experiencing narrative worlds*. New Haven, CT: Yale University Press.

Gerrig, R. J., & McKoon, G. (1998). The readiness is all: The functionality of memory-based text processing. *Discourse Processes, 26*, 67–86.

Givón, T. (1992). The grammar of referential coherence as mental processing instructions. *Linguistics, 30*, 5–55.

Goldman, S. R. (2004). Cognitive aspects of constructing meaning through and across multiple texts. In N. Shuart-Ferris & D. M. Bloome (Eds.), *Uses of intertextuality in classroom and educational research* (pp. 313–347). Greenwich, CT: Information Age Publishing.

Goldman, S. R., & Bisanz, G. L. (2002). Toward functional analysis of scientific genres: implications for understanding and learning processes. In J. Otero, J. A. Leon, & A. C. Graesser (Eds.), *The psychology of science text comprehension* (pp. 19–50). Mahwah, NJ: Erlbaum.

Goldman, S., & Varma, S. (1995). CAPping the construction integration model of discourse comprehension. In C. A. Weaver, S. Mannes, & C. R. Fletcher (Eds.), *Discourse comprehension: Essays in honor of Walter Kintsch* (pp. 337–358). Hillsdale, NJ: Erlbaum.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101*(3), 371–395.

Graesser, A. C., Millis, K. K., & Zwaan, R. A. (1997). Discourse comprehension. *Annual Reviews in Psychology, 48*, 163–189.

Graesser, A. C., Gernsbacher, M. A., & Goldman, S. R. (Eds.). (2003). *Handbook of discourse processes*. Mahwah: Erlbaum.

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: a comparative meta-analysis of instructional interventions from reading education and science education. *Reading Research Quarterly, 28*, 117–159.

Haviland, S. E., & Clark, H. H. (1974). What's new? Acquiring new information as a process in comprehension. *Journal of Verbal Learning and Verbal Behavior, 13*, 512–521.

Johnson, H. M., & Seifert, C. M. (1994). Sources of the continued influence effect: when misinformation in memory affects later inferences. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 1420–1436.

Johnson-Laird, P. N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness*. Cambridge, MA: Harvard University Press.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*, 122–149.

Kendeou, P., Rapp, D. N., & van den Broek, P. (2003). The influence of reader's prior knowledge on text comprehension and learning from text. In R. Nata (Ed.), *Progress in education* (Vol. 13, pp. 189–209). New York: Nova Science Publishers.

Kendeou, P., van den Broek, P., White, M. J., & Lynch, J. S. (2009). Predicting reading comprehension in early elementary school:

The independent contributions of oral language and decoding. *Journal of Educational Psychology, 101*, 765–778.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review, 95*, 163–182.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition.* Cambridge: Cambridge University Press.

Kintsch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*, 363–394.

Komeda, H., Kawasaki, M., Tsunemi, K., & Kusumi, T. (2009). Differences between estimating protagonists' emotions and evaluating readers' emotions in narrative comprehension. *Cognition and Emotion, 23*, 135–151.

Kreuz, R. J., & Glucksberg, S. (1989). How to be sarcastic: The echoic reminder theory of verbal irony. *Journal of Experimental Psychology General, 118*, 374–386.

Long, D. L., & De Ley, L. (2000). Implicit causality and discourse focus: The interaction of text and reader characteristics in pronoun resolution. *Journal of Memory & Language, 42*, 545–570.

Long, D. L., & Lea, R. B. (2005). Have we been searching for meaning in all the wrong places? Defining the "search after meaning" principle in comprehension. *Discourse Processes, 39*, 279–298.

Mandler, J., & Johnson, N. (1977). Remembrance of things parsed: story structure and recall. *Cognitive Psychology, 9*, 111–151.

McCrudden, M. T., Magliano, J. P., & Schraw, G. (2010). Exploring how relevance instructions affect personal reading intentions, reading goals, and text processing: A mixed methods study. *Contemporary Educational Psychology, 35*, 229–241.

McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review, 99*, 440–466.

McNamara, D. S., Kintsch, E., Songer, N. B., & Kintsch, W. (1996). Are good texts always better? Interactions of text coherence, background knowledge and levels of understanding in learning from text. *Cognition and Instruction, 14*, 1–43.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227–234.

Myers, J. L., & O'Brien, E. J. (1998). Accessing the discourse representation during reading. *Discourse Processes, 26*, 131–157.

O'Brien, E. J., Rizzella, M. L., Albrecht, J. E., & Halleran, J. G. (1998). Updating a situation model: A memory-based text processing view. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 24*, 1200–1210.

O'Brien, E. J., Cook, A. E., & Guéraud, S. (2010). Accessibility of outdated information. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 36*, 979–991.

O'Reilly, T., & McNamara, D. S. (2007). Reversing the reverse cohesion effect: Good texts can be better for strategic, high-knowledge readers. *Discourse Processes, 43*, 121–152.

Rapp, D. N., & Kendeou, P. (2007). Revising what readers know: Updating text representations during narrative comprehension. *Memory & Cognition, 35*(8), 2019–2032.

Rapp, D. N., & Taylor, H. A. (2004). Interactive dimensions in the construction of mental representations for text. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30*, 988–1001.

Rapp, D. N., & van den Broek, P. (2005). Dynamic text comprehension: an integrative view of reading. *Current Directions in Psychological Science, 14*, 276–279.

Rouet, J.-F. (2006). *The skills of document use: From text comprehension to web-based learning.* Mahwah: Erlbaum.

Sanders, T. J. M., & Noordman, L. G. M. (2000). The role of coherence relations and their linguistic markers in text processing. *Discourse Processes, 29*, 37–60.

Singer, M. (1994). Discourse inference processes. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 479–515). San Diego, CA: Academic Press.

Sparks, J. R., & Rapp, D. N. (2011). Readers' reliance on source credibility in service of inference generation. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 37*(1), 230–247.

Thiede, K. W., Griffin, T. D., Wiley, J., & Anderson, M. C. M. (2010). Poor metacomprehension accuracy as a result of inappropriate cue use. *Discourse Processes, 47*, 331–362.

Traxler, M. J., & Gernsbacher, M. A. (2006). *Handbook of psycholinguistics* (2nd ed.). San Diego, California: Academic Press.

van den Broek, P., Young, M., Tzeng, Y., & Linderholm, T. (1999). The landscape model of reading. In H. van Oostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 71–98). Mahwah, NJ: Lawrence Erlbaum.

van den Broek, P., Lorch, R. F., Jr., Linderholm, T., & Gustafson, M. (2001). The effects of readers' goals on inference generation and memory for texts. *Memory & Cognition, 29*, 1081–1087.

van den Broek, P., Rapp, D. N., & Kendeou, P. (2005). Integrating memory-based and constructionist processes in accounts of reading comprehension. *Discourse Processes, 39*, 299–316.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension.* New York: Academic Press.

Wineburg, S. S. (2001). *Historical thinking and other unnatural acts: Charting the future of teaching the past.* Philadelphia: Temple University Press.

Wolfe, M. B. W. (2005). Memory for narrative and expository text: Independent influences of semantic associations and text organization. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31*, 359–364.

Zwaan, R. A. (1994). Effect of genre expectations on text comprehension. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 920–933.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123*, 162–185.

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The construction of situation models in narrative comprehension: An event-indexing model. *Psychological Science, 6*, 292–297.

Language Acquisition

Language Acquisition and Development

Susana Lopez Ornat
Dpto. Psicologìa Básica II, Facultad de Psicologìa
Universidad Complutense de Madrid, Madrid, Spain

Synonyms

First language acquisition; L1 learning process; Language development; Language acquisition

Definition

Language acquisition is a process which starts 3 months before birth (Elman et al. 1996; Karmiloff and Karmiloff-Smith 2001) and gradually leads to the child's mastery of his/her native language/s, at around adolescence.

Language *learning*, language *acquisition* and language *development* can be understood as synonymous. However, this lexical differentiation carries interesting theoretical nuances.

Theoretical Background

Why would a child *acquire* and not *learn* or *develop* a language?

The term *acquisition* reflects the influence of Noam Chomsky, and of nativist (generativist) models inspired by his work, since the late 1950s. The term is rooted in linguistics and emphasizes the notion that grammar is only triggered by the environment rather than learned. It also implies that language development is rather independent of other kinds of development, whether linguistic or otherwise. The process depends on inherited grammatical knowledge. Its modeling is formalist, with the role of experience reduced to the bare minimum.

The term *learning* ties up with *behaviorism* and is rooted in psychology. In the late 1950s, Skinner put forward the first scientific explanation of how a language is *learned*. It focused on experience and on an associative language learning process, with reinforcement by adults gradually shaping the child's language performance.

Currently, the constructivist–emergentist models describe language development as a process of ontogenetic, gradual, complex, and adaptive change. Change is driven by a complex interaction of experience and the learning brain, plus some *general* innate constraints. Emergentist models claim to reveal how the grammar of a language is learned. Their evidence would imply that it is not enough to "land" in a linguistic setting – *á la Skinner* – but instead, it is necessary to add rich internal cognitive dynamics to the learning process. Their evidence would also imply that knowledge which is already linguistic and is innate – *á la Chomsky* – is not needed in a scientific account of the language development process.

Much of the current research on child language is based on emergentism (Bavin 2009). Emergentist models are related to the theory of complexity. It is argued that the language acquisition process itself is a recursive process by which interactions among primitive linguistic elements give rise to higher level emergent linguistic entities with emergent properties, such that interactions amongst these new emergent linguistic entities give rise to yet higher level emergent entities with their own emergent properties, and so on.

Current language acquisition research has gained reliability, depth, and detail using new methodology. Neuro-imaging techniques are frequently used, identifying neurological correlates of early language processing (Elman et al. 1996). A form of computer modeling (connectionism, neural nets) is a rich source of hypotheses of possible brain-like processes of analysis and representation (Elman et al. 1996). Nowadays research in the field is often multicultural and multidisciplinary. Research questions are better focused and new experimental methods like eye tracking or preferential looking have been devised to investigate early comprehension processes. As questions have become more precise, fine-grained analyses based on massive detailed information have been devised. Nevertheless, longitudinal corpora still form the backbone for a number of questions in the field, especially when studying new phenomena or new languages.

The use of child language corpora itself has been enhanced by the availability of computer software and

hardware, which has enormously facilitated research. Nowadays the language which is directed *to* the child is also a research field, seeking to further elucidate the observed growth in the child's linguistic competence. Since 1991, collaboration has resulted in the database of the Child Language Data Exchange System (CHILDES) (http://childes.psy.cmu.edu), which includes longitudinal acquisition data from normal monolingual and bilingual children of many languages, plus the same sort of data for atypical language development. Parent report measures for documenting the linguistic and communicative development of infants and toddlers have also been created. A screening instrument for differentiating atypical from normal development from very early on (8 months) exists for many different languages (www.sci.sdsu.edu/cdi/cdiwelcome.htm).

Important Scientific Research and Open Questions

Most present-day scientific questions have to do with how babies, toddlers, and children "crack the code" to become competent language users. Language has a formal structure which is never explicitly taught to the small child. In spite of that, by about 27 months of age children successfully start finding the grammar of their language/s.

Nativist models propose all humans are endowed with genetic grammatical knowledge termed UG (Universal Grammar). UG is a set of very general grammatical "rules" which will somehow mature and then guide the child in its search for the grammar of the environmental language/s it is born to (Chomsky 1972; Hauser et al. 2002). Because language acquisition is assumed to depend on the genetic UG endowment, and/or its "maturation," research from this perspective focuses on possible descriptions of the genetic UG. The model does not focus on the roles played by the environment, by the experience, by the brain, nor by the cognitive processing of the learner.

Emergentist models are not strictly empiricist. Rather, several innate but *general* brain processing constraints are described which bias the human learning process and experience (Bavin 2009; Elman et al. 1996; Karmiloff and Karmiloff-Smith 2001; Tomasello 2003). As opposed to nativism, along development, the child's brain develops language-specific processing mechanisms, which are a *consequence* of its successful language learning history.

As for open research questions, within emergentist models the notion of *local learning* constitutes a lively research field today. According to this, children learn linguistic categories through statistical learning procedures applied to specific examples. Analyses of these categories lead to rule-like structures themselves then subject to analysis. This language learning process would, at first, advance practically item-by-item. This is why researchers observe that, at first, a certain language structure (an inflection, an agreement, a syntactic structure) is only produced correctly with one or a few words, and not with others, in specific local contexts, and not in others (Bavin 2009; Tomasello 2003).

Another set of open research questions stems from the fact that although the language development process is apparent in the growth of the child's production, it also occurs both in the *input* and in the learning *system* itself. Both the input and the learning system change along the process becoming, themselves ever more complex. The learning system is said to *filter* the quantity and quality of input it receives as a function of its own developmental state (Elman et al. 1996). In turn, it modifies itself, creating various types of transitional states on the way. It is these transitional states that are the focus of much current research.

A third set of issues concerns the development of intentional communication. The general cognitive skills of small children will help them identify the distributional patterns of their language(s) but will also help them identify the intentions of the model speakers (Tomasello 2003). Closely tied to this is the issue of imitation. Imitation plays an essential role in the takeoff of any particular language acquisition process. Children begin to learn linguistic structures by imitating linguistic exemplars which implement them, even though, in the end, what they learn is the *language*, the formal conventional system. Imitation is not a single learning mechanism, but a conflation of many of them. In order for an immediate imitation of a linguistic structure to take place:

1. The learning system must have oriented its attention to that structure.
2. The intention of the imitated speaker must have been hypothesized.
3. The detected structure must have been segmented out of the continuous speech stream.

4. The system must have built a motor equivalent of the perceived structure.
5. The articulatory system must produce it.

Currently, each one of those processes constitutes a research field of its own. A linguistic structure which can be "imitated" can also be internally "represented" and stored. This inner availability, in turn, would allow the system to search for statistical regularities in the stored materials.

There is now much research activity on what could be part of a neurological support of imitation, the Mirror Neuron System, first described in adult macaque monkeys. This is a series of neurons that fire not only when the subject performs an action but also when it observes another performing that action (Tomasello 2003).

Another group of current research questions focus on the acquisition of discourse, in later language development. During the *early* language acquisition process, the child succeeds in learning a basic linguistic code (phonology, lexicon, morphology, syntax, semantics, pragmatics) of his/her language/s. Five-year-old children are still not fully developed speakers, but they have the foundations of their language/s. From then onward, until adolescence, the process is termed *late* language acquisition (Bavin 2009).

Narrative and dialogue are special cases of discourse. Dialogue itself is an "easy" case of narrative by which human beings can build oral texts through cooperation. Narrative involves guiding a listener through a beginning, a middle, and an end while linking successive sentences together by using linguistic instruments such as tense marking, connectives, and pronouns. Such linguistic instruments (cohesion devices) allow the speaker to refer back to things said earlier, to leave things unsaid, to link events coherently, to progress through the narrative smoothly, to avoid going back through every detail (Karmiloff and Karmiloff-Smith 2001). Research today is examining how conceptual coherence and linguistic cohesion relate to one another dynamically at every stage of children's discourse development. The development of subtle linguistic features such as humor, sarcasm, and metaphor each constitute a research field today. Language development is a very long developmental process, perhaps the slowest development of all human cognitive abilities.

But linguistic development in literate societies also includes the learning of a metalanguage. In many societies, by the time children are starting to acquire some basic oral discourse skills, they also start to be explicitly trained in reading and writing. This new linguistic level requires the learning of letter and written word recognition, the refinement of phonological awareness, the development of completely new spelling skills, the learning of letter-to-sound correspondences, and the learning of new narrative skills as applied to the written form. This metalevel of linguistic development, in turn, creates its own difficulties in development and its own observable effects on brain connectivity. All of them are subject of specialised research today.

There are many different types of language learners for each of which there is dedicated research (Bavin 2009). For example, for the child born into a bi/trilingual environment the normal process of language learning takes place in the various languages simultaneously. With the exception of some trivial confusions, the bi/trilingual baby, toddler, or small child gets to match the linguistic level of monolingual children in his/her languages at around age 4–5. The same overall normality is found in deaf children born to deaf parents who are users of a sign language. Most deaf babies, though, have hearing parents who do not know a sign language, and these babies have more difficulties. Atypical language developments, like specific language impairment (SLI), autism spectrum disorder (ASD), Williams syndrome, and Down syndrome each constitute highly developed specialized fields, with interest not just on their own, but also for issues of brain plasticity and of brain activity patterns as dependent on linguistic development and linguistic experience.

Even within "normal" language development processes there are variations. There are differences in the language acquisition process which depend on differences in culture, or in language, or in socioeconomic status (SES) but in addition deep individual differences have been found in "equivalent" children, i.e., the same culture, the same language, and the same SES. These variations, difficult to reconcile with nativist (UG) models, are linked with subtle differences in linguistic experience and processing as would be predicted by an emergentist model.

People might suppose all adults belonging to the same linguistic community will be equivalent in their mastery of their common language. But that intuition rests on the typical descriptive paradigm for mainstream linguistics. The intuition of the homogeneous

speech community is a fiction. Instead, one of the more striking ways in which individuals differ is in their learning and use of language (Bavin 2009; Elman et al. 1996). Interestingly, some individual variations in language development suggest that the learning system follows alternate *paths* or routes in the acquisition of particular sounds, or words, or grammar, or of narrative (Karmiloff and Karmiloff-Smith 2001). This plasticity of the process constitutes another interesting research issue today.

Cross-References

► Bilingualism and Learning
► Connectionist Theories of Learning
► Constructivist Learning
► Developmental Cognitive Neuroscience and Learning
► Imitation: Definitions, Evidence, and Mechanisms
► Language Development and Behavioral Methods
► Self-Organized Learning
► Speech Perception and Learning

References

Bavin, E. L. (Ed.). (2009). *The Cambridge handbook of child language.* New York: Cambridge University Press.

Chomsky, N. (1972). *Language and mind.* New York: Harcourt.

Elman, J. L., Bates, E., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness: A connectionist perspective on development.* Cambridge: MIT Press.

Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: what is it, who has it, and how did it evolve? *Science, 298*, 1569–1579.

Karmiloff, K., & Karmiloff-Smith, A. (2001). *Pathways to language: From fetus to adolescent.* Cambridge: Harvard University Press.

Tomasello, M. (2003). *Constructing a language: A usage-based theory of language acquisition.* Cambridge: Harvard University Press.

Language Affordance

Language affordance can be defined as the possible relationships in the environment that if correctly perceived, it can connect language sign to language user and to the language context. The prosodic features as voice quality or body language encapsulate language affordances. It is teachable and so perceptual understanding that is critical for language acquisition can be developed.

Language and Emotioning

A term coined by Humberto Maturana to indicate that communication does not convey information but that communication is the act of *living in* the inseparable combination of language and emotion. Languaging and emotioning constitute the process of living that enables us to organize experience and engage in interaction with ourselves and others, in the course of which we create our worlds.

Language and Learning

Christine D. Tsang
Department of Psychology, Huron University College at the University of Western Ontario, London, ON, Canada

Synonyms

Language acquisition; Language development

Definition

Language learning is traditionally viewed as being constrained by innate perceptual and processing abilities specialized for language acquisition. While the notion of innate constraints in language learning is the predominant theory in the field of language acquisition, the types of constraints and the degree to which learning language is constrained by innate and environmental factors are the subjects of much current research.

Theoretical Background

While infants seemingly learn all the various facets of language easily and quickly, the way in which they do this is not well understood. Indeed, the acquisition of language is a surprisingly complex task, requiring the infant learner to perceive and produce the sounds of language (phonemes), and decipher grammar, all in the span of less than 3 years. The developmental timeline of language learning has been well documented and develops similarly across all cultures, suggesting an innate basis for language development.

The predominant theory of primary language acquisition asserts that infants are born with a fundamental set of innate mechanisms specifically devoted to language learning (Chomsky 1965). The nativist theory rests on two assumptions: First, the linguistic input available from the environment is of such poor quality that the sample of possible utterances an infant learner receives is too sparse to explain the language knowledge the infant possesses in just a few short years; and second, that general learning processes, such as classical conditioning and operant conditioning, are not strong enough on their own to deal with the poor quality linguistic input available in the environment. Chomsky (1965) posited the existence of a "language acquisition device," which initially allows the infant learner to perceive and produce all possible phonemes of all languages, but eventually focuses in on the phonemes contained in one's native language based on environmental input. The language acquisition device proposed by nativist theorists includes perception-based processes, such as categorical perception, and also production-based processes, such as babbling. Extending Chomsky's notion of language-specific learning, Lenneberg (1967) proposed the "critical period hypothesis," which posits that primary language acquisition must occur during an innately specified time frame, or critical period, likely ending around the time of puberty. The underlying assumption of this hypothesis is that language learning occurring after the critical period is qualitatively different than learning during the critical period. Together, these theories now form the predominant view of maturational constraints on the acquisition of language, such that while experience is a necessary component of language development, its role is simply to fine-tune the output already constrained by innate factors.

More recently, with the rise of artificial neural networks and a focus on developing artificial intelligence, empiricist theories of language acquisition have emerged. These theories suggest that the infant learner is born with generalized basic learning mechanisms, not domain-specific (e.g., language-specific) mechanisms. In other words, in contrast to nativist theories which posit specialized innate language mechanisms, empiricist theories claim that innate learning processes are not limited to only the language domain, but rather, are generalized learning mechanisms for information processing. Thus, there is no "language acquisition device" but rather general information processing mechanisms that allow the learner to focus on regularities in the linguistic input.

Important Scientific Research and Open Questions

Research examining the acquisition of the formal structure of language (i.e., grammar) forms the basis of some of the strongest arguments for a nativist account of language acquisition. In a computational investigation of the constraints of language learnability, Gold (1967) reported that classes of language most like human language are not learnable unless the system has some initial constraints as to how to approach the language. This view is supported by evidence showing that young children apply the rules of grammar to novel or nonsense words, pointing to the existence of a "universal grammar" module present from birth.

Other evidence that young children are predisposed to the rules of grammar without any training comes from the fact that young children seem to make grammatical errors that are consistent with the notion that they are applying regular rules of grammar, such as saying "I runned" (incorrectly applying the past tense rule to an irregular verb) instead of "I ran" (see Pinker 1994). Evidence supporting Lenneberg's critical period hypothesis are also numerous. For example, there are very few reports of successful primary language learning occurring after puberty, and research examining how second language acquisition shows that second language learning in adulthood is qualitatively different from primary language learning during infancy and early childhood (e.g., Johnson and Newport 1989).

Although the theories of Chomsky and Lenneberg have dominated the field of language acquisition for over 40 years, recently connectionist or neural network accounts of development have been gaining traction. These modern empiricist accounts refute nativist claims that only an innate language module can explain the rapidity of language development given the impoverished nature of the input. Empiricist accounts of language acquisition suggest that rather than an impoverished input, the linguistic environment is in fact rich with statistical regularities that can assist in language acquisition (see Bates and Elman 1996), and furthermore that infant listeners are able to take advantage of these regularities to learn a wide range of

language-related tasks, ranging from the phonemes of a language and word boundaries to word meanings and grammar (e.g., Saffran et al. 1996).

Recently, studies examining artificial grammar learning by infants and neural networks have shifted from the conception of language learning as being innately constrained and specified to a more domain-general problem of information processing that is constrained by both innate and environmental factors. The basic paradigm involves the construction of models of language based on a theory or hypothesis as to how language might be learned, and then observing whether natural human language learning and the artificial model learning are similar in terms of learning progression and outcome. The advantage of using artificial languages is their simplicity. Natural languages are highly complex, containing several possible cues that interact and could be used in isolation or together by the language learner to decode the input. In other words, natural linguistic input is difficult to control. Artificial languages can be designed to test specific aspects of language learning, such as the use of transitional probabilities in word segmentation (Saffran et al. 1996), or more generally, the use of pattern-based abstractions in language learning (see Gomez and Gerken 2000 for a review). Even more interestingly, the abstraction of patterns in a signal, such as the abstraction of transitional probabilities, is neither limited to language, nor to human information processing. Several studies have documented statistical abstraction abilities in infants performing nonlanguage tasks such as visual pattern perception and tone sequences, and nonhuman primates have been shown to segment words using statistical probabilities (Hauser et al. 2001). Together, this body of research supports the view that language learning does not need to be innately specified by specialized language-learning mechanisms.

Despite the acknowledgment from both nativist and empiricist theories, that both innate and environmental factors must contribute to language acquisition, it still remains an open question as to which aspects of language acquisition are innate and which are acquired through learning. Current research is still investigating how much of the initial system is constrained by innate knowledge, and how much of the initial system is changed by dynamic interaction with environmental input and vice versa.

Cross-References

▶ Acoustic and Phonological Learning
▶ Developmental Cognitive Neuroscience and Learning
▶ Language Acquisition and Development
▶ Phonological Representation
▶ Speech Perception and Learning
▶ Statistical Learning in Perception

References

Bates, E., & Elman, J. (1996). Learning rediscovered. *Science, 274*, 1849–1850.

Chomsky, N. (1965). *Aspects of a theory of syntax*. Cambridge, MA: MIT Press.

Gold, E. M. (1967). Language identification in the limit. *Information and Control, 16*, 447–76.

Gomez, R. L., & Gerken, L. (2000). Infant artificial language learning and language acquisition. *Trends in Cognitive Sciences, 4*, 178–186.

Hauser, M. D., Newport, E. L., & Aslin, R. N. (2001). Segmentation of the speech stream in a non-human primate: Statistical learning in cotton-top tamarins. *Cognition, 78*, B53–B64.

Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology, 21*, 60–99.

Lenneberg, E. (1967). *Biological foundations of language*. New York: Wiley.

Pinker, S. (1994). *The language instinct: How the mind creates language*. New York: Morrow.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science, 274*, 1926–1928.

Language Aptitude

A person's natural disposition for learning an L2.

Language Behavior

▶ Intelligent Communication in Animals

Language Development

▶ Language Acquisition and Development
▶ Language and Learning
▶ Infant Language Learning

Language Learning Strategies

Specific activities, steps, plans, or procedures learners apply in order to improve their second language abilities. Language learning strategies are often used intentionally in order to reach certain language learning goals.

Language Learning Through Multimedia

► Multimedia CALL

Language Modeling

► Analogical Modeling of Language

Language Partners

► Tandem Learning

Language Transfer

► Cross-Linguistic Influence and Transfer of Learning

Language-Based Learning Disabilities

Elena L. Grigorenko
Child Study Center, Department of Psychology, Department of Epidemiology and Public Health, Yale University, New Haven, CT, USA

Synonyms

Comprehension disorder; Developmental language disorders; Disorder of written expression; Dysgraphia; Dyslexia; Learning disabilities; Specific reading disorder/disability; Speech and language disorders

Definition

Language-based learning disabilities (impairments) are a subgroup of learning disabilities (hereafter, LDs) that are rooted in deficiencies pertaining to the acquisition of spoken and written language. These LDs manifest themselves in multiple domains of academic functioning, but primarily in the domains of literacy (i.e., vocabulary acquisition, reading, and writing).

Theoretical Background

As a category, the group of phenomena referred to as LDs arose along with the notion of obligatory education as a developmental requirement for citizens of modern societies. As obligatory education spread at the junction of the nineteenth and twentieth centuries, so did the realization that, for unknown reasons, when presented with the same educational materials in the classroom, some children learned more easily than others, while there were also children who could not learn much at all, or who could learn, but only with great difficulty. Throughout human history, as societies have faced the issue of limited resources, questions have arisen as to *who* should both have the right and be required (i.e., have a societal obligation) to be educated and *how* to pay for obligatory education.

The "who" question then became a question of whether it was worth trying to educate all children or were there ways to differentiate those children who had a typical capacity to learn from those who had difficulty in learning. Were there such a way, then the latter category of children could be identified early and offered a different type of education or "services" distinct from what typical children would receive in their regular classrooms. It is in this context that intelligence testing and the concept of an intelligence quotient (IQ) originated. Practices of segregating children based on IQ, however, were quickly proven to be only partially effective. Even after keeping only children with typical IQ in regular classrooms, they still contained children who failed to acquire the obligatory academic skills (e.g., literacy and numeracy skills) at the same rate or with the same ease as their peers, in spite of their normal intelligence. It was then noticed that their difficulties were relatively specific and pertained to particular domains of academic functioning.

Moreover, it became apparent that the presence of children with such difficulties was observed quite often (unlike those children who could not learn at all) and, thus, those children could not be isolated from regular classrooms by dint of their sheer numbers. Therefore, rather than isolating them, attempts were made to differentiate these groups of children found in regular classrooms, and the categories of "regular educational needs" and "special educational needs" were introduced. Typically (but see recent developments in the USA pertaining to the concept of *Response to Intervention, RTI*), the diagnosis of LD is established based on the observed discrepancy between the measured level of general cognitive ability (IQ) and academic achievement in a specific domain (e.g., reading or writing). Having a diagnosis of LD, in the context of obligatory education, means that children with LDs have special educational needs, and therefore are eligible for free services and accommodations. This conclusion, however, has given rise to a cluster of related questions, specifically, (1) how LDs can be understood, that is, where they originate from and why; (2) how LDs should be identified; and (3) how LDs should be prevented, treated, and remediated.

With regard to the "how" questions, the answers have been shaped by two major societal forces. One force pertains to the developing understanding of human rights in general and children's rights in particular, especially the rights of children with special educational needs. It has been in operation both at the inter- and intra-national levels of all developed and many developing countries, and continues to push educational systems around the world to accommodate and address the needs of these children. The second force represents the grassroots movement of parents, who, while being educated in typical classrooms themselves, had children who experienced difficulties acquiring specific academic skills. These educated parents were able to organize themselves and exert enough pressure at multiple societal levels to result, in combination with the higher-level societal forces mentioned above, in the creation of the special laws and practices that now regulate the education of children with special educational needs in general and children with LDs in particular. The resulting concept of the right to free appropriate public education underscores the irreplaceability of education with any other kind of "services" for children with special needs, including those with LDs. All children have the right to be educated and are required to be educated, but the word "appropriate" is an important qualifier that defines both the content and the process of education for children with special needs.

Since its emergence in the early twentieth century, the concept of LD has undergone multiple transformations. Currently, LDs exist, conceptually, on two parallel planes: the *individual* plane, which is most closely related to the question(s) of "who(s)," and stresses the importance of understanding the phenomenon of individual differences across the whole spectrum of all children in terms of the ways they acquire skills of spoken and written language and related academic skills (successfully or not, with ease or with difficulty, within typical or atypical trajectories); and the *societal* plane, which addresses the question(s) of "how(s)" and has guided the regulations pertaining to the identification of special needs when the acquisition of relevant skills is atypical, and the process and content of free and appropriate education that is suitable for such special needs.

Important Scientific Research and Open Questions

Thousands of scientific publications have been devoted to the concept of LD in general and language-based LDs in particular. Broadly speaking, the research covered in these publications can be grouped into six major categories.

The first category addresses issues concerning the classification of language-based LDs. There is an agreement in the field that all LDs are a subcategory of developmental disorders, that they onset early in life and remain present throughout the life course, although they might change in their behavioral manifestation. Yet, there is no single definition for the classification of LDs in general, or for language-based LDs in particular. Definitions and classifications of LD vary depending on the general approach to developmental disorders being used: as exemplified in the guidelines of the World Health Organization, presented in the *International Classification of Disease and Related Health Problems* (ICD-10); as provided by the guidelines of the *American Psychiatric Association*, outlined in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV or DSM-IVR, revised); according to the US laws, as captured by the *Individuals with Disabilities*

Education Improvement Act (IDEIA); or using country-specific classification and regulation documents. This variegated quilt of definitions and classifications makes the task of comparative research rather difficult and, on top of this diversity, researchers often use so-called research definitions of language-based LDs, which are not used in formal classification schemes but are prevalent in the research literature (e.g., Grigorenko 2008).

The second category of research investigates the overlap between various types of language-based LDs within this group of disabilities (e.g., disorders of spoken language such as apraxia, specific language impairment, dyslexia, and dysgraphia), the overlap of language-based LDs with other types of LDs (e.g., dyscalculia), and the overlap with other developmental disorders (e.g., attention deficit hyperactivity disorder and autism). At this point, it is quite clear that these disorders are not independent and do co-occur in various combinations. Yet, although the field has generated some interesting and promising findings pertaining to these overlaps (e.g., Hulme and Snowling 2009), their extent, nature, and time course are largely unknown. Therefore, to substantiate and ground these findings, it is important to carry out large-scale longitudinal studies in different languages with different linguistic properties on cohorts identified early and followed throughout their years of schooling.

The third research category pertains to the generation and testing of psychological models of LD in general and language-based LDs in particular, and the generality and specificity of these models across different languages (e.g., Share 2008). As indicated above, this type of research is an attempt to understand the role of intelligence in learning. Subsequently, however, it has differentiated into many other lines of research that aim to dissect the holistic manifestations of various language-based LDs into the lower-level components that constitute their psychological texture. The intent behind this category of research is four-fold: (1) to grasp the componential machinery of a particular disability in order to capture its engine and identify that engine's breakable (and, therefore, reparable) parts; (2) to identify components that are present in all or some disabilities and track the impact of their deficient functioning on the observed overlaps between various LDs; (3) to understand the developmental sequence of the emergence and crystallization of these components; and (4) to investigate whether these machineries are similar or different in different languages.

Fourth, there is a substantial body of research on the etiology and epidemiology of LDs in general and language-based LDs in particular. This research has pointed out the multifactorial nature of language-based LDs, where genetic factors are considered to be important risk factors whose influence unfolds within the context of particular protective or mitigating environments (e.g., Grigorenko 2009). These research findings have shaped the prevalent view of language-based LDs as neurological developmental conditions whose manifestation is based on genetic factors, but whose severity and specific presentation can be substantially impacted by circumstances of upbringing and schooling. Thus, in terms of epidemiological studies of LDs, it is important to identify developmental risk factors that can onset these conditions, investigate their impact pathways, and qualify and quantify their frequency and importance.

The fifth category of research pertains to the educational applications of the scientific understanding of language-based LDs and the development of preventive and remediational pedagogical technology. This is, of course, the most important junction of scientific research and educational practice, because it directly impacts the millions of children who have language-based LDs. Numerous approaches to teaching children with LDs have been developed, and there is a substantial body of conclusive knowledge with regard to the effectiveness of various strategies of teaching (Fletcher et al. 2007). These strategies are based on views of these conditions as developmental disorders and are rooted in modern psychological theories. The concept of *Response to Intervention* as the basis for LD identification and remediation has been developed within this line of research.

Finally, the last category of research has been developed to understand how best to configure education in any society to meet the needs of children with language-based LDs at all stages of their lives, before, during, and after formal schooling. This research is carried out across multiple disciplines and reflects political and societal changes in attitudes toward educating children with special needs (Elliott and Grigorenko 2011). It also crosses both definitional planes (see above), the individual and societal. At the individual plane, this research investigates what is

needed to meet the specific needs of each child so that any individual pattern of learning can be realized to its full potential. Within this context, the identification of LD is as important as the identification of any atypical learning profile, as it sets in motion the application of strategies known to work for a particular category of children. Thus, the category of LD is an important recognition of a particular learning trajectory that should – just as an identification of giftedness would – activate a set of most appropriate teaching techniques. At the societal plane, however, as educational systems around the world move, almost unequivocally, toward inclusive education, the category of LD might be losing its initial value and meaning. As every child, at least in developed countries, is eligible for free and appropriate education and their individual educational pathways are guided by evidence-based assessment and intervention, the category of LD may become obsolete. Certainly, it should not be as influential as it was throughout the twentieth century, during which very different circumstances existed pertaining to the politics of education and the state of scientific knowledge. As the individualization of education increases, individual students' educational profiles will become more important than the categories they may be sorted into. In short, LD profiles will always exist on the individual plane, but the LD categories that describe them on the societal plane might well disappear.

Cross-References

► Impaired Verbal Associative Learning
► Language Acquisition
► Language and Learning

References

Elliott, J. G., & Grigorenko, E. L. (2011). *The dyslexia debate*. New York: Cambridge University press.

Fletcher, J. M., Lyon, G. R., Fuchs, L. S., & Barnes, M. A. (2007). *Learning disabilities*. New York: Guilford.

Grigorenko, E. L. (2008). Developmental disorders of learning. In I. H. L. Roediger (Ed.), *Cognitive psychology of memory* (Vol. 2, pp. 745–758). Oxford: Elsevier.

Grigorenko, E. L. (2009). Speaking genes or genes for speaking? Deciphering the genetics of speech and language. *Journal of Child Psychology and Psychiatry, 50*, 116–125.

Hulme, C., & Snowling, M. J. (2009). *Developmental disorders of language learning and cognition*. New York: Wiley-Blackwell.

Share, D. L. (2008). On the anglocentricities of current reading research and practice: The perils of overreliance on an "outlier" orthography. *Psychological Bulletin, 134*, 584–615.

Latent Inhibition

Robert E. Lubow
Department of Psychology, Tel Aviv University, Ramat Aviv, Israel

Synonyms

Stimulus preexposure effect

Definition

Latent inhibition (LI) is demonstrated when a previously unattended stimulus is less effective in a new learning situation than a novel, or previously attended, stimulus. The term, "latent inhibition," dates back to Lubow and Moore (1959). The LI effect is "latent" in that it is not exhibited in the stimulus preexposure phase, but rather in a subsequent test phase. "Inhibition" simply connotes that the behavioral effect is expressed in terms of relatively *poor* performance on a new learning task. The LI effect is extremely robust, appearing in all mammalian species that have been tested and across many different learning paradigms, thereby suggesting that it provides some adaptive advantage, such as protecting the organism from associating old, irrelevant stimuli with other, more important, events.

Theoretical Background

The LI effect has received a number of theoretical interpretations. One class of theory holds that inconsequential stimulus preexposures result in reduced associability for that stimulus. The loss of associability has been attributed to a variety of mechanisms that reduce attention, which then must be reacquired in order for learning to proceed normally. Alternatively, it has been proposed that LI is a result of retrieval failure rather than acquisition failure. Such a position advocates that, following stimulus preexposure, the acquisition of the new association to the old stimulus proceeds normally. However, in the test stage, two associations (the stimulus-no consequence association from the preexposure stage and the stimulus-consequence association of the acquisition stage) are retrieved and compete for expression. The non-preexposed group performs better than the preexposed group because there is only the second association to be

retrieved. For reviews of both sets of theories, see Lubow and Weiner (2010).

Important Scientific Research and Open Questions

The LI effect is modulated by many factors, of which context is one of the most important. In virtually all LI studies, the context remains the same in the stimulus preexposure and test phases. However, if context is changed from the preexposure to the test, then LI is severely attenuated. Stimulus preexposure-context effects play major roles in all current theories of LI, and in their applications to schizophrenia where it has been proposed that there is a breakdown in the relationship between the preexposed stimulus and the context, either as a cause or an effect of the high levels distractibility in some subgroups of patients. As a consequence, working-/short-term-memory would be inundated with experimentally familiar but phenomenally novel stimuli, each competing for the limited resources required for efficient information processing. This description fits well with the positive symptoms of schizophrenia, as well as with much research findings.

The assumption that the same attentional process that produces LI in normal subjects is dysfunctional in schizophrenics is based on the considerable evidence that dopamine agonists, such as amphetamine, which aggravate the positive symptoms of schizophrenia, attenuate LI. On the other hand, dopamine antagonists, such as haloperidol, which ameliorates the positive symptoms of schizophrenia, potentiate LI (for review, Weiner and Arad 2010). These effects have been found in experiments with healthy human subjects as well as with rats. In addition, manipulations of putative dopamine pathways in the brain also have the expected affects on LI. Thus, hippocampal and septal lesions interfere with the development of LI, as do lesions in selective portions of the nucleus accumbens, all of which have been implicated in schizophrenia (for review, Weiner 2010).

These findings have encouraged considerable research. Thus, a number of studies have reported that acute, non-medicated schizophrenic patients show reduced LI compared to chronic, medicated schizophrenics and to healthy subjects. On the other hand, there is no difference in the amount of LI in the latter two groups, and even some suggestion that chronic schizophrenia patients, particularly those with negative symptoms, may display the opposite of an LI effect. Related to the first point, symptomatically normal subjects who score high on self-report questionnaires that measure psychotic-proneness or schizotypality also exhibit reduced LI compared to those who score low on those scales (for review, Kumari and Ettinger 2010).

The observed relationship between LI and schizophrenia has stimulated a search for the neural substrates that may be common to the behavioral LI phenomenon and the psychopathology. Thus, in addition to studying the effects of dopamine agonists and antagonists, those of glutamatergic, GABAergic, serotonergic, and cholinergic neurotransmitters also have been explored, as have their neuro-developmental and genetic underpinnings. Most recently, LI procedures have been used with mutant mice to search for schizophrenia candidate genes.

Over and above illustrating a fundamental strategy for information processing and providing a useful tool for examining attentional dysfunctions in pathological groups, LI procedures have found practical applications, such as in the screening for drugs that can ameliorate schizophrenia symptoms. LI has also been used to explain why certain therapies, such as alcohol aversion treatments, are not as effective as might be expected. On the other hand, LI procedures may be used to counteract some of the undesirable side-effects that frequently accompany radiation and chemotherapies for cancer, as for example food aversion. Finally, LI research has suggested techniques that may be efficacious in the prophylactic treatment of certain fears and phobias.

In spite of the wide-ranging LI research programs and the extensive data base that has accumulated, a number of outstanding issues require further investigation. There is a need to more fully explicate, integrate, and expand the behavioral models of LI and to firmly link them to their neural, pharmacological, and genetic substrates. Relatedly, much more research is necessary to specify the relationship between different LI abnormalities and schizophrenia symptom clusters. On the practical side, a reliable and robust within-subject procedure for producing LI in humans must be developed, so that performance to the preexposed

and the non-preexposed stimuli can be obtained from the same subject. Such a procedure would greatly increase the ability to collect valid data from patient groups. In addition, it is necessary to ensure that the effects produced in human LI experiments are based on the same underlying behavioral and neural substrates as those in animal studies. Such a translational approach would promote illuminating causal mechanisms of basic information processes and their disruption in schizophrenia.

In summary, the basic LI phenomenon represents the output of a selective attention process that results in learning to ignore irrelevant stimuli. As such, it has become an important factor in the development of learning and information processing theories, as well as in modeling attentional dysfunctions in schizophrenia.

Cross-References

► A Salience Theory of Learning Associative Learning
► Attention and Implicit Learning
► Comparator Hypothesis of Associative Learning
► Perceptual Learning
► Pre-exposure Effects on Spatial Learning
► Task-Irrelevant Perceptual Learning
► The Role of Attention in Pavlovian Conditioning

References

Kumari, V., & Ettinger, U. (2010). Latent inhibition in schizophrenia and schizotypy: A review of the empirical literature. In R. E. Lubow & I. Weiner (Eds.), *Latent inhibition: Cognition, neuroscience, and applications to schizophrenia* (pp. 419–447). New York: Cambridge University Press.

Lubow, R. E., & Moore, A. U. (1959). Latent inhibition: The effect of non-reinforced preexposure to the conditioned stimulus. *Journal of Comparative and Physiological Psychology, 52,* 415–419.

Lubow, R. E., & Weiner, I. (Eds.). (2010). *Latent inhibition: Data, theories, and applications to schizophrenia.* New York: Cambridge University Press.

Weiner, I. (2010). What the brain teaches us about latent inhibition (LI): The neural substrates of the expression and prevention of LI. In R. E. Lubow & I. Weiner (Eds.), *Latent inhibition: Cognition, neuroscience, and applications to schizophrenia* (pp. 372–415). New York: Cambridge University Press.

Weiner, I., & Arad, M. (2010). The pharmacology of latent inhibition and its relevance to schizophrenia. In R. E. Lubow & I. Weiner (Eds.), *Latent inhibition: Cognition, neuroscience, and applications to schizophrenia* (pp. 276–318). New York: Cambridge University Press.

Latent Learning

JOHN C. MALONE
Department of Psychology, University of Tennessee, Knoxville, TN, USA

Synonyms

Incidental learning; Learning without reward

Definition

The word *latent* comes from the Greek "lanthameine" (to escape notice) and the Latin "latent" (to lie hidden). It refers to a power or quality that is present, though not now visible. *Learning* is a word that originated in Old English as "leornian" and referred to the gaining of knowledge. "Latent learning" therefore means gaining of knowledge, including skills, not now apparent, but which could become so. The treatment here is restricted to the usage of the learning theories of the twentieth century and excludes the vast literature on "learning without awareness" (see, Cohen and Schooler 1997).

Theoretical Background

During the early and mid-twentieth century the dominant theories of learning were variations on the stimulus-response (S-R) view, which is itself a variant of the more general "behaviorist" view. Beginning with Edward Thorndike (1898), and greatly expanded and refined by Clark L. Hull (1943), this approach viewed organisms as machines and sought to discover the rules that governed them. Hull developed this way of thinking to its ultimate end and, along with his colleagues and many followers, established S-R psychology as the ideal form of behaviorism. Hull's psychology was clearly dominant by the mid-twentieth century (see Amsel and Rashotte 1984; Malone 2009).

According to Hull, learning occurs when situational cues ("stimuli") become connected to specific responses that have been followed by reduction of a biological drive (e.g., hunger) or produce stimuli associated with drive reduction (e.g., signs of food). In short, learning occurs only when behaviors are followed by reward/reinforcement ("reward" and "reinforcement" are not the same thing, but the two terms were used interchangeably in the mid-twentieth

century) and that consists of drive reduction or cues associated with drive reduction. I may walk through a maze a thousand times, but I will not learn the maze unless rewarded at the end. Hull realized, as did Thorndike, that it is difficult to test this theory and exclude all possible sources of reward. Thus, I may repeatedly go through the maze or repeat the lines of a poem and, after each repetition, say to myself, "I have finished again," thus rewarding my behavior. Nonetheless, the dominant view in the 1930s was that all learning required some sort of clear reinforcement. In animal research – Hull's specialty – that meant food for a hungry animal.

This background makes Tolman's report of "latent learning" intelligible. Blodgett (1929) and Tolman and Honzik (1930) showed that hungry rats could learn a complex maze with 14 or more choice points without food reward and perhaps learn it better than rats that were trained with food reward. Their procedure, results, and interpretation are described in many sources, including most introductory psychology textbooks. Malone (1990), Barker (2001), and Jenson (2006) also describe this research and point out the faults in their interpretation – Jensen was particularly persuasive in this respect.

The experiments are easily summarized (consider Tolman and Honzik's study). They trained 3 groups of rats in a 14-unit T-maze, represented in the upper panel of Fig. 1. A straight runway led to a choice point, where the rat could go right or left. One choice led to a blind alley and the other led to another choice point. Since there were 14 choice points, the maze would be difficult for a human subject, especially since subjects were run only 1 trial per day.

One group of rats received food in the goal box (the HR, or hungry-rewarded group), but the other two groups found nothing at the end of the maze. They were just removed from the goal box and returned to their home cages. The experimenters recorded the "errors" made by animals in each of the three groups during the first 10 days (ten trials) of training. As a hint concerning later criticisms of the experimenters' interpretation of these data, you may wonder what constitutes an "error" for the two groups run without food reward. Why should they make "successful" choices, when there is no food at the end of the maze?

By the tenth day, the rats that had received food in the goal box had reduced their errors from about ten per day to about three, so it seemed that the food reward was strengthening the correct habits as Hull would predict (see Fig. 1, lower panel). The slight improvement in the performance of the unrewarded groups was paid little attention. On the eleventh day, one of the previously unrewarded groups (HNR-R) found food in the goal box for the first time. If food delivery continued, Hull would predict that these rats would slowly catch up with the HR group. But, as Fig. 1 shows, the newly rewarded rats surpassed the always-rewarded rats by the next day and on subsequent days they showed even fewer errors than did the HR subjects.

There seemed only one interpretation – that of Tolman and his followers. The rats that had the 10 days' experience in the maze, with or without food, had all learned the maze and knew which choices to make at the choice points. But only the rewarded subjects – the HR group – had reason to reach the goal box. The unrewarded groups' learning was "latent," not shown in performance, and the HNR-R subjects showed it when food was finally in the goal box. This account was widely accepted and matched our intuitions. Most of what we learn is what might be called "latent." What we learn as specifically taught, with feedback (reward), is a small part of what we know.

But Tolman and his group had a broader agenda. They argued, as Tolman summed it up in 1948, that the demonstration of "learning without reward" showed that learning is really a cognitive process and that what are learned are "cognitive maps," spatial representations of environments (Tolman 1948). The rats that received no food reward, nonetheless, formed a map of the maze and when there was reason to reach the goal box, they showed it.

Jensen (2006) showed that this has remained the interpretation reported by introductory psychology textbook writers almost a century after it was proposed, ignoring the fact that the interpretation has been long discredited. Many long lived but erroneous beliefs persist because the experimental data, however flawed, seem to conform to our common sense explanations of our own behavior.

Important Scientific Research and Open Questions

Hull accounted for such evidence for latent learning in ways that are no longer relevant. But years after his

Latent Learning. Fig. 1 Upper Panel: Diagram of a pair of 14-unit T-mazes as used by Tolman & Honzik. Lower Panel: Plot of the decrease in blind-alley entrances ("errors") made by Tolman & Honzik's three groups

response, others offered convincing alternative accounts. Bear in mind, the alternatives were originally between S-R psychology and "cognitive maps" in rats' brains!

Some investigators considered the ordinary behavior of rats, which have (as we all do) a tendency to explore new environments – could this account for what seemed to be latent learning? Consider the following findings.

MacCorquodale and Meehl (1954) trained rats to run in a complex maze with food in the goal box and all

blind alleys blocked – only the correct choices could be made. Later, when the blocks were removed, every rat entered *every* blind alley evidently showing the natural exploratory behavior of rats. What of Tolman and Honzik's rats? The always-rewarded group improved gradually, since their exploratory behaviors would count as "errors," as they checked the blind alleys. Meanwhile, the nonrewarded groups would surely have completed their exploring by the tenth day and, when the goal box held food, these "newly rewarded" rats would quickly make the choices that were now "correct." Further evidence comes from second experiments by the same authors in which rats were allowed to explore a complex maze before training began. These rats made only 20% of the "errors" that were made by inexperienced rats. Once the blind alleys have been explored, there is no reason to enter them and thus commit what will be counted as errors.

So, latent learning, as promoted by Tolman, was an artifact created by a researcher who did not really understand rat behavior. In addition to the evidence of MacCorquodale and Meehl, others, like Barker (2001), pointed out that Tolman and Honzik's "unrewarded" subjects were still taken to their home cages after leaving the maze every day – that, of course, is where they were customarily fed. Thus, were they really "unrewarded" for reaching the goal box?

Tolman's "latent learning" demonstrations were therefore only part of a game he was playing with the S-R psychologists of his time. While he was wrong, he surely knew, as we all do, that learning commonly occurs without discernible rewards/reinforcers or feedback.

Cross-References

▶ Incidental Learning
▶ Pre-exposure Effects on Spatial Learning
▶ Reinforcement Theory
▶ Tolman, Edward

References

Amsel, A., & Rashotte, M. (Eds.). (1984). *Mechanisms of adaptive behavior: Clark L. Hull's theoretical papers.* New York: Columbia University Press.

Barker, L. M. (2001). *Learning and behavior: Biological, psychological, and sociocultural perspectives* (3rd ed.). Upper Saddle River: Prentice-Hall.

Blodgett, H. C. (1929). The effect of the introduction of reward upon the maze performance of rats. *University of California Publications in Psychology, 4*, 113–134.

Cohen, J. D., & Schooler, J. W. (Eds.) (1997), *Scientific approaches to consciousness* (based on the 25th Annual Carnegie Mellon Symposium on Cognition). Mahwah, NJ: Erlbaum.

Hull, C. L. (1943). *Principles of behavior.* New York: Appleton.

Jensen, R. (2006). Behaviorism, latent learning, and cognitive maps: Needed revisions in introductory psychology textbooks. *Behavior Analyst, 29*(2), 187–209.

MacCorquodale, K., & Meehl, P. H. (1954). Edward C. Tolman. In W. K. Estes, S. Koch, K. MacCorquodale, P. H. Meehl, C. G. Mueller, W. N. Schoenfeld, & W. S. Verplanck (Eds.), *Modern learning theory.* New York: Appleton.

Malone, J. C. (1990). *Theories of learning: A historical approach.* Belmont: Wadsworth.

Malone, J. C. (2009). *Psychology: Pythagoras to present.* Cambridge: MIT Press.

Thorndike, E. L. (1898). Animal Intelligence: An experimental study of the associative processes in animals. *Psychological Review Monograph, 2*(Suppl 8).

Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review, 55*, 189–208.

Tolman, E. C., & Honzik, C. H. (1930). Degrees of hunger, reward and nonreward, and maze learning in rats. *University of California Publications in Psychology, 4*, 241–275.

Latent State-Trait Models

▶ Models of Measurement of Persons in Situations

Lateral Temporal Cortex

The part of the temporal lobe located closer to the sides of the head. The lateral temporal cortex is implicated in processes such as auditory perception and semantic processing.

Law of Effect

Michael Domjan
Department of Psychology, The University of Texas at Austin, Austin, TX, USA

Definition

The Law of Effect is a specific mechanism of goal-directed or instrumental behavior. According to the

Law of Effect, a response that results in a positive or desirable outcome is more likely to occur in the future because the positive outcome strengthens an association between the response (R) and the stimulus context (S) in which the response occurred. Importantly, the response outcome or goal is not part of the S-R association that is responsible for future occurrences of the response.

Theoretical Background

The Law of Effect has been one of the most influential and enduring mechanisms of learning since its formulation more than 100 years ago by Edward Lee Thorndike. Thorndike proposed the Law of Effect to explain the learning that he observed in his famous puzzle box experiments. The puzzle boxes were made of slats of wood that served to confine an animal (cat, chicken, or dog) at the start of each trial. Each box had a door that was opened if the animal performed a specified response. In one box, for example, the cat had to pull a wire loop to release the escape door. In other boxes, the door could be opened by pressing a lever or by performing a sequence of responses (pressing a treadle, pulling a string, and pushing a bar). The animals that served in the experiments were typically hungry and could obtain food when they successfully escaped from the box.

Initially, a cat put in a puzzle box would claw and bite the wooden slats and try to squeeze through spaces between them. During this unsuccessful and disorganized activity, the cat might happen by chance to make the particular response that was required to release the puzzle box door. With repeated trials, the cat's behavior became much more organized and "goal directed." Instead of making a lot of unsuccessful attempts to escape, the cat would perform the required response soon after the start of the trial. Thus, learning was evident in a decrease in the time it took to escape from the puzzle box.

Thorndike's puzzle box experiments provided the first systematic empirical investigation of instrumental conditioning and served to establish instrumental conditioning as one of the basic paradigms for the study of learning and behavior analysis (Chance 1999). Some have referred to the basic finding that behavior is increased by a positive or desirable outcome as the "empirical Law of Effect." However, Thorndike reserved the term "Law of Effect" to a specific

theoretical mechanism he proposed to explain his results. Most of Thorndike's puzzle box experiments were reported in his Ph.D. dissertation in 1898, but he did not formally state the Law of Effect until he published his book, *Elements of Psychology*, in 1905. Initially, Thorndike proposed both a positive and a negative form of the Law of Effect. The positive form of the law states that following a response with a reinforcing or positive outcome strengthens an S-R association between the response and stimulus context in which the response was made. The negative form of the Law of Effect states that following a response with an aversive or negative outcome weakens the S-R association. Later in his career, Thorndike withdrew the negative Law of Effect because he failed to find good evidence for it. Most references to the Law of Effect are to the positive version of the law.

In formulating the Law of Effect, Thorndike was keen to provide a mechanistic explanation that was not teleological and did not require cognitive concepts such as ideas, goal seeking, and decision making. As a graduate student, Thorndike had met the influential comparative psychologist C. Lloyd Morgan and followed Morgan's canon of keeping explanations of animal behavior as simple as possible. According to the Law of Effect, instrumentally learned behavior is impelled by cues (S) that were present when the response was previously reinforced. Most importantly, although instrumental behavior appears to be goal directed, according to the Law of Effect the goal or response outcome is not a part of the S-R association that is responsible for the behavior.

After Thorndike's pioneering work, studies of instrumental conditioning proceeded along two divergent paths. One path is the tradition of behavior analysis started by B. F. Skinner and his intellectual successors, which emphasizes the quantitative measurement and modeling of behavior in relation to its controlling variables (Chance 1999). Behavioral analysis has greatly expanded the empirical and quantitative characterizations of instrumental behavior. However, this area of research has not addressed issues related to the S-R mechanism of Thorndike's Law of Effect. The other major path for the study of instrumental conditioning has been much more theory driven and focused on the associative mechanisms that are responsible for instrumental behavior. This line of work was started by Clarke Hull and Kenneth Spence who accepted Thorndike's S-R

mechanism and built major theories of instrumental behavior based on the basic concept that a positive response outcome acts back from the response to strengthen an S-R association (Amsel and Rashotte 1984).

A major contribution of Hull–Spence theory was the formulation of an S-R mechanism to explain how behavior can be triggered by the expectation of reward. According to this proposal, contextual cues (S) in the presence of which the instrumental response is reinforced become associated with the reinforcer or response outcome (O) through Pavlovian conditioning. This results in an S-O association. A Pavlovian conditioned response, called the fractional anticipatory goal response (r_g) comes to be elicited by the contextual cues (S). This fractional anticipatory goal response was considered to be the behavioral manifestation of the expectancy of reward. Once r_g has become conditioned, sensory feedback from r_g becomes part of the context for the instrumental behavior. By Thorndike's Law of Effect, reinforcement of the instrumental response in the presence of these reward expectancy cues serves to establish an S-R association between these cues and the instrumental behavior. According to Hull and Spence, with the addition of this new S-R association, the instrumental behavior comes to be elicited by both the external stimuli (S) provided by the training context (through Thorndike's original Law of Effect) and the internal cues provided by reward expectancy. Interestingly, the idea that instrumental responses are stimulated by both external cues irrespective of the goal event and internal cues attendant to the expectation of reward remains dominant in contemporary theoretical analyses of habitual behavior (Wood and Neal 2007).

The S-R mechanisms of Hull–Spence theory provided a detailed account of how Pavlovian reward expectancies or S-O associations are involved in the motivation of instrumental behavior. The details of the fractional anticipatory goal response mechanism did not survive empirical scrutiny, but subsequent analyses have retained the idea that instrumental behavior is mediated by S-O associations that are learned during the course of instrumental conditioning (e.g., Rescorla and Solomon 1967). Because of this mediation, instrumental behavior can be modified by the presentation of Pavlovian conditioned stimuli in Pavlovian-instrumental transfer tests.

Studies of Pavlovian-instrumental transfer effects were the first of a series of phenomena that indicated that the mechanisms of instrumental responding are more complicated than originally characterized by the Law of Effect. Alternative accounts have emphasized that a representation of the reinforcer or response outcome is important for instrumental responding. An experimental design frequently used to reach this conclusion involves changing the value of the reinforcer after training. For example, a rat may be initially trained to press a bar to obtain a few drops of sugar water and to pull a chain to obtain a dry pellet of food. Once both instrumental responses have been established, one of the response outcomes (sugar water or pelles) is devalued by pairing it with illness. Making one of the response outcomes or reinforcers aversive after instrumental conditioning results in suppression of the response that previously produced that outcome. The fact that reinforcer devaluation reduces the associated response indicates, contrary to the Law of Effect, that the mechanisms of instrumental behavior include a representation of the reinforcer or response outcome.

How might the response outcome be involved in the mechanisms of instrumental behavior? Evidence has supported three different associative structures. The first is the S-O association that was introduced by Hull and Spence and later modified by Rescorla and Solomon. The S-O association links the reinforcer with the contextual cues present when the instrumental response is made. A second mechanism involves a link between the instrumental response and the response outcome, in the form of an R-O association. According to the R-O association, performance of the instrumental response activates a representation of the reinforcer. Interestingly, neither the S-O nor the R-O association can act alone to generate instrumental behavior, since neither provides a way to get the behavior started. A third mechanism that involves a hierarchical associative structure solves this problem. According to this third mechanism, the R-O association is activated by the contextual cues S that are present during instrumental conditioning. This mechanism may be represented as S-(R-O). The S-(R-O) mechanism is similar to the three-term contingency proposed by B. F. Skinner. However, specific evidence for the hierarchical associative structure was not available until experiments involving reinforcer devaluation were performed late in the twentieth century.

Important Scientific Research and Open Questions

Studies have identified that instrumental conditioning results in the learning of S-O and R-O, S-(R-O) associations. However, the existence of these associations does not indicate that the S-R association of the Law of Effect is no longer relevant. Quite the contrary. Contemporary analyses of habit learning and drug addiction emphasize that habitual behaviors are driven by S-R mechanisms akin to the Law of Effect that do not incorporate a representation of the response outcome or reinforcer (Wood and Neal 2007). Yin and Knowlton (2006), for example, concluded that "the S-R/reinforcement theory of Thorndike and Hull has, therefore, stood the test of time when judged by its success at capturing the nature of habit learning" (p. 467). The Law of Effect has remained an important mechanism of instrumental behavior for two reasons. First, reinforcer devaluation and related procedures do not always suppress instrumental responding. These negative findings have been used to argue that there are instances in which a representation of the reinforcer is not involved in maintaining the instrumental response. The second line of evidence favoring S-R mechanisms is that different neural systems seem to be involved in responding that is, or is not, sensitive to reinforcer devaluation (Yin and Knowlton 2006). Thus, the different mechanisms of instrumental behavior can be differentiated at the level of neural systems.

One major challenge for future research is to develop better diagnostic criteria for identifying S-R associations. At this point, S-R associations are inferred primarily from negative evidence – lack of sensitivity to manipulations involving the reinforcer. Developing positive diagnostic criteria would be a major step forward. Another major challenge for future research is to identify what conditions favor the activation of S-R associations rather than associations involving the reinforcer. Progress on this issue has begun. One of the major variables that favors S-R as opposed to alternative associations is the extent of training. Overtraining an instrumental response reduces its sensitivity to reinforcer devaluation. Other circumstances that favor (or impede) S-R learning remain to be discovered. Finally, future research should focus on identifying variables that shift control of instrumental behavior from one associative mechanism to another. Such research is particularly relevant in trying to modify undesirable habits. The S-R nature of habitual responding is probably why such behavior is so resistant to educational and other efforts intended to convince clients of the undesirable consequences of their actions.

Cross-References

► Habituation
► Habituation and Sensitization
► Instrumental Conditioning
► Thorndike, Edward L.

References

Amsel, A., & Rashotte, M. E. (1984). *Mechanisms of adaptive behavior: Clark L. Hull's theoretical papers, with commentary.* New York: Columbia University Press.

Chance, P. (1999). Thorndike's puzzle boxes and the origins of the experimental analysis of behavior. *Journal of the Experimental Analysis of Behavior, 72*, 433–440.

Rescorla, R. A., & Solomon, R. L. (1967). Two-process learning theory: Relationships between Pavlovian conditioning and instrumental learning. *Psychological Review, 74*, 151–182.

Thorndike, E. L. (1905). *Elements of psychology.* New York: Seiler.

Wood, W., & Neal, D. T. (2007). A new look at habits and the habit-goal interface. *Psychological Review, 114*, 843–863.

Yin, H. H., & Knowlton, B. J. (2006). The role of the basal ganglia in habit formation. *Nature Reviews, Neuroscience, 7*, 464–476.

L

Law of Simple Action

► Matching

Layered Learning

► Cumulative Learning

Leadership Learning

► Management Learning

Learnability

CHARLES YANG
Department of Linguistics & Computer Science,
University of Pennsylvania, Philadelphia, PA, USA

Definition

Learnability is the formal study of language acquisition in a mathematical and computational setting. It attempts to precisely specify the mechanisms of language learning, characterize the conditions that make language acquisition feasible, and provide guidance for the empirical research on child language development.

Theoretical Background

In a typical setting of formal learnability (Gold 1967), the learner is presented with a sequence of examples drawn from an unknown target language, which can be viewed as a set of strings composed of an alphabet. The learner's task is to converge on to the target language after seeing a finite, or computationally tractable, amount of examples (Valiant 1984). Generally speaking, learnability study has revealed the difficulty of language learning without a suitably constrained space of hypotheses that constrain the learner's initial state (Vapnik 1995). These results are very general and hold irrespective of the specifics learning algorithm.

The constrained hypothesis space for feasible language learning can be broadly identified as an innate Universal Grammar. It may result from constraints that are specific to language, or their interactions with more general principles of cognition, perception, and learning.

In practice, two general directions can be taken to achieve learnability. One approach is to further restrict the classes of languages the learner entertains. For instance, while the general class of finite state languages is not learnable, a subclass in which strings have mutually substitutable parts is learnable. The other approach is to provide the learner with additional information such as the distribution of strings in the target language. Both approaches, however, make additional assumptions about the learner's innate knowledge about the target language that require independent motivations. A learnable but more restrictive class of languages may prove inadequate for the description of natural language. In some cases, such as the use of distributional information in learning, the learner is also taxed with computational complexity that may not be feasible in a psychologically plausible model of learning.

Important Scientific Research and Open Questions

The main challenge for learnability research is to make the abstract study of learning more directly relevant to the empirical work on child language.

The learning model must succeed on a relatively small linguistic sample, perhaps only ten million utterances, which is approximately the amount of input data a child receives by the time he/she has successfully acquired the major properties of their language. To appreciate the challenges that a language learner faces, it has proven informative to examine the statistical properties of natural languages that serve as the input. The well-known Zipf's law (Zipf 1949) reveals that very few units of language (e.g., words) are high-frequency events while the vast majority appear very rarely, if at all, even in very large samples of language. This skewed distribution is more pronounced for linguistic combinations such as phrases and grammatical rules. The learning model, like the child, must be able to generalize rapidly and accurately on scanty data.

A grammatical theory that limits the range of possible human languages is a natural response to the results from learnability research. All major linguistic theories allow only a finite, albeit potentially large, number of grammars. The learner's task is to select the grammar(s) used in the linguistic environment. Ideally, the descriptive apparatus in linguistic theories ought to provide compact descriptions of empirical facts as to simplify the task of learning. Research efforts have been dedicated to the study of learning algorithms under specific theories of grammar in both syntax and phonology. Important issues include convergence, robustness, sample complexity, and the fit between the learning model and child language. An important issue here is the relationship between the learning model and the model of grammar that is being learned: some learning models explicitly make use of the properties of the grammatical theory while others are general and have applications in other domains of learning (Yang 2004).

Another current direction for learnability study is to test the validity of distributional learning

mechanisms identified in the psychological literature. Distributional analysis over linguistic units, which forms the basis for linguistic theorizing and dates back to the structuralist tradition, has been found, in at least some rudimentary form, in young children under a variety of experimental settings. It remains to be seen under what conditions distributional analysis provides psychologically plausible and linguistically accurate mechanisms for language learning. Mathematical considerations and computational modeling are useful since language learning involves the interaction among multiple, and frequently conflicting, strategies, which are typically considered in isolation in experimental studies (Yang 2004).

Perhaps the most pressing development in learnability research is to draw stronger connections with the empirical study of child language (Yang 2004; Berwick 1985). It is expected that the algorithmic process of language learning be reflected in the developmental patterns of child language, which can be assessed through naturalist production, experimental elicitation, and/or other more indirect means. Moreover, the search for an acquisition theory applicable across languages should likewise be reflected in the computational approach, which must address the apparent diversity and complexity of the world's languages.

Cross-References

► Computer Simulation Model
► Feature Selection (Unsupervised Learning)
► Formal Learning Theory
► Knowledge and Learning in Natural Language
► Language Acquisition and Development
► Learning Algorithms
► Mathematical Linguistics and Learning Theory
► PAC Learning
► Rule Formation
► Statistical Learning Theory and Induction
► Stochastic Models of Learning

References

Berwick, R. (1985). *The acquisition of syntactic knowledge.* Cambridge, MA: MIT Press.

Gold, E. M. (1967). Language identification in the limit. *Information and Control, 10*, 447–474.

Valiant, L. (1984). A theory of the learnable. *Communications of the ACM, 27*, 1134–1142.

Vapnik, V. (1995). *The nature of statistical learning theory.* New York: Springer.

Yang, C. (2004). Universal grammar, statistics, or both. *Trends in Cognitive Sciences, 8*(10), 451–456.

Zipf, G. (1949). *Human behavior and the principle of least effort: An introduction to human ecology.* Cambridge: Addison-Wesley.

Learned Aggression in Humans

MICHELYN C. BUTLER, MARIBETH GETTINGER
Department of Educational Psychology, University of Wisconsin-Madison, Madison, WI, USA

Synonyms

Bullying; Physical aggression; Relational aggression; Violence

Definition

Although definitions of aggression vary, most researchers agree that aggressive acts are both *intentional* and potentially *hurtful* to the victim. Thus, learned aggression in humans is defined as learned (not instinctive) behavior or actions that are meant to harm another individual. The aggressive actions may occur in various forms, for example, verbal, physical, or psychological. Historically, research has focused primarily on physical forms of aggression, such as instances of hitting, pushing, kicking, or throwing objects, all with the intent to physically harm another person. More recently, researchers have begun to investigate nonphysical forms of aggression that are also intended to hurt others. For example, verbal aggression entails outbursts or language used in social settings hurts an individual's self-concept or causes psychological pain.

Relational aggression, also known as covert aggression, is a type of verbal aggression in which harm is caused by damage to relationships or social status within a group (e.g., social exclusion, threats to end a friendship, or spreading rumors). Relational aggression has been studied most often among preadolescent and adolescent girls. Another distinction in aggression among humans is between instrumental and hostile aggression. Instrumental aggression is used as a means of securing some personal reward or to achieve a goal, such as a victory. Unlike instrumental aggression, hostile aggression is an act of aggression against another

person with the goal of inflicting pain or causing suffering for the victim. Moreover, hostile aggression is accompanied by anger on the part of the aggressor.

Theoretical Background

Philosophers and psychologists have theorized about the nature of aggression in humans for centuries. There are different reasons why a person may act aggressively toward others. Various theories, including innate or biological theories as well as learning theories, have been postulated to explain the development of aggression in humans. Three prevailing theories of aggression, which are summarized below, are predicated on the notion that human aggression is a learned behavior.

Albert Bandura, a social-cognitive psychologist, is most famous for developing the *social learning theory* of human development and, in particular, for conducting research on aggression in children (Bandura 1973). His research began with the "Bobo doll" experiments in the early 1960s at Stanford University. Children between 3 and 6 years of age from the university's nursery school participated in these experiments. Specifically, half of the toddlers witnessed (individually) an adult model attack the Bobo doll by hitting it; the other children were placed individually in a room with a nonaggressive adult model who simply played with small toys, ignoring the Bobo doll. Subsequent to being in a room with either an aggressive or nonaggressive adult, each child was placed in a room alone with several toys (including a mallet and Bobo doll). Bandura found that children who had been exposed to an aggressive model were more likely to engage in physically aggressive actions with the toys (including hitting the Bobo doll) than were those who had been exposed to a nonaggressive model (Bandura et al. 1961). According to Bandura, children who observed aggressive, adult behavior learned that such behavior was acceptable. Bandura's social learning theory postulates that people learn from one another in a social context, via observation, imitation, and modeling. In other words, individuals, especially children, imitate or copy aggressive behavior by personally observing others, such as adults in their environment or the mass media.

Gerald R. Patterson extended the behavioral component of social-cognitive theory through his research with family dyads (Patterson 1982). Patterson's theory, referred to as the *coercion model*, states that aggressive behaviors develop in families when parents use coercion as the primary mode for controlling their children. Poor parental discipline skills and coercive management practices cause escalation of child–parent conflict which, in turn, increases children's aggression. Through this coercive sequence, children learn to behave in noncompliant and aggressive ways. Patterson argued that parents can unknowingly reinforce aggressive behaviors in children by nagging, scolding, and yelling when children misbehave. These ongoing, negative, reciprocal child–parent interactions serve to maintain the coercive pattern and reinforce aggressive and noncompliant behavior. At some point in the coercive process, negative reinforcement of a child's aggressive and noncompliant misbehavior occurs when the parent fails to follow through with promised consequences. According to Patterson, when a parent fails to discipline adequately and/or follow through with consequences, children learn they can continue to engage in aggressive behavior (without consequence) to coerce parents into meeting their needs. In other words, children learn that by responding to their parents' negative and coercive behaviors with increased aggression, they can shape parental behaviors for their own benefit. Over time, children learn to move quickly to intense levels of negative and aggressive behavior.

Beyond Bandura's theory of observational learning and Patterson's theory of reinforced aggression, a third theory of learned aggression posits that aggressive behavior serves a communicative purpose or function for individuals (Carr and Durand 1985). Within the *functional* or *social-communicative theory*, children presumably engage in aggressive behaviors because aggression functions as a mode of social communication. This theory stems from the notion that some nonverbal behaviors, specifically crying, constitute a primitive or proto-communicative act. This belief dates back to the ancient Greek philosopher, Plato, and then resurrected with the French philosopher, Rousseau. Both philosophers wrote about the purpose of crying and believed that crying serves as a means of communicating a baby's needs and wants. Additional research has documented the development of social-communicative crying among infants to gain attention, to escape an uncomfortable or negative situation, or to gain a desired object or food. As a typically developing child matures, more sophisticated means of communication (e.g., speech) increase while the basic, primitive

forms of communication (e.g., crying) decrease. In this way, speech replaces crying as a more appropriate and useful means of communication. This social-communicative theory has been generalized to other human behaviors including aggression. In particular, Brownlee and Bakeman (1981) studied aggression in toddlers and found that their aggressive behaviors (e.g., hitting) served multiple communicative purposes. For example, when a child hit another child with an open hand, the child being hit (victim) typically ceased contact with or moved away from the perpetrator. This led the researchers to speculate that the aggressive behavior was escape-motivated and was used in place of verbal communication ("Leave me alone!"). In this way, aggressive behaviors, such as hitting, are maintained as long as the aggressive behavior continues to serve a reinforcing function for the child, that is, as long as the individual is successful in meeting his or her needs.

Important Scientific Research and Open Questions

Why humans take part in aggressive acts and engage in aggressive behavior has been the subject of considerable research and debate, as have questions concerning the nature of factors that bring out aggression. Because aggression is a form of behavior and because the biological, cultural, and learned origins of behavior are difficult to separate from one another, it is likely that definitive answers to the nature of aggression will continue to be sought. Future research will continue to examine the role of temperament, personality, and environmental variables in the development of aggressive behavior. The social learning, coercive, and communicative theories of aggression, explained previously, are predicated on the assumption that aggression is a learned, not instinctive, behavior. Although research demonstrates that people learn aggressive behavior early in life, studies focusing on ecological or individual temperament characteristics have also contributed to an understanding of the development of aggression. Most contemporary researchers agree that aggressive behavior is multidetermined and that it begins early in one's life. Studies have identified several factors which lead to an increased risk of aggressive behavior in children and adolescents, including being the victim of abuse, possible hereditary factors, substance abuse, neurological impairment, mental health issues, and environmental stressors including poverty,

deprivation, death, neglect, or divorce. What is not clear and, thus, should continue to be the focus of future research is whether such individual and environmental variables have a direct influence on aggression, or if the effect is mediated by social learning and parenting experiences (e.g., television viewing, punitive parenting, observing or being exposure to aggressive behavior). Theorists who conceptualize aggression as a learned behavior allow for an impact of frustration, stress, or temperament in making it more likely that an individual who has learned aggressive responses (through observation or reinforcement) will, in fact, use them.

In addition, within a theoretical perspective that views aggression as a learned behavior, researchers will continue to identify and validate effective strategies for reducing and/or preventing aggressive behavior. Based on this understanding of the nature and development of aggressive behavior, an important question for clinicians and researchers alike is: How do people learn *not* to be aggressive? Research has demonstrated that aggressive behavior is often established by the age of 8, and that children who are aggressive at this age are likely to be aggressive as adults. Who will become aggressive and where and when this will happen are difficult to predict. Nonetheless, reducing the factors that place individuals at risk of acquiring aggressive behavior patterns and eliminating or reducing opportunities for children to witness violence and aggression can prevent aggressive behavior. Children can be raised *not* to learn aggressive behavior and, as such, to resist violence. Parents, family members, and other people who care for children can teach them how to deal with frustration without being aggressive. This can include providing children consistent attention and support, showing children appropriate behavior by setting a good example through their own actions, never hitting children or using physical punishment, being consistent about rules and disciplines, preventing children from seeing violence in the home or community, and in the media, as much as possible, and teaching nonaggressive ways to resolve conflicts and meet their needs, especially the use of language and communication.

Cross-References

▶ Family Background and Effects on Learning
▶ Functional Learning

► Imitation and Social Learning
► Media Violence Effects on Learning
► Model-Based Imitation Learning
► Reinforcement Learning
► Social Learning

References

Bandura, A. (1973). *Aggression: A social learning analysis.* Englewood Cliffs: Prentice-Hall.

Bandura, A., Ross, D., & Ross, S. A. (1961). Transmission of aggression through imitation of aggressive models. *Journal of Abnormal and Social Psychology, 63*, 575–582.

Brownlee, J. R., & Bakeman, R. (1981). Hitting in toddler-peer interaction. *Child Development, 52*, 1076–1079.

Carr, E. G., & Durand, V. M. (1985). The social communicative basis of severe behavior problems in children. In S. Reiss & R. R. Bootzin (Eds.), *Theoretical issues in behavior therapy* (pp. 220–254). New York: Academic.

Patterson, G. R. (1982). *Coercive family processes.* Eugene: Castalia.

Learned Change of Behavior Potential, Learned Competency, Learned Ability

► Subject of Learning

Learned Helplessness

THOMAS R. MINOR, TRACI N. PLUMB
Department of Psychology, UCLA, University of California, Los Angeles, CA, USA

Synonyms

Behavioral depression; Cognitive, motivation, and emotional impairment; Psychological trauma; Uncontrollable and unpredictable aversive events

Definition

Learned helplessness refers to the behavioral and physiological pathology resulting from experience with traumatic, uncontrollable aversive events. The learning that occurs under these circumstances produces cognitive, motivational, and emotional impairment that disrupts attempts at active coping and ongoing commerce with the environment. These features of learned helplessness also are integral components of major depression and related mood disorders (Seligman 1975). As such, the paradigm has a long history as an animal model of this type of psychiatric illness.

Theoretical Background

The learned helplessness procedure is the traditional method for analyzing the ability of psychological variables to modulate the impact of traumatic stress. This line of research grew out of a series of experiments conducted in the mid- to late 1960s by a group of graduate students in Richard Solomon's laboratory at the University of Pennsylvania. Overmier, Seligman, and Maier collaborated to demonstrate that exposure to a series of unsignaled, inescapable electric shocks dramatically impairs later escape/avoidance learning in dogs (Overmier and Seligman 1967; Seligman and Maier 1967; Seligman 1975). These experiments are historically important at two levels: First, they provide the foundation for a contingency analysis of instrumental learning and second, they provide one of the first major experimental models of behavioral depression in humans and greatly facilitated empirical analysis of that psychiatric disorder.

The Learned Helplessness Effect

The learned helplessness effect refers to the behavioral phenomenon that occurs when an animal is exposed to uncontrollable traumatic stress. In the classic experiment, sets of three dogs were restrained in harnesses and exposed to a series of escapable shocks, yoked inescapable shocks, or simple restraint (Seligman and Maier 1967). The first dog (the Master) in this triadic design could exert behavioral control simply by turning its head to press an adjacent panel to terminate shock. The second dog received yoked, inescapable shock. Shock commenced at the same time for both dogs and terminated only when the Master completed the escape response. The third dog in the triad was restrained in the harness and received no shock. This dog provided a non-stressed behavioral baseline against which the effects of stressor controllability could be assessed during later testing.

The learned helplessness effect is defined by the disruption of escape/avoidance performance 24 h after exposure to an uncontrollable stressor. Figure 1 shows median latency of barrier jumping in a shuttle-

Learned Helplessness Effect

Learned Helplessness. Fig. 1 Median escape/avoidance latencies in a shuttlebox on each of ten trials for groups of dogs exposed to escapable shock, yoked inescapable shock, or restraint in a different apparatus 24 h earlier. The maximum possible latency on a trial was 60 s (Adapted from Seligman and Maier 1967)

box on each of ten trials for each of the three groups (Seligman and Maier 1967). The maximum possible latency on a trial was 60 s. Restrained and escape groups learned the barrier jumping response with equal efficiency. By contrast, animals receiving yoked, uncontrollable shock typically fail to respond on each of the ten trials. This poor performance by those receiving the uncontrollable stressor, in conjunction with the efficient performance shown by those receiving equal amounts and durations of controllable stress, defines the learned helplessness effect.

This general pattern among groups holds for a wide variety of behavioral and biological stress indexes. The learned helplessness effect has been demonstrated in most mammalian species. Most important, because escapably and inescapably shocked animals receive the same pattern, intensity and duration of shock during stress pretreatment, the differential performance of these two groups in the test phase provides unequivocal evidence that some psychological variable related to behavioral control, or lack thereof, modulates the impact of the shock stressor.

Learned Helplessness Hypothesis

The learned helplessness hypothesis accounts for this pattern of results by assuming that subjects learn the behavioral contingency to which they are exposed during stress pretreatment and respond accordingly during the test. Specifically, uncontrollable and unpredictable aversive events are assumed to represent the area in an instrumental contingency space that corresponds to response-reinforcer independence. Figure 2 illustrates this relationship. The figure plots the relationship between two conditional probabilities involving a response and its outcome. The p (outcome/response) – read the probability of an outcome given a response – is a formal statement about the likelihood of reward when a response is executed. The p (outcome/no response) states the formal relationship between the delivery of a reward (or outcome) when a response does not occur. Both of these conditional probabilities can vary between 0 and 1. The difference between these two probabilities defines the overall contingency in the situation. The diagonal line in the plot represents a range of conditions over which responding and outcomes are independent (Seligman et al. 1971). The idea that animals learn about response-outcome contingencies, even when there is no contingency, had a substantial and long-lasting impact on our understanding of how we learn about our world.

Learning the independence between responding and shock termination during the original aversive

Learned Helplessness. Fig. 2 Contingency space showing the relationship between two conditional probabilities involving a response and its outcome. The p (outcome/response) is the likelihood of reward when a response is executed. The p (outcome/no response) is the likelihood of a reward when a response does not occur. Both of these conditional probabilities can vary between 0 and 1. The difference between these two probabilities defines the overall contingency in the situation. The *diagonal line* in the plot represents a range of conditions over which responding and outcomes are independent or uncontrollable (Adapted from Seligman et al. 1971)

experience results in the expectation that future events will be similarly uncontrollable. This expectation of learned helplessness works in three ways to impair later escape/avoidance. First, the negative expectation proactively interferes with the learning of the positive escape contingency that exists during testing. Second, the expectation that responding will be ineffective at modifying test shocks reduces the motivation to engage in the type of instrumental behavior that would increase contact with the escape contingency. Finally, feelings of helplessness lead to a change in emotional tone that is akin to major depression. These cognitive, motivational, and emotional deficits combine to disrupt test performance.

Important Scientific Research and Open Questions

These basic observations have stimulated an enormous amount of research on the psychology and neurobiology of stressor controllability, psychological trauma, and major depression. More recent experiments now link learned helplessness phenomena to the induction and prolonged maintenance of fear during exposure to

the uncontrollable stressor, rather than experience with the uncontrollable stressor per se. Manipulations that mitigate the pattern or total time in fear during stress pretreatment dramatically improve test performance. In this regard, escape or coping responses protect against pathology by reducing pretreatment fear. Fear during uncontrollable shock also is alleviated by stimuli that mimic the signal features of an escape response. Thus, stimuli signaling the termination of shock or a shock-free period (safety signals) are as protective as behavioral control. One practical consequence of this line of research is that the learned helplessness paradigm has morphed from a model of major depression to a model of PTSD with comorbid depression (Minor et al. 1990).

The behavioral paradigm has also been used in recent years to understand the impact of psychological trauma on brain chemistry and endocrinology. This research is too extensive and complicated to review here. Briefly, the circuitry and neuroendocrine systems implicated in the learned helplessness effect overlap considerably with those implicated in fear conditioning and anxiety disorders.

New research and therapies for depression have developed based on the idea that learning to be optimistic can counter expectations of helplessness (Reivich et al. 2005). This new approach is based on an early finding that experience with controllable shock prior to experience with uncontrollable shock blocks the development of later escape/avoidance deficits. The idea is that developing strong expectations of control or optimism is completely incompatible with developing expectations of helplessness. In this regard, optimism training has been shown to mitigate symptoms of major depression and prevent relapse in humans.

Cross-References

► Avoidance Learning
► Contingency Learning
► Coping with Stress
► Emotional Learning
► Learning from Failure
► Learning Mechanisms of Depression
► Mastery Learning
► Punishment and Reward
► Stress and Learning
► Transfer of Learning

References

Minor, T. R., Trauner, M. A., Lee, C., & Dess, N. K. (1990). Modeling signal features of escape response: Effects of cessation conditioning in "learned helplessness" paradigm. *Journal of Experimental Psychology: Animal Behavior Processes, 16*(2), 123–136.

Overmier, J. B., & Seligman, M. E. (1967). Effects of inescapable shock upon subsequent escape and avoidance responding. *Journal of Comparative and Physiological Psychology, 63*(1), 28–33.

Reivich, K., Gillham, J. E., Chaplin, T. M., & Seligman, M. E. (2005). From helplessness to optimism: The role of resilience in treating and preventing depression in youth. In S. Goldstein & R. B. Brooks (Eds.), *Handbook of resilience in children* (pp. 223–237). New York: Kluwer Academic/Plenum.

Seligman, M. E. (1975). *Helplessness: On depression, development, and death.* San Francisco: Freeman.

Seligman, M. E., & Maier, S. F. (1967). Failure to escape traumatic shock. *Journal of Experimental Psychology, 74*(1), 1–9.

Seligman, M. E., Maier, S. F., & Solomon, R. L. (1971). Unpredictable and uncontrollable events. In F. R. Brush (Ed.), *Aversive conditioning and learning* (pp. 347–400). New York: Academic.

Learned Variability

► Reinforced Variability and Operant Behavior

Learned Versus Innate

► Learning and Instinct

Learner Characteristics

HENDRIK DRACHSLER, PAUL A. KIRSCHNER
Centre for Learning Sciences and Technologies (CELSTEC), Open University of the Netherlands, Heerlen, DL, The Netherlands

Synonyms

Learner model; Learner profile

Definition

The concept of *learner characteristics* is used in the sciences of learning and cognition to designate a target group of learners and define those aspects of their personal, academic, social, or cognitive self that may influence how and what they learn. Learner characteristics are important for instructional designers as they allow them to design and create *tailored instructions* for a target group. It is expected that by taking account of the characteristics of learners, more efficient, effective, and/or motivating instructional materials can be designed and developed.

Learner characteristics can be personal, academic, social/emotional, and/or cognitive in nature. *Personal* characteristics often relate to demographic information such as age, gender, maturation, language, social economic status, cultural background, and specific needs of a learner group such as particular skills and disabilities for and/or impairments to learning. *Academic* characteristics are more education- and/or learning-related such as learning goals (of an individual or a group), prior knowledge, educational type, and educational level. *Social/emotional* characteristics relate to the group or to the individual with respect to the group. Examples of social/emotional characteristics are group structure, place of the individual within a group, sociability, self-image (also feelings of self-efficacy and agency), mood, etc. Finally, *cognitive* characteristics relate to such things as attention span, memory, mental procedures, and intellectual skills, which determine how the learner perceives, remembers, thinks, solves problems, organizes, and represents information in her/his brain.

With respect to learner characteristics, there are often large differences between the characteristics of different learners and groups of learners such as children, students, professionals, adults, older people, and disabled persons. These groups differ in their motivation, prior knowledge, expertise level, study time, and physical abilities. The differences within the learner characteristics have an impact on the structure of the instruction and the degree of *support* and *guidance* of the learning process.

Theoretical Background

The theoretical roots of learner characteristics can be traced back to Witkin (1949, 1978 p. 39) who saw them as a "characteristic mode of functioning that we reveal throughout our perceptual and intellectual activities in a highly consistent and pervasive way." In other words, learner characteristics are seen as traits and not as states. As early as 1949, Witkin published research related to

field dependence/field independence. Field-dependent people have difficulty separating an item from its context while a field-independent person can easily break up an organized whole into its relevant parts.

A second driving force with respect to learner characteristics – and especially cognitive learner characteristics – was Guilford who referred to them as intellectual abilities (Structure of Intellect Model, Guilford 1967). He organized these abilities along three dimensions, namely, operations (cognition, memory, divergent production, convergent production, and evaluation), content (visual, auditory, symbolic, semantic, and behavioural), and products (units, classes, relations, systems, transformations, and implications). Guilford saw these dimensions as being independent of each other yielding, theoretically, 150 different components of intelligence on which learners can differ.

With respect to the coupling or use of specific instructional approaches for specific learner characteristics, Cronbach and Snow (1977) posited their model of aptitude–treatment interactions, which held that certain instructional strategies (i.e., treatments) will be more or less effective for different individuals depending upon the individual's specific abilities (i.e., aptitude). This model presupposes that optimal learning is the result of the instruction being perfectly matched to the learner's aptitudes.

Important Scientific Research and Open Questions

Though there are many important questions, these can be categorized into major categories, namely:

What learner characteristics are – or may be – truly important for making learning more effective, efficient and/or enjoyable? There is no such thing as "the" learner characteristic(s). Learning characteristics are highly individual and vary for every learner. Are there certain characteristics that are more important (i.e., play a greater role in influencing how instruction affects the learner) than others? Instructional designers must constantly deal with new and differing groups of learners and thus must make decisions as to what characteristics of the target group are most important when tailoring instruction.

Is it possible to discern different learning styles and how do we do this? There is much debate as to whether learning styles actually exist. Pashler et al. (2009) conclude that the "contrast between the enormous popularity of the learning-styles approach within education and the lack of credible evidence for its utility is, in our opinion, striking and disturbing. If classification of students' learning styles has practical utility, it remains to be demonstrated" (p. 117).

Are preferred learning styles as reported by learners really suitable for tailoring instruction? If this is the case, learners with certain learning characteristics would get certain learning materials allocated to them. As a consequence, the learners receive learning content that fits to their preferred learning style. This approach is contentious for a number of reasons, for example, because (1.) what learners say that they do while studying does not usually correspond to what they actually do, (2.) even if this were not the case, learners prefer not only one learning approach, but rather certain learning styles for particular situations, and finally (3.) is that which is preferred actually what is best for the learner (Kirschner et al. 2006).

The current research on learner characteristics has an impact on the personalisation of learning within the field of technology-enhanced learning (TEL). In TEL, personalization is a key approach to overcome the plethora of information in the Knowledge Society, and especially of adults and professionals. It is expected that personalized learning has the potential to reduce delivery costs, to create more effective learning experiences, to accelerate study time to competence development, and to increase collaboration between learners.

TEL researchers use the definition of learner characteristics from the sciences of learning and cognition as metadata descriptions to create so-called *learner models*. Such a learner model is customized to the target group of a TEL learning environment. Most of the time, it contains learning goals, prior knowledge levels, and certain personal preferences a learner can specify in a learner profile. In the early e-Learning days, TEL researchers tried to match learning content or adjust a learning environment to the information a learner has personally entered in a learner profile. Nowadays, the learning characteristics metadata fields are filled with statistical numbers based on different mathematical methods to model a learner. The mathematical methods take into account the dynamic behaviour of learners in a learning environment.

Thus, they record activities of learners like most viewed pages, time elapsed on pages, written texts from blogs, comments, or discussions boards, contributed hyperlinks, and their content to create a learner model. The collected information is gathered and clustered in the learner characteristics metadata fields. Based on this mathematical model, each learner receives a score for each of the learner characteristics. This score can be compared with the score of other learners and with the content in a TEL environment by similarity measures. The similarity measure between the score of a learner A and learner B allows to make reasoning between the two learners. In the current TEL research, this reasoning is used to offer tailored information about most suitable learning content or suitable peer learners to an individual learner. A good overview about this research field and learner modelling can be found in Manouselis et al. (2011).

Cross-References

► Abilities and Learning
► Aptitude-Treatment-Interaction
► Individual Differences
► Knowledge Representation
► Learner Preferences and Achievement
► Learning Styles
► Role of Prior Knowledge in Learning Processes

References

Cronbach, L., & Snow, R. (1977). *Aptitudes and instructional methods: A handbook for research on interactions*. New York: Irvington.

Guilford, J. P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 46*(2), 75–86.

Manouselis, N., Drachsler, H., Vuorikari, R., Hummel, H. G. K., & Koper, R. (2011). Recommender systems in technology enhanced learning. In P. B. Kantor, F. Ricci, L. Rokach, & B. Shapira (Eds.), *Recommender systems handbook*. Berlin: Springer.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2009). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*, 105–119.

Witkin, H. (1949). The nature and importance of individual differences in perception. *Journal of Personality, 18*, 145–170.

Witkin, H. (1978). *Cognitive styles in personal and cultural adaptation*. Worcester: Clark University Press.

Learner Characteristics and Online Learning

Minoru Nakayama[1], Rowena Santiago[2]
[1]Tokyo Institute of Technology, Meguro, Tokyo, Japan
[2]California State University San Bernardino, San Bernardino, CA, USA

Synonyms

Aptitude; Attitude; Competence; Learning style; Performance

Definition

Learner characteristics can be defined as various measures of leaners' psychological, behavioral nature, and attitudes toward everything related to learning. Because of the broad range of learner characteristics, its specific components have been operationally defined in e-learning research and measured in various ways. In particular, aptitude of learners is often discussed as a construct of learner characteristics, where aptitude is defined as "any characteristic of a person that forecasts his probability of success under a given treatment" or "whatever makes a person ready to learn rapidly in a particular situation (or, more generally, to make effective use of a particular environment)" (Cronbach and Snow 1977). Swan (2004) reported that various constructs of learner characteristics such as motivation, attitude, learning styles, gender, and culture affect online learning performance. Successful learning performance in e-learning environments has also been linked to instructional designs that adapt to student aptitude and personality (Nakayama et al. 2010). Since aptitude could influence learning performance and outcomes, as well as learners' career paths starting with course selection, aptitude is considered to play a major role in terms of learner characteristic and e-learning.

Theoretical Background

According to previous studies, aptitude scales include tests of IQ, personality, psychological attributes, skills, and various attitudes which can be measured using developed scales. One of the most cited studies on the relationship between learner's aptitude and leaning

methodologies is Chronbach and Snow's Aptitude-Treatment Interaction (ATI) model, which proposed that various individual learner characteristics or individual differences interact with certain instructional treatments, and that functions for alternative treatments be compared to find out what benefits can be obtained by matching individuals to appropriate instructional design or treatment (Cronbach and Snow 1977). Learning effectiveness through the use audiovisual aids or multimedia systems is frequently discussed using the ATI model.

Recent years have seen a rapid growth in information communication technology (ICT). Similarly, the use of ICT in various e-leaning environments is fast increasing. These changes have led to greater awareness of the diversity of learning characteristics that could contribute to success in ICT-enhanced learning environments. In some cases, change in one's learning style was also needed as new learning structures such as collaborative learning or project-based learning are introduced into these new e-learning environments.

Therefore, to design, to improve or to develop better e-learning environments, learner's characteristics should be taken into consideration because individual learner characteristics could determine the degree of one's readiness for e-learning and for optimizing one's learning success in e-learning environments.

According to conventional studies, testing instruments that are used to measure learning characteristic constructs can be classified into two categories. The first category are the standardized tests which are mostly standardized psychological tests, while the other category deals mostly with the measure of attitudes using developed scales. Below are examples of these instruments for measuring specific constructs:

- Intelligence: The most famous scale is IQ, but there are many other types of intelligence tests. For instance, in the area of child development, "verbal" and "non-verbal," or "intellectual abilities" are often measured using these tests (Cronbach and Snow 1977).
- Personality: Personality can be measured using the IPIP or Big-5 Model which measures the following factors: "Extraversion," "Agreeableness," "Conscientiousness," "Neuroticism," and "Openness to Experience." Factor scores can be calculated using a survey which is available online (IPIP 2001).

- Motivation: Motivation is sometimes measured as part of personality tests, but stand-alone motivation tests also exist. Most motivation tests measure "Intrinsic Motivation" and "Extrinsic Motivation" or "Achievement Motivation" (Miyamoto and Nasu 1995).
- Thinking Style: Sternberg's thinking styles which consist of 13 components is an example of a test for measuring this cognitive construct. Its three components are "legislative style," "executive style" and "judicial style" (Matsumura and Hiruma 2000).

Additionally, various psychological tests have been developed and standardized to measure constructs such as cognitive style, critical thinking, and test anxiety (Miyamoto and Nasu 1995).

There is also a growing trend in measuring literacy in areas such as information science and mathematics which are well beyond the conventional reading and writing literacies. These literacy tests usually measures one's mastery of both knowledge and skills or problem solving abilities in these areas.

Important Scientific Research and Open Questions

Learning characteristic such as behavioral construct or attitude can be measured using a scaling technique. Most scales are created using a set of question inventory which is often similar to standardized tests.

Below is an example of a learning characteristic scale that was used for e-learning evaluation of student attitude in e-learning environment (Nakayama et al. 2010). As this scale is originally extracted as a factor using factor analysis, most scales are established using factor analysis and simple scaling technique which combines some question items. All question responses should correlate to each other; therefore Cronbach alpha coefficient was introduced to determine internal consistency and validity of the items.

Table 1 shows the means for each question item using a five-point Likert scale for the initial survey (Initial Scores) that was given to students during the second week of classes, and the end-of-term survey at the final session (Final Scores). Both alpha coefficients show a high value of 0.8, between 0 and 1, because these question items were extracted as a factor. Though there are some significant differences in response scores between initial and final class session, these means did

Learner Characteristics and Online Learning. Table 1
Question items for e-learning evaluation and scores (N = 67)

Question items	Initial Scores		Final Scores
Q1. E-learning is easy to follow and understand	3.2		3.4
Q2. I learn better in online course	2.5	<	2.9
Q3. On-line materials are useful to me	3.4		3.4
Q4. It is easy to schedule online learning time	3.2		3.2
Q5. Online course content is interesting	3.2	>	3.0
Q6. Overall, online course is a favorable learning experience	3.6		3.4
Mean score	3.2		3.2
Cronbach alpha coefficient	0.8		0.8

Significant level $<$: $p < 0.05$

Learner Characteristics and Online Learning. Fig. 1
Scatter gram of the individual scores between the beginnings and the ends of courses (r = 0.46)

coincide. Therefore, mean score as an evaluation scale did not change during the class sessions. When individual scores are compared between beginning and end of class sessions, there are some deviations as shown in Fig. 1. Correlation coefficient is r = 0.46, so individual assessment scores are not consistent.

Generally, psychological measures such as personality are consistent as learning progresses, but learner's impression of the learning experience may change during the learning process. This suggests that there are two types of learner characteristics, namely, static and dynamic characteristics. Tests that will measure these two types of learner characteristics could lead to designing better e-learning environments.

Cross-References

► Aptitude-Treatment-Interaction
► Attitude Change Through Learning
► Learner Characteristics
► Learning Style(s)
► Literacy and Learning
► Measurement of Change in Learning
► Motivation and Learning: Modern Theories
► Online Learning
► Personality and Learning
► Personality Effects on Learning

References

Cronbach, L. J., & Snow, R. E. (1977). *Aptitudes and instructional methods, a handbook for research on interactions.* New York: Irvington.

International Personality Item Pool (2001). A scientific collaboratory for the development of advanced measures of personality traits and other individual differences. http://ipip.ori.org/. Accessed 27 Oct 2004.

Matsumura, N., Hiruma, F., Sutairu, S. (2000). *Thinking styles* (translation of Sternberg [1997] "Thinking Style" and author's review). Tokyo: Shinyousha.

Miyamoto, M., & Nasu, M. (1995). *Theory and development of achievement motivation.* Tokyo: Kanekoshobo.

Nakayama, M., Yamamoto, H., & Santiago, R. (2010). Online learning management and learners' behaviour: A case study of online learning in Japan. In F. Lazarinis, S. Green, & E. Pearson (Eds.), *Developing and utilizing e-learning applications.* Hershey: Information Science Reference.

Swan, K. (2004). Learning online: current research on issues of interface, teaching presence and learner characteristics. In J. Bourne & J. C. Moore (Eds.), *Elements of quality online education, into the mainstream.* Needham: Sloan Center for Online Education. http://www.rcet.org/research/publications/LE03.pdf. Accessed 11 Dec 2010.

Learner Control

ALI SIMSEK
Institute of Communication Sciences,
Anadolu University, Eskisehir, Turkey

Synonyms

Locus of instructional control; Self-regulated learning; Student-controlled instruction

Definition

Learner control refers to instructional strategies through which learners can exercise some level of control over the events of instruction. It means that learners make their own decisions regarding the sequence, pace, flow, amount, and review of instruction. Allowing learners control their own learning process implies that instructional control is handed over to learners in order to accommodate their individual differences toward the purpose of maximizing their gains.

Instruction is considered to be more externally controlled when the learner follows a predetermined/fixed sequence without any control over the lesson. On the other hand, instruction is thought to be more internally controlled in settings where the learner exercises certain amount of control over the contingencies of a lesson (Hannafin 1984).

In learner-controlled instructional situations, the designer often identifies the elements of instruction over which learners will exercise control; and while using the program, learners make corresponding decisions at appropriate points. In many cases, learner control takes the form of learner preferences because they often make choices in terms of instructional events. Such choices usually involve the sequence of instruction, pace of learning, amount of content, number of exercises, type of feedback, paradigm of review, and difficulty of test items. The executive power regarding such contingencies of instruction can be exercised by learners either on individual basis or in a small group.

Theoretical Background

The concept of learner control is intuitively appealing because learners differ in intelligence, ability, prior knowledge, interests, learning styles, motivation, personality, locus of control, self-efficacy, epistemological beliefs, and so forth. Through the opportunity of learner control, learners are assumed to have a chance to adjust instruction to their individual differences and eventually benefit more from it.

Although no open arguments exist against learner control, there are some arguments on the degree of learner control such as how much executive control should learners have. There are also arguments regarding appropriate context and operational structure of learner control. In other words, the type and level of learner control is considered to be more important than whether an opportunity of learner control is provided.

Learner control is often discussed within the context of computer-based instruction due to the computer's capability to deliver individualized lessons and monitor ongoing earner performance. The computer can present to individual learners tailored lessons with wide variations in pace, sequence, level, path, amount, and types of information. In such situations, the computer allows learners to decide the type of instruction that they would like to receive.

Learner control may apply to any format of instructional delivery system including correspondence courses, personal projects, and independent study. In fact, precedents of learner control in traditional settings go back to the audio-tutorial approach and personalized system of instruction. Typical variations in learner control may also apply to the following situations: Learners can write a paper on a topic they select based on their own interests and expertise. Learners can select alternative formats for their presentations such as oral, poster, or virtual. Learners can choose to take a class in a lecture format, an online format, or a blended format. Learners can decide the number of exercises to complete in an instructional unit. All these situations allow learners to make their choices by exercising some level of control over the events of instruction.

Rationale behind the concept of learner control is quite strong. Many educators suggest that learner control improves learners' involvement, motivation, mental investment, achievement, and attitudes toward learning. They claim that learner control provides learners freedom to select learning activities that suit

their needs, expectations, and preferences. The idea is that informed learner control by motivated learners generally increases effectiveness, engagement, and efficiency of instruction.

Strategic availability of learner control options can also provide structural support for the values of individual autonomy, personal relevance, active engagement, and reflectivity, all important characteristics of contemporary education (Lebow 1993). In short, through learner control, learners can become system independent because they can manipulate and accommodate instructional treatments to their own momentary cognitive requirements.

Important Scientific Research and Open Questions

There is substantial research on learner control. Studies on learner control have typically compared learner-controlled and program-controlled instructional treatments in a variety of educational settings including both adult learning and school learning. However, the knowledge base is still inadequate to make generalizations. Some variables have been investigated exclusively, while the others were examined only by a few studies. More importantly, much of the research has yielded inconclusive results (Simsek 1993). Overall, the empirical evidence on learner control in instructional contexts does not support its unconditional use.

As far as achievement is concerned, the results have been mixed. Most studies have found no significant differences between learner-controlled and program-controlled treatments. Some of the researchers use this result to support the use of learner control; emphasizing that since learner control is not detrimental, it is beneficial to allow learners to control their own learning because they take responsibility, make assessment of the situation, and eventually become effective decision makers.

Although there is contrasting evidence in a few studies, empirical research reports that students in learner-controlled conditions spend more time to complete the lessons than those in the program-controlled situations. This is particularly true when students exercise learner control in small groups. The time on task difference in such cases is usually attributed to the amount of socializing. It is interesting, however, that

shorter time usually relates to the poor performance, particularly when learners spend extensive amount of time to figure out how to operate the learner control features of the delivery system or when they terminate the lessons prematurely.

Most studies found positive effects of learner control on attitudes of learners, although there are a few exceptions in the literature reporting contrasting evidence. Interestingly, males prefer more learner control than females. This may be due to the fact that males often tend to spend more time with computers and thus are more likely to look at the elements that are not directly related to the content of the lesson.

The matter of the fact is that learner control may be more beneficial under certain conditions, while program control may be more beneficial under other conditions so that strategies of instructional control should be used carefully.

Mature and more capable learners perform equally well under both learner control and program control. On the other hand, younger and less capable learners tend to perform better under program control. It appears that more able learners are capable of employing effective learning strategies but less able learners are likely to benefit more from the maximum level of instructional support provided through program control based upon expert judgments.

When instruction does not require prior understanding/knowledge of the content or accurate insights into what information needs to be presented for effective learning, learner control may be an appropriate strategy. Similarly, learner control may provide effective results in learning verbal information because learners can pass over the parts of the content they have already learned and this does not cause any serious problem. On the other hand, learner control may not be useful if the nature of content is to be mastered completely before progress since students exercising learner control may skip and not learn vital elements of the content. This becomes particularly evident when the lesson involves hierarchical or procedural tasks that require higher understanding or mastery in each step of instruction (Steinberg 1989).

If the learning task is considered difficult by learners, alternative ways of adapting the content to individual differences should be employed. Research has demonstrated that using familiar contexts for

sophisticated tasks usually result in better achievement and attitudes. Therefore, special consideration should be given to instructional strategies that allow learners to select contextual properties of lessons according to their own backgrounds (Simsek 1993).

It appears that learner control requires effective decision making. When learners are capable of making appropriate decisions for their own learning, the option of learner control is beneficial. This situation has several implications: First, learners should be trained about metacognitive skills so that they become better decision makers for their own learning. Second, learner control option should be provided with mature and capable learners instead of all learners. Third, learner control should not be given just for taking advantage of interactive power of the current technologies; the decisions should be educationally justified. Finally, some level of advisement should be an integral part of the learner control strategy in order to help learners make proper decisions for their own learning.

Cross-References
► Interactive Learning
► Learner Preferences and Learning
► Personalized Learning
► Student-Centered Learning

References

Hannafin, M. J. (1984). Guidelines for using locus of instructional control in the design of computer-assisted instruction. *Journal of Instructional Development, 7*(3), 6–10.

Lebow, D. (1993). Constructivist values for instructional systems design: Five principles toward a new mindset. *Educational Technology Research and Development, 41*(3), 4–16.

Simsek, A. (1993). *The effects of learner control and group composition on student performance, interaction, and attitudes during computer-based cooperative learning.* Unpublished doctoral dissertation, University of Minnesota, Twin Cities.

Steinberg, E. R. (1989). Cognition and learner control: A literature review, 1977–1988. *Journal of Computer-Based Instruction, 16*(4), 117–124.

Learner Model

► Learner Characteristics

Learner Preferences and Achievement

FANG-YING YANG, YI-CHUN CHEN
Graduate Institute of Science Education, National Taiwan Normal University, Taipei, Taiwan

Synonyms
Preferences in learning and achievement

Definition
According to Oxford English Dictionary, "*preference*" is defined as "a greater liking for one alternative over another or others". Learner preferences thus can be referred to as students' liking for some element(s) of learning and chosen ways of interaction with the element(s) of learning. In literature, studies about learner preferences fall into two categories. One concerns learners' preferred types of environmental or instructional formats, and the other deals with learners' preferred ways of cognitive activities. Studies in the latter category appear more frequently in the name of "learning styles." In general, learner preferences serve as predictor of whether students may engage themselves in some particular format of learning environment, and an indicator of how students may approach and process information or materials to be learned. Studies about learner preferences and achievement thus attempt to answer whether the preference factors as mentioned above can predict school performance.

Theoretical Background
In educational literature, studies about learner preferences and achievement fall into two major categories, namely, environmental and cognitive preferences. Related studies are introduced as follows.

Environmental Preference
In this category of studies, major research topics include preferences toward different environmental or instructional formats and types of examinations. In the conventional classrooms, the environmental or instructional formats are usually characterized as contrary designs, such as student/learner-centered vs. teacher-centered learning environments and constructivist-oriented vs. reproduction-oriented learning

environments. By definition, the student or learner-centered environments emphasize students' active control or self-regulation in learning while the teacher-centered format highlights the dominating role of teachers in transmitting content knowledge. The constructivist-orientated environments focus on the construction of meanings and conceptual understanding while reproduction stresses the importance of rote learning.

Wierstra et al. (1999) surveyed over 800 university students from various countries in Europe and found that students in general preferred a learning environment that is less reproduction oriented and has a strong emphasis on active learning. A later study (Wierstra et al. 2003) showed that students' preferences of learning environments were corresponding to their learning orientations. Tsai (2000) found that high-school students in Taiwan preferred the constructivist-learning environment, but the actual learning environment perceived by students was rather conventional and lecture-giving style. Lee et al. (2009) identified three different types of preferences toward teacher authority, including preferences toward teacher-centered authority (i.e., teacher-centered atmosphere), uncertain authority (i.e., no explicit preference was shown), and sharing authority (i.e., both teacher-centered and learner-centered styles of teaching and learning were emphasized). It was found that students who preferred sharing authority tended to have more favorable learning attitudes, whereas students in the uncertain authority group displayed lower attitudes and achievements. In computer-assisted learning environments, Chang and Tsai (2005) uncovered interactions among students' subject-matter attitudes, environmental preferences, and classroom instructions. In brief, the teacher-centered instructional approach seemed to enhance more positive attitudes about subject matter particularly among students who exhibited less constructivist-oriented environment preference. On the other hand, the student-centered instructional approach was more beneficial to students who had higher preference toward constructivist-oriented environments.

In literature, few studies explicitly analyzed the effect of learning environment preference on achievement. In Lizzio's study (Lizzio et al. 2002), it was found that students' perceptions of their current learning environment were a strong predictor of learning outcomes at university. Accordingly, a match between preferred and perceived learning environment is expected to bring about optimal performance. Such an expectation was supported by a study conducted by Kopcha and Sullivan (2008) who found that in the learner-controlled, computer-based classroom, students with high prior knowledge achieved better when their preference for control was matched with the type of control they received. Nevertheless, it should be noted that in their study students with low prior knowledge achieved better when their preference was mismatched.

As far as the format of examination was concerned, BenChaim and Zoller (1997) found that secondary school students preferred written, open book, unlimited time examinations that emphasize learning with understanding rather than mechanical rote learning. However, female students seemed to prefer more of the conventional type of tests than male students did. It was also found that when students' preferred types of examination that focused on developing higher-order cognitive skills (HOCS) were applied, their performance enhanced. It was thus suggested that deliberate efforts should be made to encourage and facilitate teachers' compliance with their students' preferred examination types.

In recent years, alone with the applications of the online technologies in the instructional design, more attention was paid to discuss the learner preferences about the web-based or online learning environments and their effects on web-based or online learning. From students' oral responses, Tsai (2005) showed that high-school students strongly preferred the Internet-based learning environments that could connect scientific knowledge with real life situations. Meanwhile, female students tended to place more emphasis on the instructional guidance for science learning as well as the presentation of scientific knowledge in authentic contexts than did male students. By questionnaire survey, Lee and Tsai (2005) found that male students placed higher emphasis than female students did on the student negotiation, critical judgment, and epistemological awareness that could be enhanced by the Internet-based learning environments. In the meantime, students, when compared with their teachers, expressed higher preferences toward student negotiation, reflective thinking, critical judgment, and epistemological awareness of Internet-based learning environments. Yang and Tsai (2008) discovered that university students preferred more of individual and structured

instructional configurations, and also welcomed the outward mode of interaction. Moreover, students held a rather contextual belief about web-based learning, which was found to be correlated with their environmental preferences.

Above studies demonstrated students' environmental preferences in the online and web-based contexts but the effects of different preferences on learning has not been extensively discussed. A recent study presented by Yang and Chang (2009) showed that most university students demonstrated only moderate preferences toward the explorative and interactive web-based learning environments, and they seemed to be conservative about the effectiveness of the new form of learning. Further regression analysis indicated that preferences toward inquiry-based instructional design, outward interaction, and simple form of personal epistemology predicted concept achievements. Whereas, belief about effectiveness of web-based learning was a negative predictor for concept achievement. In short, while it has been shown that the online or web-based instructional design promotes concept learning, the effect is actually mediated by students' environmental preferences and personal beliefs.

Cognitive Preferences

The major research topics in this category deal mostly with learning styles. Theoretical models about learning styles are classified into four groups with respect to learning process, orientation to study, instructional preference, and cognitive skill. Brief descriptions about these style modes are presented below.

The process models are referred to as learners' preferred method for assimilating information. For instance, Kolb (1976) specified learning styles into diverger, converger, assimilator, and accommodator kinds. The orientation models describe individuals' preferred approaches to learning. An example is the three approaches proposed by Biggs (1985), namely, surface, deep, and achieving approaches. The instructional-preference models measures learners' preferences for environmental or instructional factors. For example, Dunn et al. (1989) proposed numerous "learning style elements" grouped across different instructional "stimuli" such as environmental, emotional, physiological, sociological, and psychological preferences. As for the models characterized based on the cognitive skill, they present learning style as

a multi-modal construct that aims to describe a range of intellectual functioning related to learning activities (Ridng and Rayner 1998). More detailed descriptions about these style models, corresponding instruments, and comparisons among the instruments can be found in several review articles (e.g., Cassidy 2004; Riding and Rayner 1998; Felder and Brent 2005). In addition to above mentioned classifications on learning styles, some scholars conceptualized learning styles based on the social interaction, such as cooperative, competitive, and individualistic preferences (e.g., Grasha 1996).

As for the associations between learning styles and achievement, it is generally believed that learning style influences learning performance. And, a widely accepted argument is that surface approach was negatively correlated with academic achievement while a deep approach to learning mediated achievement. Nevertheless, some recent studies show inconclusive results. For instance, a study conducted by Drysdale et al. (2001) revealed that the association between learning style and academic performance was more evident in students of science and math-related majors while no significant relationship was found in arts and social science students. Duff et al. (2004) found that approaches to learning such as deep, surface, and strategic approaches are poor predictors of academic performance. Furnham et al. (2009) analyzed the effects of personality traits, learning approaches, and general abilities (indicated by the intelligence and general knowledge tests) on the results of a standardized test (General Certificated in Secondary Education). They uncovered that intelligence was the best predictor of school performance while the learning approaches accounted for relatively little variance. Moreover, some scholars argued that the effects of learning styles on performance could have been mediated by environmental variables and students' perceptions about learning environments (Duff et al. 2004).

In classroom practice, it has been advocated that greater learning occurs when teaching styles match learning styles. However, there are studies demonstrating that students whose learning styles heavily match the teaching style might not be able to develop critical skills in their less preferred learning style categories (e.g., Felder 1996; Felder and Silverman 1988). As mentioned earlier, Kopcha and Sullivan (2008) showed that a match between learning preference and instructional approach improved learning for only students

with higher prior knowledge. Felder and Brent (2005) suggested that the optimal teaching style should be a balanced one that sometimes matches students' preferences, so that the distress level is not too high for them to learn effectively, and sometimes goes against their preferences, forcing students to develop intellectual and critical skills.

Important Scientific Research and Open Questions

According to the studies reviewed above. Several issues or questions are worth of further exploration.

1. Although it has been showed that a match between desired and perceived learning environment enhances learning, to what extent should the gap between desired and perceived environments be reduced if the goal instruction is to develop cognitive skills or attitudes that are against learner preferences?
2. In the context of web-based learning, it has been shown that environmental preferences and personal beliefs play an important role in mediating learning. However, the scope of web-based learning is in so far limited in concept learning. More studies are needed to discuss different aspects of learning.
3. Is learning style a domain-general or domain-specific construct? When learning different subject matters, do students display consistent learning styles?
4. Similar to the previously raised issue, to what extent should learning and teaching styles be matched? What the instructors should do if the goal of instruction is to encourage the development of cognitive skills against students' preferred styles?
5. According to the literature review, it is reasonable to hypothesize that students' preferences toward learning environments would interact with their learning styles or approaches, which may consequently result in different learning outcomes. More empirical studies are needed to verify the hypothesis.
6. Most studies about environmental preferences involve university students. Studies on learners of different educational levels are necessary to clarify the effects of environmental preferences on learning.
7. Similarly, studies about learning styles took place mostly in language and social-study classrooms. More investigations are needed in different knowledge domains.

Cross-References

► Learner Characteristics
► Learning Style(s)
► Preference Learning

References

BenChaim, D., & Zoller, U. (1997). Examination-type preferences of secondary school students and their teachers in the science disciplines. *Instructional Science, 25*, 347–367.

Biggs, J. B. (1985). The role of metalearning in study processes. *British Journal of Educational Psychology, 55*, 185–212.

Breckler, J., Joun, D., & Ngo, H. (2009). Learning styles of physiology students interested in the health professions. *Advances in Physiology Education, 33*, 30–36.

Cassidy, S. (2004). Learning styles: An overviews of theories, models and measures. *Educational Psychology, 24*, 419–444.

Chang, C. Y., & Tsai, C. C. (2005). The interplay between different forms of CAI and students' preferences of learning environment in the secondary science class. *Science Education, 89*, 707–724.

Drysdale, M. T., Ross, P., & Schulz, R. A. (2001). Cognitive learning styles and academic performance in 19 first-year university courses: Successful students versus students at risk. *Journal of Education for Students at Risk, 6*, 271–289.

Duff, A., Boyle, E., Dunleavy, K., & Ferguson, J. (2004). The relationship between personality, approach to learning and academic performance. *Personality and Individual Difference, 36*, 1907–1920.

Dunn, R., Dunn, K., & Price, G. E. (1989). *Learning style inventory*. Lawrence: Price Systems.

Felder, R. M. (1996). Matters of style. *ASEE Prism, 6*, 18–23.

Felder, R. M., & Brent, R. (2005). Understanding student differences. *Journal of Engineering Education, 94*(1), 57–72.

Felder, R.M., & Silverman, L.K. (1988). Learning and teaching styles in engineering education. *Engineering Education, 78*, 674–681.

Furnham, A., Monsen, J., & Ahmetoglu, G. (2009). Typical intellectual engagement, big five personality traits, approaches to learning and cognitive ability predictors of academic performance. *The British Journal of Educational Psychology, 79*, 769–782.

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS: 88. *Science Education, 82*(1), 93–109.

Grasha, A. (1996). *Teaching with style*. Pittsburgh: Alliance.

Kolb, D. A. (1976). *The learning style inventory: Technical manual*. Boston: McBer.

Kopcha, T. J., & Sullivan, H. J. (2008). Learner preferences and prior knowledge in learner-controlled computer-based instruction. *Educational Technology Research and Development, 56*, 265–286.

Lee, M. H., & Tsai, C. C. (2005). Exploring high school students' and teachers' preferences toward the constructivist internet-based learning environments in Taiwan. *Educational Studies, 31*, 149–167.

Lee, M. H., Chang, C. Y., & Tsai, C. C. (2009). Exploring Taiwanese high school students' perceptions of and preferences for teacher authority in the earth science classroom with relation to their attitudes and achievement. *International Journal of Science Education, 31*, 1811–1830.

Lizzio, A., Wilson, K., & Simons, R. (2002). University students' perceptions of the learning environment and academic outcomes: Implications for theory and practice. *Studies in Higher Education, 27*, 29–51.

Riding, R. & Rayner, S. (1998). *Cognitive Styles and Learning Strategies, Understanding Style Differences in Learning and Behaviour.* London: David Fulton.

Sonnenwald, D. H., & Li, B. (2003). Scientific collaboratories in higher education: Exploring learning style preferences and perceptions of technology. *British Journal of Educational Technology, 34*(4), 419–431.

Tsai, C. C. (2000). Relationships between student scientific epistemological beliefs and perceptions of constructivist learning environments. *Educational Research, 42*, 193–205.

Tsai, C. C. (2005). Preferences toward internet-based learning environments: High school students' perspectives for science learning. *Educational Technology & Society, 8*, 203–213.

Wierstra, R. F. A., Kanselaar, G., Van der Linden, J. L., & Lodewijks, H. G. L. C. (1999). Learning environment perceptions of European university students. *Learning Environment Research, 2*, 79–98.

Wierstra, R. F. A., Kanselaar, G., Van der Linden, J. L., Lodewijks, H. G. L. C., & Vermunt, J. D. (2003). The impact of university context on European students' learning approaches and learning environment preferences. *Higher Education, 45*, 503–523.

Yang, F. Y., & Chang, C. C. (2009). Examining high-school students' preferences toward learning environments, personal beliefs and concept learning in web-based contexts. *Computers & Education, 52*(4), 848–857.

Yang, F. Y., & Tsai, C. C. (2008). Investigating university student preferences and beliefs about learning in the web-based context. *Computers & Education, 50*(4), 1284–1303.

Learner Profile

► Learner Characteristics

Learner Supports

► Adaptive Game-Based Learning

Learner-Centered Education

► Learner-Centered Teaching
► Person-Centered Learning

Learner-Centered Instruction

► Student-Centered Learning

Learner-Centered Lesson Planning

► Learner-Centered Teaching

Learner-Centered Principles

► Learner-Centered Teaching

Learner-Centered Teaching

GEORGIA C. BROOKE, HEIDI L. ANDRADE
University at Albany, State University of New York, Albany, NY, USA

Synonyms

Child-centered teaching; Learner-centered education; Learner-centered lesson planning; Learner-centered principles; Person-centered instruction; Student-centered learning

Definition

A learner-centered perspective couples a focus on individual learners – their experiences, perspectives, backgrounds, talents, interests, capacities, and needs – with a focus on the best available knowledge about learning and teaching practices that promote motivation and achievement for all learners. Grounded in the Learner-Centered Psychological Principles (APA Work Group of the Board of Educational Affairs 1997), this dual focus is used to inform decision-making and drive educational reform.

Theoretical Background

In 1990, concern over national declines in student achievement prompted the American Psychological Association (APA) to charge the Presidential Task

Force on Psychology in Education with producing a synthesis of research on human learning, development, and motivation in order to generate a framework for school reform (APA Work Group of the Board of Educational Affairs 1997). The goals of the Task Force were to determine how existing knowledge of learning could be translated into student achievement and provide guidance for educational institutions.

Inspired by information processing and constructivist approaches, researchers and educators on the Task Force pushed for a shift toward learner-centered, as opposed to teacher-centered, instruction that emphasizes the active, reflective nature of learning (APA Work Group of the Board of Educational Affairs 1997). This shift required consideration of how schooling and education are conceptualized, and how to foster passionate learners (McCombs and Whisler 1997). By 1993, 12 fundamental principles about learners and learning had emerged. They were amended in 1997 to include two principles reflecting diversity and standards. The principles are divided into four domains relevant to learning: (1) Cognitive and Metacognitive factors, (2) Motivational and Affective factors, (3) Developmental and Social factors, and (4) Individual Differences factors.

The final 14 *Learner-Centered Psychological Principles* are necessarily broad, reflecting more than a century of knowledge:

I. Cognitive and Metacognitive Factors
  1. *Nature of the Learning Process.* The learning of complex material is most effective when it is an intentional process of constructing meaning from information and experience.
  2. *Goals of the Learning Process.* The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge.
  3. *Construction of Knowledge.* The successful learner can link new information with existing knowledge in meaningful ways.
  4. *Strategic Thinking.* The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex goals.
  5. *Thinking About Thinking.* Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking.
  6. *Context of Learning.* Learning is influenced by environmental factors including culture, technology, and instructional practices.

II. Motivational and Affective Factors
  7. *Motivational and Emotional Influences on Learning.* What and how much is learned is influenced by motivation. Motivation to learn, in turn, is influenced by an individual's emotional states, beliefs, interests, goals, and habits of thinking.
  8. *Intrinsic Motivation to Learn.* The learner's creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevance to personal interests, and choice and control.
  9. *Effects of Motivation on Effort.* Acquisition of complex knowledge and skills requires extended learner effort and guided practice. Without learners' motivation to learn, the willingness to exert this effort is unlikely.

III. Developmental and Social Factors
  10. *Developmental Influences on Learning.* As individuals develop, there are different opportunities for and constraints on learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account.
  11. *Social Influences on Learning.* Learning is influenced by social interactions, interpersonal relations, and communication with others.

IV. Individual Differences Factors
  12. *Individual Differences in Learning.* Learners have different strategies, approaches, and capabilities for learning that are a function of previous experience and heredity.
  13. *Learning and Diversity.* Learning is most effective when differences in learners' linguistic, cultural, and social backgrounds are taken into account.
  14. *Standards and Assessment.* Setting appropriately high and challenging standards and assessing the learner as well as the learning process – including diagnostic process and outcome assessment – are integral parts of the learning process.

McCombs and Whisler (1997) define learner-centered instruction in terms of six characteristics: (1) Student choice regarding projects and graded assignments, (2) Individualized pace with flexible time frames, (3) Opportunities to demonstrate knowledge in a variety of ways, (4) Participation in individual and group learning activities, (5) Student responsibility for the learning process, and (6) Refinement of understanding using critical thinking skills.

Important Scientific Research and Open Questions

Since the introduction of APA's Learner-Centered Psychological Principles, a large number of studies and educational programs have provided evidence to suggest that learner-centered systems are more effective than traditional, teacher-centered approaches in terms of an array of indicators of school performance including academic achievement, knowledge retention, closing the minority achievement gap, graduation rates, motivation, self-regulation, self-efficacy, self-esteem, creativity, tolerance, diversity, and multiculturalism (Salinas and Garr 2009; Salinas et al. 2008).

To measure the degree to which teachers' practices are learner-centered, researchers often use the Assessment of Learner Centered Practices (ALCP), a survey created by McCombs in 1999 for teachers and students in grades K-20 (i.e., Salinas and Garr 2009). The ALCP assesses beliefs, assumptions, and perceptions of practice through a series of self-report surveys with Likert-type items related to the factors of the psychological principles (APA Work Group of the Board of Educational Affairs 1997; McCombs and Miller 2007). The ALCP has been validated with over 30,000 teachers and students. Related measures include the Learner-Centered Battery, Teacher Beliefs Survey (TBS), Early Childhood Classroom Observation Measure (ECCOM), and Teacher Classroom Practices Questionnaire (TCPQ) (Donohue et al. 2003; Perry et al. 2007; Salinas et al. 2008).

For example, in a longitudinal study of 257 first-grade students, Perry et al. (2007) explored the relationships between teachers' learner-centered practices and students' academic achievement, behavioral adjustment, and academic self-efficacy. After controlling for previous achievement, classes with which teachers used more learner-centered approaches had higher mean scores on a standardized mathematics achievement test. Learner-centered classes demonstrated more positive interpersonal behavior and lower levels of intrapersonal behavior problems than classes with more teacher-centered instruction. In addition, academic self-efficacy was significantly higher in the more learner-centered classes.

Salinas and Garr (2009) sought to examine the relationship between learner-centered instruction and the minority achievement gap that has been notoriously resistant to intervention. In their study, 236 students from six learner-centered and matched traditional schools were compared in terms of standardized test scores, multi-talent perception, and attitudes toward diversity (Salinas and Garr 2009). They found a significant difference in standardized test performance between traditional and learner-centered schools. In the learner-centered schools, the gap between minorities and non-minorities was "completely closed" (p. 235). Moreover, students in the learner-centered schools had higher scores on important skills and dispositions such as self-efficacy, curiosity, active learning strategies, mastery orientation, initiative, innovation, and value of diversity.

While much of the extant research on the effects of learner-centered teaching has been conducted in grades K-12, Salinas et al. (2008) examined higher education, known to be dominated by a teacher-centered paradigm that limits opportunities for students to connect material to their own life experiences (McCombs and Whisler 1997). Salinas and colleagues compared the knowledge retention rates of students in traditional and learner-centered classrooms by asking students to retake their course's final multiple choice exam one semester after its initial administration. While a decline in performance was observed in both groups, the decline was much sharper for the teacher-centered instruction group, calling into question the predominant instructional paradigm in higher education.

In addition to providing support for the role of learner-centered instruction in achievement, motivation, learning, and practical skills, research also suggests an influence of this mode of instruction on social behavior (Donohue et al. 2003). Peer rejection predicts numerous deleterious outcomes for students, including school dropout, delinquency, and psychopathology (Donohue et al. 2003). In their longitudinal study, Donohue and her colleagues examined social behavior in learner-centered and teacher-centered classes. By

comparing behavior in fall and spring across the two groups, they found children in learner-centered classrooms displayed less peer rejection, fewer interpersonal behavior problems, and less anger and more empathy toward a hypothetical disruptive peer. These findings seem particularly relevant in an era that has experienced increases in school bullying, stereotyping, and violence (Salinas and Garr 2009).

While valuable research has been conducted on the benefits of learner-centered instruction, many questions and issues remain to be addressed. A pressing concern is the increasing demand for external accountability that has shifted control of curriculum and instruction from teachers to the state and federal governments; the learner-centered model argues that control over learning should reside in the learner, with the teacher as facilitator (Salinas and Garr 2009). Another issue is related to teacher education and the number of teachers who are receiving high-quality pre- and in-service education in learner-centered teaching. Instructional reform at the K-12 level is hampered when teachers are taught largely by professors who receive little pedagogical training and, as a result, model predominately traditional, teacher-centered approaches to instruction (Salinas et al. 2008). A third issue in need of inquiry is grounded in the democratic underpinnings of learner-centered instruction, which raises questions regarding how groups of culturally diverse students adapt to this framework. Additional, rigorous research should be done on the effects of learner-centered instruction on the minority achievement gap, on students who are rejected and bullied by their peers, and on generation Y children who, according to McCombs and Whisler (1997), feel disconnected, alienated, and stressed.

Cross-References

▶ Climate of Learning
▶ Humanistic Approaches to Learning
▶ Learner Preferences and Achievement
▶ Personalized Learning
▶ Person-Centered Learning
▶ School Climate and Learning
▶ Socio-Constructivist Models of Learning
▶ Student-Centered Learning

References

American Psychological Association Work Group of the Board of Educational Affairs. (1997). *Learner-centered psychological principles: A framework for school reform and redesign*. Washington, DC: American Psychological Association.

Donohue, K. M., Perry, K. E., & Weinstein, R. S. (2003). Teachers' classroom practices and children's rejection by their peers. *Applied Developmental Psychology, 24*, 91–118.

McCombs, B. L., & Miller, L. (2007). *Learner-centered classroom practices and assessments: Maximizing student motivation, learning and achievement*. Thousand Oaks: Corwin.

McCombs, B. L., & Whisler, J. S. (1997). *The learner-centered classroom and school: Strategies for increasing student motivation and achievement*. San Francisco: Jossey-Bass.

Perry, K. E., Donohue, K. M., & Weinstein, R. S. (2007). Teaching practices and the promotion of achievement and adjustment in first grade. *Journal of School Psychology, 45*, 269–292.

Salinas, M. F., & Garr, J. (2009). Effect of learner-centered education on the outcomes of minority groups. *Journal of Instructional Psychology, 36*(3), 226–237.

Salinas, M. F., Kane-Johnson, S. E., & Vasil-Miller, M. A. (2008). Long-term learning, achievement tests, and learner centered instruction. *Journal of the Scholarship of Teaching and Learning, 8*(3), 20–28.

L

Learner-Driven Learning

▶ Scaffolding Discovery Learning Spaces

Learners, Learning and Burnout

▶ Burnout in Teaching and Learning

Learning

▶ Affective and Cognitive Learning in the Online Classroom
▶ Approximative Learning Vs. Inductive Learning
▶ Cognitive Learning
▶ Competency-Based Learning
▶ Cue Summation and Learning
▶ Dreaming: Memory Consolidation and Learning
▶ Mental Models and Lifelong Learning
▶ Measurement of Student Engagement in Learning
▶ Physiological Homeostasis and Learning
▶ Video-Based Learning

Learning a Taste

► Aesthetic Learning

Learning Across the Life Span

► Adult Learners' Characteristics

Learning Action Affordances and Action Schemas

Richard P. Cooper
Department of Psychological Sciences, Birkbeck,
University of London, London, UK

Synonyms

Activities of daily living; Routines; Triggering conditions

Definition

An *affordance* is an action that is suggested or somehow implied to an agent capable of performing that action by an object or situation in the agent's immediate environment. Thus, a light switch at shoulder height might be said to "afford pushing," while a cup with a handle in reach might be said to afford grasping by the handle with a certain type of grip. Both of these cases involve artifacts that have a shape and learned associations which are suggestive of the corresponding action, but the word affordance connotes not just that an action is possible by an agent. It also connotes that (a) the action is in some sense actively facilitated by the design of the object or environment that supports it and (b) this facilitation is transparent – it does not involve any deliberate reasoning or cognitive processing by the actor.

An *action schema* is a representation of a frequently performed, stereotyped, sequence of actions that abstracts over the specific actions while maintaining their common elements. Thus, an action schema for tying a shoelace would consist of the regular sequence of grasping, twisting, and pulling movements involved

in tying a shoelace, regardless of the specific shoe, the thickness or elasticity of the lace, and so on. Action schemas can be hierarchically structured, with the elements of a schema corresponding not just to abstract actions but also to other (simpler) schemas. Thus, a chef might develop an action schema for making a hollandaise sauce which will involve many subschemas for the individual steps, each of which may have its own subschemas and so on. Various sources of evidence suggest that objects or environments can afford not just actions, but also action schemas. This implies that learning must somehow couple affordances with action schemas.

Theoretical Background

The concept of an affordance was introduced by the US ecological psychologist James J. Gibson in 1977. Gibson's primary argument was that much of our action is driven directly by the visual environment and not mediated by complex cognitive processes. Thus, when reaching for a pencil we do not think about how to shape our hand to form an appropriate grip, rather our hand automatically forms the right shape in response to the shape of the pencil, and that shape is different from the shape used to grasp a cup. The concept was refined by Don Norman by relating it to the agent's experience and goals. There are many affordances surrounding us at any moment, from those offered by door handles and light switches to those provided by every key on a keyboard, but the affordances that actually shape our action are determined by our intentions or goals – whether we wish to open the door or what words we wish to type. Similarly, affordances appear to be acquired or at least modulated by experience. For example, in principle, a door handle might be pushed or pulled or turned clockwise or counter-clockwise, but with experience we develop preferences for twisting a door handle in one direction rather than another.

Objects, particularly those that are designed for a specific purpose, appear with learning to be capable of affording not just actions but relatively complex action schemas. Consider a pair of folded spectacles. An action schema associated with such an item involves unfolding the arms of the spectacles and placing the spectacles on one's nose with the arms of the spectacles over one's ears. Evidence that an action schema of such complexity might be associated with the object comes from a class of neurological patients with brain damage

(e.g., following stroke) whose behavior appears to be controlled not by the patients' intentions but by the objects around them. Thus, patients suffering from *utilization behavior* are often unable to prevent themselves from performing well-formed stereotyped action sequences that are triggered or afforded by objects in their immediate environment. A utilization behavior patient might, for example, when provided with a pair of spectacles unfold them and put them on his/her nose, even if he/she is already wearing a pair. Similarly, he/she may, if provided with a jug of water and a glass, pour water into the glass and drink, even if he/she has stated moments before that he/she is not thirsty and does not want water. Utilization behavior and similar neurological conditions therefore provide strong evidence for the psychological reality of action schemas and affordances for action schemas, as well as for the claim that both are acquired or learned rather than being innate.

A second line of support for the psychological reality of action schemas comes from the influential work of Karl Lashley (1890–1958) on the control of sequential behavior. The dominant theoretical paradigm at the time argued that all behavior was learned stimulus–response associations. If this were true, sequential behavior would need to be explained in terms of each action (i.e., each response) serving as the stimulus for the next action. Lashley (1951) argued that this "associative chaining" view of sequential behavior could not account for behaviors in which an action in a stereotyped sequence depended not just on the previous action but also on its position in the sequence or the sequence's overall objective. The argument implied that a higher order representation of a sequence (effectively an action schema) was involved in the control of action to ensure that individual actions in the sequence cohere.

Lashley's arguments concern normal, well-structured, action sequences, but the slips and lapses made by distracted individuals in everyday action also support both the concept of action schema and the associated link to affordances. Reason (1979) analyzed descriptions of action errors made by normal individuals over the course of a week. Many of these errors occurred when individuals were performing routine actions in an automatic way and appeared to consist of fragments of an intended, well-learned, action schema being omitted or replaced by other stereotyped

behaviors that were appropriate given the time of day or the specific physical environment. Thus, slips and lapses in action also suggest that routine action is controlled by action schemas and that those schemas may be afforded or triggered by specific features of the environment.

The dominant theoretical perspective for how action schemas interact in the control of routine behavior is provided by the contention scheduling/supervisory attentional system model of Norman and Shallice (1986). Within this model, representations of action schemas compete for control of behavior through a process called contention scheduling. Individual schemas may be triggered by sensory input (i.e., by situations which afford them), giving them an advantage in the competition. Similarly the supervisory attentional system may bias competition toward an intended schema. Action is ultimately controlled, however, by the schema that wins the competition, and this is likely to involve a mix of situational and attentional support.

Important Scientific Research and Open Questions

While the concepts of action affordances and action schemas are both well supported, the issues of how each is learned and how they are bound together remain contentious. One possibility is that action affordances are learned through associative learning so that features of the physical environment come to be associated with the neural representation of an action. On this account, when an action is performed associations are strengthened between the mental representation of all features of the current environment and that action. Features of the environment that are consistently associated with an action will then come to form stronger associations, while those that are inconsistently associated will come to form weaker connections.

An alternative account suggests that action affordances are acquired through reinforcement learning (Sutton and Barto 1998). This approach assumes that actions are performed for a purpose and that an action may therefore either succeed, yielding positive feedback (reinforcement), or fail, yielding negative feedback (punishment). Associations between the action and the representation of features of the environment may then be strengthened or weakened as appropriate. Reinforcement learning thus assumes

that actions are goal-directed or purposive, and that the expected consequences of an action are neurally represented in order to compare expected and actual feedback and thereby determine an action's success or failure. It also allows affordances for action to be dependent upon the actor's goals, so that an action may be afforded in one situation when the actor has one set of goals but not in the same physical situation when the actor has another set of goals.

There are also multiple accounts of how action schemas might be learned. One possibility is that schemas are learned through imitation. This is plausible in the case of learning to tie a shoelace, where a parent or guardian instructs the child on the appropriate sequence of moves and the child imitates. It also appears possible, however, to learn action schemas by following a set of instructions, or by generating and then executing an action plan. In each of these cases, however, for the sequence of actions to become routinized and schematic it is necessary for the sequence to be performed many times in many different settings. Repetition is therefore a key element of the process of learning an action schema.

Beyond this, the issues are clarified by adopting the perspective of the Norman and Shallice model. Within this model the effects of explicit instruction can be seen merely to provide the supervisory attentional system with a set of subschemas in the correct sequence. Learning a schema by instruction and learning it by generating and executing a plan are therefore effectively equivalent within the model (though self generation of the sequence may be beneficial to learning for another reason – because it may then be easier to regenerate the plan without instruction).

The model suggests two alternative approaches to schema learning. First, learning may involve the transfer of declarative knowledge of a sequence, represented within the supervisory attentional system, into procedural knowledge of that sequence, represented within the contention scheduling system. Second, it may involve associations between actions and existing action schemas within the contention scheduling system, simply by virtue of those actions and action schemas being frequently performed in succession. This second option is suggestive of an associative learning mechanism similar to that possibly involved in the learning of action affordances, but for such an account to be viable it must address the shortcomings identified

by Lashley of associative chaining. Vigorous debates have as yet failed to answer the question of whether connectionist or PDP models approaches to sequence learning can adequately address these shortcomings.

An alternative account derives from reinforcement learning, and in particular the application of reinforcement learning to domains with both sequential and hierarchical structure. If action schemas are assumed to be purposive, then a reinforcement signal may be computed at the end of each fragment of purposive behavior. Temporal difference learning, a variant of reinforcement learning for the acquisition of sequential relations, may then use this reinforcement signal to adjust associations between actions and their position within the nascent action schema, which itself is associated with the mental representation of its purpose. The advantage of this approach is that it offers the prospect of binding the developing schema to a neural representation of its affordances, and therefore addressing both aspects of learning within a single framework.

Cross-References

► Action Schemas
► Affordances
► Implicit Sequence Learning
► Reinforcement Learning
► Sequence Learning

References

Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting, and knowing* (pp. 67–82). Hillsdale: Erlbaum.

Lashley, K. S. (1951). The problem of serial order in behavior. In L. A. Jeffress (Ed.), *Cerebral mechanisms in behavior* (pp. 112–136). New York: Wiley.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. Davidson, G. Schwartz, & D. Shapiro (Eds.), *Consciousness and self regulation* (Vol. 4, pp. 1–18). New York: Plenum.

Reason, J. T. (1979). Actions not as planned: The price of automatization. In G. Underwood & R. Stevens (Eds.), *Aspects of consciousness* (pp. 67–89). London: Academic.

Sutton, R. S., & Barto, A. G. (1998). *Reinforcement learning: An introduction*. Cambridge, MA: MIT Press.

Learning Actions

► Learning Activity

Learning Activity

ANDREY I. PODOLSKIY
Department of Developmental Psychology, Moscow State University, Moscow, Russia

Synonyms

Exertion of learning; Learning actions

Definition

Learning activity as considered in the framework of the general activity approach (A. Leontiev) is a special kind of human activity whose main objective is the acquisition of knowledge, skills, and competencies produced by society in the process of history by means of special learning actions taken upon learning objects in accordance with their substance and structure (Davydov 1982; Hedegaard and Lompscher 1999). It is important to distinguish this specific meaning of the term from its nonspecific, widespread use.

Theoretical Background

Children and adults appropriate elements of social experience while performing any activity (playing, working, etc.). Thus, learning/appropriation processes do not necessarily belong to a learning activity (in the narrow sense defined above), and the concepts "*learning*" and "*appropriation*" should not be identified with learning activities only. Certainly, children and adults can also appropriate knowledge by playing, working, and performing other activities. Unlike such activities, however, "the learning activity that involves appropriation is performed only when these processes take the form of goal-directed transformation of a particular material" (Davydov 1999, p. 126)

Like other human activities, learning activity has its own specific object-related content. The main components of any human activity, such as needs, motives, goals, conditions, means, actions, and operations, can be directly related to the learning activity. According to V. Davydov children can only appropriate knowledge and skills through learning activity when they have an *internal need and motivation* to do so (Davydov 1999). Learning needs and motives direct learners to transform the material to be appropriated to reveal the interrelations between its internal relations and external appearances (see also the entry on ▶ Mental Activities of Learning in this volume).

Consequently, the student needs to conduct real or imaginary experiments with the material in order to open these interrelations and separate the general core aspects of the material (the object) from particular aspects. Knowledge about general aspects is considered to be ▶ theoretical knowledge constructed by the learner by means of experimentation and exploration.

Important Scientific Research and Open Questions

There exist two important conditions that serve to organize students' learning activity. The first condition has to do with inculcating and stimulating a need to learn in the student. Although the significance of this component of learning activity is widely accepted, the issue has not yet been sufficiently operationalized and requires special discussion. The second condition is concerned with the formulation of learning tasks for students which require their exploratory and experimenting activity. Naturally, the presence of the learning tasks by itself is not enough to initiate and ensure successful performance of learning activity. In addition, a number of learning actions are needed. In the first learning action, students have to reformulate the task if it cannot be resolved in a manner they are familiar with. The second learning action consists in making models that represent already known relations, which requires that the representation reflect general relations between the elements of the task. Special learning actions are needed to transform the model itself in order to highlight and carefully study the properties of the general relation already found. Another learning action consists in defining the system of relations between the features of the object being explored. Finally, control and evaluation are also included in the list of learning actions (Davydov 1999). Every learning action should be appropriated by a student who is working toward an *internalization* of knowledge (see also the ▶ Mental Activities of Learning entry in this volume). This means that many individual elements of the learning actions as well as the entire actions themselves can and do become the object of careful attention by researchers and teachers. Examples include formulation of the hypothesis, different parts of the modeling action, etc.

The essential features of learning activity are coordination, communication, and cooperation between learners and with other people, the quality of this last aspect determining concrete learning results to a great extent. The study of interrelations between individual and cooperative learning is currently in the focus of scholarly attention (Rubtsov 1991; Zukerman 2001).

The theory of learning activity (Elkonin 1989; Davydov 1999) became one of the foundations of the idea of ▶ developmental teaching, which first appeared in the Soviet/Russian literature (Davydov, Elkonin, Zankov) and spread further to Northern and Western Europe (Chaiklin, Hakkarainen, Hedegaard, Engeström, Lompscher, et al). According to V. Davydov "the basis of developmental teaching is its content. From the content stem the methods (of modes) of teaching organization. This proposition typifies the views of Vygotsky and Elkonin" (Davydov 1988, p. 19). The main task of developmental teaching is to form students' theoretical thinking as opposed to empirical thinking. In the former case (unlike in the latter one), teaching proceeds cognitive development and is a necessary prerequisite for it.

Starting in the 1960s, the theory of learning activity and the principles of developmental teaching were successfully applied in Eastern, Western, and Northern Europe as well as in the United States. Many schools utilized curricula based on this foundation. The curricula involved programs on math, physics, chemistry, native and foreign languages, art, etc. The programs are used both in primary and in secondary schools.

Cross-References

- ▶ Activity Theory of Learning
- ▶ Cultural-Historical Theory of Development
- ▶ Internalization
- ▶ Learning as a Side-Effect
- ▶ Mental Activities of Learning
- ▶ Motivational Variables in Learning
- ▶ Zone of Proximal Development

References

Davydov, V. (1988). Problems of developmental teaching. *Soviet Education, 30*(10), 3–41.

Davydov, V. (1999). What is real learning activity? In M. Hedegaard & J. Lompscher (Eds.), *Learning activity and development* (pp. 123–139). Aarhus: Aarhus University Press.

Hedegaard, M., & Lompscher, J. (1999). Introduction. In M. Hedegaard & J. Lompscher (Eds.), *Learning activity and development* (pp. 10–21). Aarhus: Aarhus University Press.

Rubtsov, V. V. (1991). *Learning in children: Organization and development of cooperative actions.* Happauge, NY: Nova Science.

Zukerman, G. A. (2001). How school students become subjects of cooperative learning activity. In M. Hadegaard (Ed.), *Learning in classrooms: A cultural-historical approach* (pp. 229–243). Aarhus: Aarhus University Press.

Learning Adjustment Speeds and the Cycle of Discovery

DAVID W. VERSAILLES[1], VALÉRIE MÉRINDOL[2]
[1]PHARE, University Paris I Panthéon Sorbonne, I-Space Institute, Paris, France
[2]CERNA, Ecole des Mines, Paris, France

Synonyms

Dynamics of exploration and exploitation; Linear and nonlinear models of innovation

Definition

The notion of discovery cycle has been proposed by Bart Nooteboom in order to analyse the various steps leading to the creation and the exploitation of new knowledge, and to innovation. The concept characterises the dynamics of innovation and technological change between the emergence of novel combination (associated to exploration) and the exploitation of existing knowledge in a variety of contexts. The cycle of discovery identifies four main steps (consolidation, generalisation, differentiation, and reciprocation), which may occur sequentially, or partially overlap when transitioning between exploration and exploitation. The cycle of discovery either enforces or destroys the contributors' individual and collective competences, the stability of interactions and the variety of exchanges.

The innovation process is characterized by knowledge-based interactions between actors. Social networks and network interactions are at stake here, and directly affect the efficiency of the innovation process. Along Nooteboom's description, the dynamics of the interaction elaborates on the diversity of knowledge assets. For each contributor to the innovation process,

learning processes vary with the discovery phases, depend on his/her initial knowledge assets, and affect the dynamics of exchange. The *adjustment speed* between learning processes represents a key variable for the explanation of knowledge creation processes and for the dynamics of innovation.

Theoretical Background

The analysis of the discovery cycle grounds in nonlinear approaches to innovation. This theory does neither refer to innovation as a succession of delimited steps dealing with basic research, industrial development, and transformation into marketable products, nor to specific patterns for the division of knowledge between contributors: R&D actors, State and public administration, and the industry. The analysis of the cycle of discovery refers to various learning processes, and also to specific adjustments between the actors (individuals and/or organisations) committed to innovation.

This development applies to individual and collective bodies, even though the variables mobilised for explaining individual and collective learning processes are not exactly the same. From an epistemological point of view, the concepts mobilised here refer to micro-foundations of economic mechanisms. They are consistent with the "situational analysis" or the "institutional individualism" developed, for instance, by Boland (2003).

The cycle of discovery refers to a continuous process where exploration and exploitation phases are constantly confronting each other (March 1991). Exploration may lead to break-through innovation while exploitation focuses on the improvement of existing innovation (Fig. 1).

Nooteboom describes the cycle of discovery as a succession of several exploration and exploitation phases; he refers to the variety of content(s) and context(s) existing at each step of the cycle. "Novel combination" grounds in heterogeneous knowledge and competencies, and produces new knowledge. During this creative moment, knowledge cannot be reproduced outside the specific context and network framing its emergence (Amin and Cohendet 2004). When it is transposed onto a different environment, knowledge is automatically transformed and reframed (which incurs specific new learning processes and the associated costs).

Learning Adjustment Speeds and the Cycle of Discovery. Fig. 1 Nooteboom (2002)'s discovery cycle

"Consolidation" refers to knowledge selection and incorporation into production systems and products delivered to markets. Consolidation occurs as soon as the contributors to innovation seek for efficiency. "Generalisation" depends on the various options (networks, infrastructures, etc.) available for testing and experimenting the results of innovation. "Differentiation" represents the moment where innovation and technologies are potentially adapted to various contexts. It may lead to incremental or radical innovation according to the practices and contexts where technology will be incorporated. "Reciprocation" identifies the step where actors become aware of their failures, and where they grasp opportunities through the confrontation with new practices.

Exploitation and exploration represent the source of recurring tensions inside networks or organisations. March explains that exploration and exploitation ground in sharply different actions and managerial modes (in relation, for instance, with flexibility, risk taking, etc.). It is possible to characterise the cognitive aspects present in innovation networks: at each phase identified by Nooteboom, interaction elaborates on the cognitive distance between contributors to the innovation network. Exploration elaborates on the cognitive distance between them, while exploitation supposes proximity.

The emergence of brand new knowledge and of novel knowledge combinations supposes open networks. Opportunities for sharing and accepting new knowledge depend on competencies and experiences. Contributors to the innovation networks do not individually master the whole set of competencies required for the appreciation of the relevance of emerging knowledge. Intrinsic complementarities and interdependencies between the contributors explain the dynamics of interaction, at all stages of the discovery process. During the consolidation step, interactions are motivated by the search for efficiency, which requires knowledge standardisation and abstraction from the various contexts where knowledge has emerged. At the generalisation step, the knowledge base then stabilises and selects among the various possible options in abstracting from locally driven experiments.

Exploration and exploitation are both compatible with single- and double-loop learning processes (Argyris and Schon 1978). Applied at the level of the organisation, double-loop learning processes refer to value changes and enacted theory. It leads to doing things in a different way, or to performing brand new activities. Single-loop learning processes allow only for the improvement of activities and processes, which are already present in the organisation. They often relate to defensive routines and values, which put an obstacle in the way of transformation. Double-loop learning is conversely better suited to radical evolutions where structures, representations, and action modes are reconsidered.

The capacity to generate radical or incremental innovation depends on the actors' respective learning capabilities, which individuals and collectives then implement at their own different speeds. The reason for these differences lies in their initial knowledge assets allowance, in their respective perceptive filters, and in their own perspective about the situation. Depending on their own objectives, actors will foster specific strategies, yet these elements only explain specific parts of the decisions made when introducing arbitrages about the contexts to be privileged, and when differentiating options.

Knowledge-related processes require an autonomous analysis, which refers to the consistency between the individuals' knowledge apparatus, and to the possibility of adjusting the contributors' perspectives. The

ability to converge together towards common projects depends on these two points. The consistency between knowledge assets depends on the individual conceptual and perceptive filters used in each context (Boisot et al. 2007). Perceptive filters bridge individuals with the external world, and allow them to make sense of raw data and information. Conceptual filters relate to the individuals' theoretical frameworks; they explain how individuals make sense of assumptions about the real world, and of particular situations. Perceptive and conceptual filters are elaborated when single- and double-loop learning processes are generated along the time, in long-lasting interactions with the reality. Individuals are not equipped with the same knowledge base. The very same logic applies at the collective level: organisations are equipped with specific (collective) knowledge bases, which manifest with the corresponding (collective) perceptive and conceptual filters.

The engine for working out projects together (and for the division of labour) lies precisely in the division of knowledge and in complementarities between them. This is also the explanation for different adjustment speeds between them. At the collective level, specific elements may be analysed in the framework of networks. It is however important to bear in mind that there is no reason to postulate that learning adjustment speeds would apply to whole categories of contributors to the innovation process, except if knowledge-based descriptions reveal that they are shaped globally by a specific scientific or cultural paradigm. At the individual level, it is relevant to introduce the assumption that each actor, in each role, will develop his/her own perspective in relation with the context situation. The interaction with the context situation may strengthen his/her position and influence, and reinforce the validity of his/her filters. As a direct consequence, he/she will be able (or not) to develop efficient anticipations on the future, to make relevant decisions, and to develop an efficient strategy. These abilities all relate to the individual knowledge base, to the ability to adapt and to learn from the situation. This is the reason why individuals are identified with specific adjustment speeds during the interaction with the other contributors to the cycle of discovery. If adjustment speeds are inconsistent with each other, learning capabilities will differ too much for a collective project to install, and for interactions to emerge.

Important Scientific Research and Open Questions

These concepts are important for three reasons.

Firstly, they represent a microeconomic foundation explaining innovation. These concepts provide an explanation for the emergence and the diffusion of innovation on the basis of knowledge processes. They link the analysis of knowledge assets with learning and transformation processes.

Secondly, these concepts provide with a common conceptual apparatus suited to the investigation of individuals, collectives, and networks.

Thirdly, the scientific apparatus elaborated in this framework represents a multidisciplinary contribution relevant at the same time in economics and in management science, in epistemology, and in cognitive sciences.

Cross-References

► Adaptation and Learning
► Adaptive Learning Systems
► Discovery Learning
► Innovation and Learning Facilitated by Play
► Organizational Change and Learning

References

Amin, A., & Cohendet, P. (2004). *Architectures of knowledge: firms, capabilities, and communites*. New York: Oxford University Press.

Argyris, C., & Schön, D. A. (1978). *Organizational learning: A theory of action perspective*. Reading (UK): AddisonWesley.

Boisot, M. H., MacMillan, I. C., & Han, K. S. (2007). *Explorations in the information space, knowledge, agents and organisation*. New York: Oxford University Press.

Boland, L. A. (2003). *The foundations of economic method, a popperian perspective* (Secondth ed.). London: Routledge.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science, Special Issue: Organizational Learning, 2*(1), 71–87.

Nooteboom, B. (2002). A heuristic discovery. In B. Nooteboom (Ed.), *Learning and innovation in organizations and economics* (pp. 170–189). New York: Oxford University Press.

Learning After School

► Remedial Learning

Learning Agent and Agent-Based Modeling

Eric Guerci, Nobuyuki Hanaki
G.R.E.Q.A.M, Centre de la Vieille Charité, Marseille, France

Synonyms

Agent-based computational economics (Social sciences); Artificial society/economy/market; Computational modeling; Multiagent learning (system)

Definition

An agent-based model is a computational model of various processes such as social, economic, and physical. Agents are autonomous, follow specific rules of behavior, and interact. Agents in such models may have zero-intelligence, so that behave randomly, or be purposeful (or goal oriented) and learn. Learning agents are those who modify their behaviors in response to the past outcomes, and they are embedded in a model where agents make decision repeatedly.

Theoretical Background

The basic units of an Agent-Based Model are agents, which are entities characterized by autonomy and by adaption. The former means that there is no central or "top-down" control over their behaviors, and the latter represents the idea that they are reactive to the environment. It is a model of a decentralized system consisting of rather simple agents that follow well-understood rules of behaviors. It aims to understand if (complex) macro properties, that are not the properties of individual agents, can emerge from interaction of such simple agents. Thus, an agent-based model is an approach suited for what is often called "generative social science" (Epstein 2007) as it searches for or tries to generate emerging macro properties.

In a model of a social system, agents are often humans or groups of humans. And to reflect the goal-oriented nature of humans, agents are endowed with abilities to learn. In a system of interactive learning agents, what an agent learns depends on what other agents learn, which is in turn influenced by how the agent learns to behave. Such an interaction among

learning agents can result in quite complex system-wise dynamics.

The boundedly rational natures of agents in agent-based models are often contrasted with *homoeconomicus*, who are rational in that they are able to process large amount of information and to conduct sophisticated optimizing calculation, often assumed in the standard economic theory. The foci of the standard economic analyses are often comparative statics, i.e., comparison of equilibriums in response to the change in parameters of the system, and not the dynamics adjustment process between the two equilibriums. Agent-based models, on the other hand, allow researchers to observe and analyze the latter dynamics in great details (Tesfatsion (http://econ2.econ.iastate.edu/tesfatsi/ace.htm); Tesfatsion and Judd 2006).

Important Scientific Research and Open Question

A broad scientific research community, encompassing social, natural, and computer scientists, has adopted various agent-based models to gain better understandings in a plethora of subjects, e.g., archaeology, civil or military conflicts, evolutions of norms, epidemiological scenarios, demography, traffic-simulation solutions, institutional design and performance, and financial market. Learning agents, however, are not always employed. Here we focus on agent-based models with learning agent.

The pioneering researches on learning agent–based models were motivated to understand their convergence properties. In particular, it stemmed among economists who were trying to provide realistic adjustment processes toward an equilibrium. Although this still remains to be an active research area, the study of out-of-equilibrium dynamics within agent-based systems has gained more attention recently. A clear example of the latter can be found in the agent-based computational finance; in particular, those analyses of bubble phenomena that are driven by the adaptive expectations of the agents.

A major open question in agent-based modeling is how to create agents who form their subjective view of the world. How to model a learning agent who learns not only how to act but also about the environments themselves is a challenging research issue. Instead of exogenously assuming the origin of counterfactual reasoning used by a learning agent, one would like to

have an agent to perform such reasoning on the basis of their subjective and adaptive perception/representation of the social environment.

The study of how to model learning agents in social environments includes joint contributions from several disciplines such as psychology, economics, and computer science (Shoham and Leyton-Brown 2009). Yet, as noted by Vohra and Wellman (2007), the cross-fertilization among disciplines is still greatly needed in order to advance agent-based models with learning agents.

Cross-References

▶ Adaptive Learning Systems
▶ Agent-Based Modeling
▶ Belief-Based Learning Models
▶ Computer Simulation Model
▶ Individual Learning
▶ Learning with Games
▶ Reinforcement Learning
▶ Simulation-Based learning
▶ Social Learning

References

Epstein, J. M. (2007). *Generative social science: Studies in agent-based computational modeling*. Princeton: Princeton University Press.

Shoham, Y., & Leyton-Brown, K. (2009). *Multiagent systems: Algorithmic, game theoretic and logical foundations*. Cambridge University Press. Available at website: http://www.masfoundations.org/

Tesfatsion, L., Website available at http://econ2.econ.iastate.edu/tesfatsi/ace.htm

Tesfatsion, L., & Judd, K. (2006). *Handbook of computational economics. Agent-based computational economics* (Vol. 2). North-Holland: Elsevier

Vohra, R., & Wellman, M. (2007). Special issue on foundations of multi-agent learning. *Artificial Intelligence, 171*(7), 363–452.

Learning Algorithms

Daniel Grollman, Aude Billard
LASA laboratory, EPFL – Ecole Polytechnique
Federale de Lausanne, Lausanne, Switzerland

Synonyms

Artificial intelligence; Data mining; Machine learning

Definition

Learning algorithms are methods by which data is processed to extract patterns that can later be applied to novel situations. Generally, a system is said to learn if the performance of some task improves (with respect to a particular metric) after the analysis of data (experience). Familiar examples of learning systems are speech recognizers that adapt to individual users, automatic text translation services, and product recommenders. Underlying all of these techniques is a *model*, which defines what assumptions are made about the data and patterns that can be discovered in it. A learning algorithm is what is responsible for generating parameters for the model by processing collected data.

Theoretical Background

Learning algorithms are developed with the aim of enabling systems to adapt to new situations. To do so, they must process data, of which there are generally three types: training data, validation data, and test data. Training data is assumed to contain all the information necessary with which to build the model, and validation data is a separate set that is used to confirm that the model works as expected. Test data is that which the system encounters after training is complete, and provides the actual measure of how successful learning was. To reduce the sensitivity of an algorithm to the particular data used in training, *cross validation* is a technique where all the available data is repeatedly randomly split into training and validation sets, and performance is measured as the average over the multiple trials.

There are many different types of learning algorithms, corresponding to the different types of patterns that can be discovered, the manner in which data is collected and analyzed, and how much information is put in by the user. Here we present some of the broad dichotomies in learning algorithms:

- Regression versus Classification: In regression one is concerned with a particular value associated with a query (i.e., How much rain will fall tomorrow?), while in classification one only cares what group the query belongs to (i.e., Is this picture of a person or a chair?).
- Supervised versus Unsupervised: In supervised learning, training data consists of queries and their correct answers, and the algorithm learns to generalize to new queries (Fig. 1a). In unsupervised learning, the algorithm must itself discover how the data should be organized (Fig. 1b). Regression

Learning Algorithms. Fig. 1 Example applications of learning algorithms. In (**a**), correspondences between languages have been learned from known translations (supervised learning). In (**b**), a robot has automatically grouped different locations on its path by similarity based only on sensor readings at those locations (unsupervised learning) (Image credits MIT and Brown University)

is typically approached in a supervised manner, while classification can be either supervised or unsupervised (if the class labels are known). There also exist semi-supervised techniques, where only some of the data has associated answers.

- Batch versus Incremental Learning: In batch learning, all of the training data is presented at once, and processed as a whole. Incremental learning instead starts with some model and adjusts this model as more data is gathered.
- Prior Knowledge versus Tabula Rasa: Often, practitioners can steer an algorithm toward discovering a particular relationship by adding in additional information as to how the world works. Tabula Rasa (literally "blank slate") indicates that no prior knowledge is assumed.
- Exploration versus Exploitation: There is a tension between exploiting what is already known and exploring unknown territory. Particularly, the potential gains (e.g., prediction accuracy) of collecting more data must be weighed against any associated cost (e.g., computation time). Often the human users of an algorithm perform this tradeoff implicitly during training, but some algorithms that actively collect their own data do it explicitly.

Important Scientific Research and Open Questions

Learning algorithm (and model) development follows multiple paths, and is often inspired by learning as observed in nature. Some are psychologically based, drawing on studies of learning and adaptation in humans and other animals, such as *reinforcement learning* (Sutton and Barto 1998), which trains agents by rewarding good results and punishing bad ones. Other techniques go a level lower, and attempt to mimic the behavior of the brain or its constituent neurons directly, such as work in *neural networks* (Bishop 2000). At a larger biological scale are *evolutionary algorithms*, which draw inspiration from species dynamics and "breed" different possible solutions to find the best (Ashlock 2006). Alternatively, mathematically based approaches abstract away the substrate of learning and seek to describe the learning process statistically (MacKay 2003).

No matter what technique is used, one common issue that must be dealt with is noise, which can arise from different sources such as the measurement process itself or sample bias. Removing noise, or *denoising*, is important as the goal of learning is to model only the signal, which is obscured by the noise. Some algorithms model the noise directly and consider it during learning, while others depend on a separate denoising preprocessor.

Improper treatment of noise can lead to over- or under-fitting. In over-fitting, the learned model conforms to the training data extremely well, but fares poorly on validation or test data; one can say that it has learned the training data too well. These errors can be a result of the learning algorithm considering the noise to be important and modeling it. Alternatively, under-fitting is akin to over-generalization, where the learned model is not specific enough, and has not extracted all that there is to be learned from the training data. This situation can arise when some important parts of the training data are considered to be noise and discarded.

As learning algorithms can only discover patterns that exist in the data they are trained on, proper data collection is key. Often, data from many different regions of the dataspace are needed, so that the learned model can be applicable all over. However, in many real world examples, the data space is extremely high dimensional. For example, a face recognition system may have a dimensionality equal to the number of pixels in an image. This has led to the so-called curse of dimensionality, which states that the number of samples necessary for successful training grows exponentially with the dimensionality of the dataspace. For large dataspaces, this number quickly outstrips our current ability to collect, store, and process the necessary data.

Dimensionality reduction or *feature extraction* techniques seek to alleviate this curse by finding which portions of the data are actually necessary for learning, and removing extraneous ones. For instance, of 100 recorded dimensions, perhaps only 2 (or 2 particular combinations of the 100) are sufficient. Likewise, instead of operating in the raw pixel space of an image, a learning algorithm could instead work with "interesting" points in the image, such as corners.

As having good data is so important, some current work in learning algorithms looks to tie the learning system and the data collection process together more tightly. That is, rather than collecting all of the data before learning, systems can use partial learning results to steer the collection of more data. Most often seen in tandem with incremental approaches, *active learning*

techniques select the data to be added based on an estimate of where the current learned model is likely to fail. If the data must be evaluated by a human, we have a *tutelage* framework, where a human and a learning agent work together to improve the capabilities of the learner.

Cross-References

▶ Initial State Learning
▶ Learning in Artificial Neural Networks
▶ Reinforcement Learning
▶ Supervised Learning

References

Ashlock, D. (2006). *Evolutionary computation for modeling and optimization.* New York: Springer.

Bishop, C. M. (2000). *Neural networks for pattern recognition.* Oxford: Oxford University Press.

MacKay, D. J. (2003). *Information theory, inference, and learning algorithms.* Cambridge: Cambridge University Press.

Sutton, R. S., & Barto, A. G. (1998). *Reinforcement learning: an introduction.* Cambridge, MA: MIT Press.

Learning and Action

▶ Action-Based Learning

Learning and Amnesia

▶ Amnesia and Learning

Learning and Anthropology

▶ Bateson, Gregory (1904–1980): Anthropology of Learning

Learning and Argumentation in Cognitive Models

▶ Learning and Argumentation in Neural-Symbolic Computation

Learning and Argumentation in Connectionist Cognitive Models

▶ Learning and Argumentation in Neural-Symbolic Computation

Learning and Argumentation in Neural-Symbolic Computation

LUIS C. LAMB[1], ARTUR D'AVILA GARCEZ[2]
[1]Institute of Informatics, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil
[2]Department of Computing, City University London, London, UK

Synonyms

Learning and argumentation in cognitive models; Learning and argumentation in connectionist cognitive models

Definition

1. Neural-symbolic cognitive model: an integrated computational cognitive model in which knowledge is represented by a logical language and (artificial) neural networks are used to perform learning, computation, and logical inferences.
2. Argumentation network: an argumentation network has the form $A = < \alpha, attack >$, where α is a set of arguments, and $attack \subseteq \alpha^2$ is a relation indicating which arguments attack which other arguments.
3. Value-based argumentation framework: a 5-tuple $VAF = < \alpha, attacks, V, val, P >$, where α is a finite set of arguments, *attacks* is an irreflexive binary relation on α, V is a non-empty set of values, *val* is a function mapping elements in α to elements in V, and P is a set of possible audiences, where we may have as many audiences as there are orderings on V. For every $A \in \alpha$, $val(A) \in V$ (Bench-Capon 2003).

Theoretical Background

The study of argumentation has long been a subject of investigation in philosophical logic, decision making,

artificial intelligence, and law (Dung 1995). In artificial intelligence, models of argumentation have been one of the approaches used in the representation of common-sense, nonmonotonic reasoning, in particular with applications to multiagent systems (Dung 1995; d'Avila Garcez and Lamb 2006; d'Avila Garcez et al. 2006). Argumentation models have been particularly successful when modeling chains of defeasible arguments, so as to reach a conclusion. Although symbolic, logic-based models have been the standard for the representation of argumentative reasoning, such models are intrinsically related to neural-symbolic cognitive models (d'Avila Garcez et al. 2009).

By establishing a relationship between neural networks and argumentation networks, *neural-symbolic cognitive models* provide a setting in which the learning of arguments is combined with reasoning capabilities in a single framework, which is now seen as a key research issue for computer science (d'Avila Garcez et al. 2009). Neural-symbolic cognitive models represent, compute, and learn arguments. In addition, neural-symbolic models are at least as general as argumentation networks, since, in addition to argument computation, they allow argument computation and learning. Let us briefly consider the relationship between argumentation frameworks and neural networks informally. We can think of a neural network as a directed graph in which the vertices represent neurons and the edges indicate the connections between (artificial) neurons. In a neural network, each edge is labeled with a real number indicating the relative weight of the connection. If we represent an argument as a neuron then a connection from neuron i to neuron j can be used to indicate that the argument i either attacks or supports the argument j. The weight of the connection can be seen as corresponding to the strength of the attack or the support. Any real number can be assigned to the weight of a connection in a neural network, and thus we will associate negative weights with attacks, and positive weights with supporting arguments. Generally speaking, an argument i supports an argument j if the coordination of i and j reduces the likelihood of j being defeated. There are different ways in which an argument may support another. For example, argument i may support argument j by attacking an argument k that attacks j; or argument i may support j directly, for example, by

strengthening the value of j. We use the terms "attack" and "support" in a loose way, since it will be sufficient to define precisely the notion of *defeat*.

To compute the prevailing arguments in a neural-symbolic cognitive model, one needs to consider the relative strength of the attacks as given, for example, by an audience. Since the strength of the different arguments is represented by the weights of the network, and since learning in neural-symbolic cognitive models corresponds to the process of progressively changing the weights of the neural network, it is natural to use neural learning algorithms to change the network as new information about the arguments becomes available.

A neural-symbolic argumentation algorithm is responsible for translating value-based argumentation networks into artificial neural networks with the use of neural-symbolic systems. The neural network created by the neural-symbolic argumentation algorithm computes the stable model semantics of the logic program associated with the argumentation network (d'Avila Garcez et al. 2005). This theorem shows that the argumentation framework can be computed and learned by the neural-symbolic cognitive model. This result guarantees that any argumentation framework with a stable model semantics has a neural network counterpart such that the neural network executes a sound computation of the prevailing arguments in the argumentation framework.

Arguments frequently attack one another in such a way that cycles in the argumentation network are formed. In such cases, a notion of relative strength of the arguments may be required to decide which arguments should prevail. Still, in some cases, circularities may lead to an infinite loop in the computation of stable models. The learning capability of neural-symbolic cognitive models neatly tackles this problem. Learning can be used to resolve circularities by the iterative change of the strength of arguments as new information becomes available. Learning and its relation to accrual, cumulative argumentation is also dealt neatly within the neural-symbolic cognitive models. Our long-term goal is to facilitate learning capabilities in value-based argumentation frameworks, as arguments may evolve over time, with certain arguments being strengthened and others weakened. At the same time, we seek to enable the parallel computation of

argumentation frameworks by making use of the machinery of neural networks.

Important Scientific Research and Open Questions

Learning and argumentation in neural-symbolic system provide a unifying framework for argumentation in artificial intelligence. They take advantage of the inference power of logical languages and of the learning capabilities of neural networks. So far, most research on argumentation in the domain of artificial intelligence has been concentrated on knowledge representation and inference (Dung 1995; Bench-Capon 2003; d'Avila Garcez et al. 2005, 2009). However, symbolic learning is one of the major research endeavors of artificial intelligence. Neural-symbolic models combine value-based argumentation reasoning and neural-symbolic learning by providing a translation from argumentation networks to neural networks. An open research problem is the relationship between fibring neural networks (i.e., the high-order recursive analysis of multidimensional neural networks) (d'Avila Garcez et al. 2009) and the general argumentation framework of Dung (1995): so far the most successful approach to argumentation used in artificial intelligence. Generalizations of Dung's framework incorporates, in addition to the notions of attack and support, the idea of recursive causality, according to which causal relations can take causal relations as input values; for example, the fact that smoking causes cancer may cause the government to restrict smoking advertising. This corresponds straightforwardly to fibring neural networks, allowing nodes to behave as networks in a recursive way, and weights to be defined as functions of the values in other networks. Another open problem is the extension of neural-symbolic argumentation by considering probabilistic weights in argumentation frameworks. This would allow for a quantitative approach to argumentation in an integrated model of reasoning under uncertainty and inductive learning.

Cross-References

▶ Argumentation and Learning
▶ Cognitive Models of Learning
▶ Connectionist Theories of Learning
▶ Learning in Artificial Neural Networks
▶ Machine Learning

References

Bench-Capon, T. J. M. (2003). Persuasion in practical argument using value-based argumentation frameworks. *Journal of Logic and Computation, 13*, 429–448.

d' Avila Garcez, A. S., & Lamb, L. C. (2006). A connectionist computational model for epistemic and temporal reasoning. *Neural Computation, 18*(7), 1711–1738.

d' Avila Garcez, A. S., Gabbay, D. M., & Lamb, L. C. (2005). Value-based argumentation frameworks as neural-symbolic learning systems. *Journal of Logic and Computation, 15*(6), 1041–1058.

d' Avila Garcez, A. S., Lamb, L. C., & Gabbay, D. M. (2006). Connectionist computations of intuitionistic reasoning. *Theoretical Computer Science, 358*(1), 34–55.

d' Avila Garcez, A. S., Lamb, L. C., & Gabbay, D. M. (2009). *Neural-symbolic cognitive reasoning. Cognitive technologies.* Berlin: Springer.

Dung, P. M. (1995). On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence, 77*, 321–357.

Learning and Consolidation in Autism

Dezso Nemeth, Karolina Janacsek
Institute of Psychology, University of Szeged, Szeged, Hungary

Synonyms

Non-declarative learning; Sequence learning; Skill learning

Definition

Learning and consolidation in autism refers to implicit learning that is defined as the acquisition of information or motor skill without conscious access to what was learned or even to the fact that learning occurred. Autism spectrum disorder (ASD) is characterized by social, communicative, and motor impairments (APA 1994).

Theoretical Background

The semantic and episodic memories of people with autism have often been studied, but neurocognitive studies of implicit learning have received less attention.

One of the most popular tasks to measure implicit learning is the serial reaction time (SRT) task in which participants are instructed to respond as quickly and as accurately as possible to the location of a stimulus that was presented at one of four possible locations on the monitor in a series of trials. Unknown to the participants, the locations of stimuli follow a predefined sequence, and participants typically become faster at responding to the locations predicted by the sequence compared to random trials. In classical SRT tasks, the structure of a sequence is deterministic with the stimuli following a simple repeating pattern as in the series 213412431423, where numbers refer to distinct events. In contrast, in a probabilistic version of the SRT task repeating events alternate with random elements. This means that the location of every second stimulus on the screen is determined randomly. If, for instance, the sequence is 123, where the numbers represent locations on the screen, in probabilistic SRT task the sequence of stimuli will be 1R2R3R1R2R3R..., with R representing a random element. The sequence is thus better hidden than in the classical SRT task. This structure is called a probabilistic second-order (lag-2) dependency, because to predict element "n" we need to know element $n-2$.

Most models of implicit learning emphasize the role of the basal ganglia and the cerebellum, while the role of the hippocampus in this process remains inconclusive. Neuropsychological studies have shown that sequence learning is impaired in people with Huntington's and Parkinson's diseases, demonstrating the impact of striatal dysfunction on this type of perceptual-motor learning. Functional brain imaging studies also show the involvement of the cerebellum, striatum, and motor cortices in implicit sequence learning tasks.

In the various neuropsychological and neurodevelopmental disorders such as autism in which IQ is involved, it has been found that explicit learning is correlated with IQ, while implicit learning is relatively independent of IQ level. Explicit processes, therefore, suffer more under circumstances with IQ impairment. Summarizing the studies of implicit learning and autism, it can be concluded that implicit learning is intact in autism. Nevertheless, if learning relies on explicit strategies such as in the case of deterministic sequences, then autistic individuals show relative impairments in learning compared to learning in a probabilistic environment.

Important Scientific Research and Open Questions

Consolidation of implicit learning received less attention in autism, although some research has investigated consolidation of episodic and semantic long-term memories. When examining consolidation it is essential to know that skill learning occurs not only during practice in the so-called online period, but also between-practice during the so-called offline phase. The process that occurs during the offline period is referred to as consolidation, which means stabilization of a memory trace after the initial acquisition or even improvement in performance following an offline period.

One study which investigated the consolidation of implicit learning in autism (Nemeth et al. 2010) found that online implicit sequence learning is unimpaired in participants with ASD, and that consolidation of the learning is intact as well. This suggests that autistic children can use the effects/results of implicit learning not only for a short period, but also for a longer stretch of time.

Learning seems to get embedded into the cognitive system, which could play an important role in therapy. Learning in general relies on implicit and explicit processes at the same time. If implicit sequence learning is spared relative to explicit learning in ASD, then emphasizing implicit processes could improve real-life learning in ASD. Using these results, therapists can design more effective educational and rehabilitation programs.

Cross-References

▶ Associative Learning
▶ Choice Reaction Time and Learning
▶ Implicit Sequence Learning
▶ Intact Implicit Learning in Autism
▶ Memory Consolidation and Reconsolidation

References

APA. (1994). *DSM-IV* (4th ed.). Washington, DC: American Psychiatric Association.

Nemeth, D., Janacsek, K., Balogh, V., Londe, Z., Mingesz, R., Jámbori, S., Fazekas, M., Danyi, I., Vetró, A. (2010). Learning in autism: Implicitly superb. *PloS One, 5*(7), e11731.

Learning and Development After School

JOHN NUNNERY, LYNDA BYRD-POLLER
Darden College of Education, Old Dominion
University, Norfolk, VA, USA

Synonyms

After school tutorial programs; Nonschool hour programs; Out-of-school time programs

Definition

An After School Program (ASP) is a generic term that can encapsulate both community-based school-age child care programs and school-run academic programs. Broadly defined, after school programs are school-based and community-based programs designed to assist families with school-aged children by providing structured and supervised activities during the times that school is not in session (Apsler 2009; Lauer et al. 2006; Roth et al. 2010). After School programs are programs that are outside of the mandated compulsory attendance timeframe of the regular school day curriculum, and may include programs during academic intercessions or summer school programs. Likewise, Parks and Recreation–based programs, community models, and school-based programs are typically designed to address specific goals or to enhance achievement in certain subject areas.

The hours that youth are in school are unarguably the most structured and purposeful times of the day for youth. Conversely, unstructured, unsupervised nonschool hours present the most opportunity for children to engage in activities that can impair their physical, emotional, and intellectual development. "The public's desire to provide adult supervision during after-school hours for high-risk children who would otherwise be unsupervised contributed to the growth of after-school programs" (Apsler 2009, p. 13). After school programs were initiated to address the problems associated with unsupervised time by providing (1) adult supervision of children during nonschool hours, (2) activities for children that are recreational and intellectually enriching, (3) a safe place for children where planned activities occur, and (4) additional academic time to improve scholastic achievement.

The need for after school supervision grew after World War II as both parents in traditional nuclear families entered the workforce, escalating divorce rates placed more children in single-parent homes, and increasing mobility removed the support structures inherent in extended families. These demographic trends created widespread need for additional child care and enrichment opportunities for children (Gayl 2004). Children of dual-earner and single-parent families were called latchkey or self-care children; because there was not an adult at home after school, many children were given a key to let themselves in and were given strict instructions to protect them until an adult was home to provide supervision (Fashola 2002). Eventually, self-care initiatives were increasingly replaced with for more formal after school programs. From the early 1990s to the current day, welfare reform and the rise in test-driven school accountability systems became requisites for after school programs.

Many agencies have tried to address the need for supervision and provide structured activities for children after school. Community service agencies and faith-based groups have offered programs that tend to focus on social skills, health and physical well-being, and cultural enrichment; whereas school-based programs have tended to focus on ameliorating academic deficits identified by standardized tests and other school accountability standards. The 21st Century Community Learning Centers Act (21st CCLC) of 1994 was the federal government's response to the need to educate, supervise, and enrich youth during nonschool hours. Senator James Jeffords and Representative Steve Gunderson supported legislation that supplied grants to rural and inner-city public schools to address the specific needs in their community, and to support efforts to make schools available for use by the community during nonschool hours (Gayl 2004).

After school programs have evolved over the years. Many of the same fundamental reasons that led to the growth in after school programs still exist today. However, the new challenges of unstructured nonschool time are global and reach far beyond the backyard. Young people have access through the Internet to the world and unsupervised time provides access to an immeasurable amount of information, places, and

activities. The challenges of keeping children safe during nonschool hours go beyond the advice given to latchkey children in the 1970s and 1980s.

Theoretical Background

After school programs are a response to a social phenomenon that attempts to address the social, cultural, and academic needs of students who would be otherwise left unsupervised. Social theories have been used to examine and study how students are socialized, developed, and promoted both in and out of school. Using these theories as a guide, after school programs have implemented mentorship opportunities to address appropriate social interactions as well as to provide modeling and vicarious learning opportunities to strengthen self-efficacy. After school programs that are responsive to the socio-emotional needs of their participants incorporate counseling services that help students learn and demonstrate self-regulatory skills.

Not all after school programs function from a preventative posture, but rather operate from a restorative or rehabilitative perspective. These programs take a more behaviorist or social deviance approach by offering programs that aim to induce behavioral change from something less productive to an action that is perceived as more productive (Gayl 2004). These types of after school programs are intended to teach and model new behaviors, to examine new roles for students, and to allow students opportunities to observe and interact with others in a safe and structured social setting. Still other programs may have a focus on the family and their philosophical perspective has been aimed at the source of the phenomenon – the family. Family relations researchers have studied the trends in order to provide resources to strengthen the family, engage the family in the education of the child, and model parenting skills to strengthen home and school relations (Fashola 2002).

Important Scientific Research and Open Questions

Although the design of after school programs has evolved through the years, little consensus exists regarding appropriate measurements of intended outcomes and program effectiveness. More and more, school-based after school programs are judged on their ability to increase student achievement and improve academic performance. The extant research on after school programs tends to focus on safety, social skills, self-efficacy, school engagement, student conduct, and academic achievement. When evaluating after school programs, the major areas that affect after school programs' effectiveness are *attendance and participation, student selection, and methodology.*

Attendance and Participation

Researchers have attempted to associate attendance and participation in after school programs with student achievement. Attendance is defined as the physical presence of the student, and participation is defined as the engagement and effort that the student puts forth while in attendance. Although these constructs are conceptually straightforward, they have proven to be difficult both to measure and to associate directly to student success. Attendance in after school programs can be complicated by the variety and increased number of available after school options for students and families. Roth et al. (2010) found that because older students are afforded more opportunities as they matriculate through middle and high school, their attendance in after school programs tends to be low and their continuous participation uncertain. Even with continuous daily attendance, there can be tremendous variation in the quality of students' daily participation as reflected by their engagement in learning activities and behavior.

Attendance and participation are important elements to consider when evaluating after school programs and critiquing the research and can provide different versions of success based on how attendance and participation are conceptualized and measured. According to Roth et al. (2010) there are five dimensions of participation that should be considered and that affect the results of after school programs. How long should a student attend an after school program in order to realize significant academic results? How frequently should a student attend each week in order to ensure improvements in schoolwork and behavior? Questions like these require more research to better understand the implications that varying amounts of attendance and participation have on student achievement and program success.

Student Selection

The way that students are selected for after school programs has a substantial effect on the validity of

research findings in the field. Student selection can make it difficult to compare programs and program results because student demographics and academic background are correlated both with eligibility and with outcomes. Oftentimes, student selection initially is based on set criteria, but, depending on the responsiveness of the student population, the treated population and the intended population may differ. Questions about who will be invited to participate, which grade level should be the focus of the intervention, the appropriate composition of a control or comparison group, and which type of student instructional grouping yield the greatest success must be considered when implementing and evaluating after school programs. Lauer et al. (2006) contend that certain program characteristics moderate the achievement of the program outcomes. One of these moderators is student selection and student grouping. How should student groups be arranged in an after school program to maximize significant individual academic gains? For some students, one-on-one student–teacher ratios are needed in order to improve student achievement, while other programs may select and group students by gender in order to accomplish the mission and goals of the program. Ultimately, "assessing the impact of after school programs depends on knowing which students enrolled and how frequently each participated" (Apsler 2009, p. 6).

Methodology

Apsler (2009) asserts that, while many positive effects of after school programs have been documented throughout the literature, most of the findings are subject to validity threats arising from serious methodological flaws. The literature is clear about the need for a more rigorous approach to investigating and evaluating the effectiveness of after school programs. Funding, student achievement, and public support depend on an accurate account of how programs use time and resources, as well as, an accurate account of the program outcomes. However, "what goes on after school cannot be separated from what happens in school" (Dryfoos 1999, p. 118). Disentangling the effects of after school programs from school effects is challenging considering that the public school curriculum and other after school options aim to affect the same outcomes. Improving how after school programs are studied will add value and strengthen the outcomes

in the field. Fashola (2002) recommends a more systematic experimental evaluation design that involves comparing student involvement and achievement pre- and posttreatment. Rigorous experimental designs provide clear evidence of the effects of the treatment and provide stakeholders with a thick description of the nature of the program as well as a valid statistical analysis of the findings.

Generalizability is the extent to which research findings from the sample population can be applied to the population at large. Increasing the generalizability in evaluative after school research would provide a level of confidence that the results are transferable from one program to comparative programs. With more rigorous and generalizable studies, the results of after school programs could influence and inform school funding, reform initiatives, and instructional best practices. There are some consistent findings however that shows promise from the research on after school programs. A review of the literature shows that even though participation can be sporadic, participation in an academic after school program can produce encouraging gains in academic outcomes (Lauer et al. 2006; Roth et al. 2010). There is also tentative support that suggests that students who spend time in academic focused after school programs may actually benefit more than their higher achieving peers on standardized measures; additionally, students who receive one-on-one tutoring in reading achieve more than large group reading program (Apsler 2009; Lauer et al. 2006).

The goal of school-based after school programs is to improve students' academic achievement. National organizations have attempted to contribute to the extant research on after school programs hoping to show that after school programs are effective in improving student achievement and enhancing student development. There is a growing concern about the quality and competitiveness of an American education. As federal and state mandates of accountability increase and funding for school reform decrease the need for effective after school programs intensifies. After school programs have become and will remain a viable means of providing academic support for youth at risk of school failure and for the community in need of safe and engaging alternatives for students left unsupervised during nonschool hours.

Cross-References

▶ Authenticity in Learning Activities and Settings
▶ Interest-Based Child Participation in Everyday Learning
▶ Learning in Informal Settings
▶ Learning in the Social Context

References

Apsler, R. (2009). After-school programs for adolescents: A review of evaluation research. *Adolescence, 44*(173), 1–19.

Dryfoos, J. (1999). The role of the school in children's out-of-school time. *The Future of Children, 9*(2), 117–134.

Fashola, O. (2002). *Building effective afterschool programs*. Thousand Oaks: Corwin Press.

Gayl, C. (2004). *After-school programs: expanding access and ensuring quality*. July Policy Report 1–8. Washington, DC: Progressive Policy Institute.

Lauer, P., Akiba, M., Wilkerson, S., Apthorp, H., Snow, D., & Martin-Glenn, M. (2006). Out-of-school-time programs: A meta-analysis of effects for at-risk students. *Review of Educational Research, 76*(2), 275–313.

Roth, J., Malone, L. M., & Brooks-Gunn, J. (2010). Does the amount of participation in afterschool programs relate to developmental outcomes? A review of the literature. *American Journal of Community Psychology, 45*, 310–324.

Learning and Education in Migration Settings

MARIËTTE DE HAAN
Langeveld Institute for the Study of Education and Development in Childhood and Adolescence, Utrecht University, Utrecht, CS, The Netherlands

Synonyms

Immigrant learning; Learning under the migrant condition

Definition

Learning and education in migration settings refers to both informal and formal learning processes that are found to fit the specific situation of immigrants. What characterizes immigrant learning is the constant adaptation to settings where little guidance is available as well as the need to cross multiple culturally diverse domains. The study of immigrant learning finds itself at the crossroads of sociocultural studies of learning, classroom studies, and anthropology and has stressed cognitive competences which can be translated into skills as defined in cognitive psychology.

Theoretical Background

General Findings on What Immigrant Learning Characterizes

The learning of immigrants is defined by the settlement in a new country after transnational migration, whether this concerns their own migration or that of their parents. The passing on of knowledge and skills is challenged in these settings as both the older and the younger generations cannot rely on longer term experience that is connected to being embedded in the original setting. As a consequence of this, the learning ecologies in which migrant learning takes place are characterized by:

- *Learning without guidance*: The constant need for learning and adaptation in settings where no or little guidance is available
- *The instability of traditions and knowledge*: Old traditions do not have the same value and are not supported socially to the same extent in the new setting
- *Atypical Intergenerational learning processes*: The younger generation sometimes learns the ways of the new country faster than the older generation which can lead to reversed socialization and unconventional role divisions between the generations
- *Culturally diverse and fragmented learning spread out over different places*: Learning processes that take place across multiple and culturally diverse settings are sometimes hard to bridge. This is true for immigrant learners in schools who face different pedagogical regimes at home and at school, but also for immigrant parents who experience a lower level of congruence between their family values and state institutions as schools, churches, and health institutions compared to mainstream parents. Recently, globalization forces have added another dimension to these processes mostly related to the possibilities for travel and online communication. As learning and socialization become less bounded to one place, crossing a diversity of pedagogical regimes now happens at larger distances and online. In immigrant families that are spread out over

different national places, or that travel back and forth to their home country, socialization might happen in multiple communities and through trans-national networks. Furthermore, online engagement allows immigrant (youth) to form alliances with and learn from others not necessarily located in their local immigrant communities. What was typical for immigrant learning, namely, that the unit for their socialization and learning is not one single space but many spaces with sometime contradictory regimes and rules, becomes even more foregrounded by these developments. However, it should also be noted that through these development immigrant learning is becoming less of a specific case and more characteristic of learning in the twenty-first century. Having multiple, culturally diverse affiliations and the pressure to develop intercultural skills to navigate through these diverse worlds is seen more and more as characteristic of social worlds highly defined by mobility and increased cultural contact.

Relation with Learning in the Twenty-First Century

Immigrant learning, or learning under the immigrant condition, is also conceived as learning that is characteristic for rapidly changing societies, characterized by a high degree of connectivity and high rhythm of exchange (de Haan 2011). The reproduction of culture becomes of a different nature in an age defined by flows as compared to one defined by stability. Learning and teaching becomes more fragmented and more the object of negotiation and conscious choice, given the confrontation of sometimes multiple and contradictory world visions that are the result of this connectivity and high rhythm of exchange. Connectivity and exchange thus enables the heterogeneity of learning experiences, which makes the boundary between immigrant learning and learning in settings with multiple and diverse settings a relative one.

Multiple Fields of Research and Disciplinary Orientations

- Research on immigrant learning has its origin in multiple disciplinary orientations and can be found in different fields of research, even if it tends mostly to be studied from a sociocultural perspective on learning. First, there is a tradition that researches *the learning of immigrant children through their*

brokering activities for their parents. As children often acquire language skills faster than parents after arrival in the new country and gain knowledge of the new country from their participation in schools, leisure clubs, and through their peers, they often are intermediaries between (state) institutions, professionals, and their parents. This tradition has documented how children learn from these situations to take up adult like responsibilities, to act like pioneers, and to navigate through and function in multiple cultural and linguistic worlds, see for instance, (Orellana Faulstich 2009). Furthermore, the study of *school learning of immigrant kids* is an established research tradition which has mostly focused on explaining the often disadvantaged position of immigrant students in terms of school outcomes. Sociology oriented research has focused on what the role is of ethnicity and class in explaining (lack of) school success. More (socio-) linguistically oriented classroom studies have focused on different cultural or linguistic norms between the home and the classroom, on unequal participation and status differences, as well as on the difficulty for minority students to develop academic identities in line with their sociocultural or social heritages (see for an overview, Elbers 2010). *The learning of immigrant adults* has also been addressed in research both in relation to how they support their children's school career as well as related to how they have reestablished their parenting practices after migration, for instance in the work of (Durán et al. 2001). Recently, the transnational aspects of immigrant's education and learning have gained attention (Suàrez-Orozco and Baolian Qin-Hilliard 2004). It has addressed how *immigrant learning is connected to globalizing forces*, and the study of *transnational families* as well as the study of *immigrant learning online* are both examples of emerging fields that capture how learning in these settings is spread out over different (transnational) spaces and networks and are not confined to one particular location. Even if the study of immigrant learning has pointed to specific competences relevant for learning in migration settings, such as the ability to navigate culturally diverge settings and the adaptive competence needed in pioneering settings typical for immigrants, few attempts have been made to connect the results of these broader

studies to findings from cognitive-oriented studies in learning sciences, but see (Nasir and Rosebery 2006). However, the study of learning and education in immigrant setting has revealed that the following competences are typically associated with these settings.

- The competence to adapt to new environments which have become accessible through movement over larger geographic distance and the adaptive expertise that this innovation demands. These competences ask *self-directed learning* and *deliberate practice* as no prior guidance is available.
- Being able to learn in environments which are highly diverse and which are characterized by multiple cultural or semiotic frameworks.
- Having multiple semiotic frames available simultaneously in order to be able to learn to function successfully in and move through environments that are defined by a relatively high degree of cultural diversity.
- Dealing with majority–minority relationships, taking into account that immigrant learners have to deal with frames of reference that are not only diverse but also operate within certain power relationships.

Immigrant learning can be seen as a specific case of adaptive learning in the sense that given schemata or scripts are changed or adapted to new settings, and schemata are made flexible so that more than one frame of reference can be active. What it makes particular is the *semiotic load* that the going through these different environments creates. This makes that migrant learning is not the same as growing into more complex and adaptable schemata, but is about being able to handle *semiotic* shifts, and being able to understand certain situations, settings, competences as being a part of (the valued skills of) specific communities with their own norms and values and standards on good practices.

Important Scientific Research and Open Questions

Up until now the study on how immigrant populations and individuals change and develop over time has been approached from the point of view of how well they adapt to mainstream populations. Immigrant learning has been approached in terms of their adaptation process, their school results, their economic success, or in other words, in terms of their "acculturation" but very little from the perspective of learning goals defined from within these populations.

Historically, the learning sciences have focused on the design of learning environments and the identification of key features of designs that lead to effective or deep learning. Implicit in this orientation is the assumption that these features are universal and can be transferred from one educational setting to the other. This assumption does not take into account the cultural nature of learning experiences. The need for and the value of broader units of analysis has been inspired by interdisciplinary work on learning as well as by sociocultural perspectives on learning. According to sociocultural perspectives on learning, intelligent actions take place in the midst of a culturally defined, complex environment and depend on the joint actions with others as well as on complex tool systems. A sociocultural perspective on learning means that learning is not seen as lifted out of sociocultural context but is inherently interwoven with it. As cognition, interaction and learning are the results of and happen with the help of historically formed and culturally informed technologies, texts, and tool systems, they are inherently cultural in nature.

This means that learning experiences, as cultural practices do, are not socially neutral, or semiotically empty, but represent a particular world vision. Especially immigrant students have to deal with multiple, different, sometime contradictory world visions which may be puzzling, or alienating. Traditional notions on learning do not account for this cultural heterogeneity and how heterogeneity also poses important intellectual problems and involve key learning skills. In future work, the broader sociocultural studies of immigrant learning should be connected to studies more explicitly focused on (cognitive) competencies in order to (1) bridge smaller scale studies to broader scale studies, but also to (2) translate the sociocultural dimensions of learning into the language of cognition and cognitive-learning processes.

Cross-References

▶ Cultural Learning
▶ Social Construction of Learning
▶ Social Influence and the Emergence of Cultural Norms
▶ Social-Cultural Research on Learning

References

de Haan, M. (2011). Immigrant learning. In K. Symms Gallagher, D. Brewer, R. Goodyear, & E. Bensimon (Eds.), *Urban education* (pp. 722–756). New York: Routledge.

Durán, R., Durán, J., Perry-Romero, D., & Sanchez, E. (2001). Latino immigrant parents and children learning and publishing together in an after-school setting. *Journal of Education for Students Placed at Risk, 6*(1,2), 95–113.

Elbers, E. (2010). Learning and social interaction in culturally diverse classrooms. In K. S. Littleton, C. Wood & J. Kleine Staarman (Eds.), *International handbook of psychology in education* (pp. 277–318). Bingley, UK: Emerald.

Nasir, N., & Rosebery, A. S. (2006). Learning as a cultural process. Achieving equity through diversity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 489–504). New York: Cambridge University Press.

Orellana Faulstich, M. (2009). *Translating childhoods: Immigrant youth, language, and culture.* New Brunswick: Rudgers University Press.

Suàrez-Orozco, M. M., & Baolian Qin-Hilliard, D. (2004). *Globalization. Culture and education in the new millennium.* Berkeley: University of California Press.

Learning and Evolution

► Repeated Learning and Cultural Evolution

Learning and Evolution of Social Norms*

Rodrigo Harrison[1], Mauricio G. Villena[2]
[1]Instituto de Economía, Pontificia Universidad Católica de Chile, Macul, Santiago, Chile
[2]Escuela de Negocios, Universidad Adolfo Ibáñez, Peñalolén, Santiago, Chile

Synonyms

Conventions; Customs; Social rules

Definition

Social norms can be understood as standards of behavior that are based on widely shared beliefs of how individual group members ought to behave in a given situation

_____
* This review is based on Villena and Villena (2004).

(Horne 2001) (see Voss 2001). *The group can be a family, an organization, or a society. Members may follow the norm voluntarily if their individual preferences are consistent with the normative behavior, or they might be enforced by punishment if the differences between individual preferences and normative behavior result in a violation of the norm.*

While social norms can be modeled using alternative theoretical learning models (see for instance, Young 1998), in this brief review we focus on the basic elements of evolutionary game theory (EGT), which has been widely used to formally study the conditions under which social norms may emerge and be established in society (Weibull 1996; Vega-Redondo 1996).

Theoretical Background

One of the key research questions regarding social norms is how they can emerge in different social environments. While norms are typically taken as given in much of the economic and sociological literature, EGT tools allow us to formally model social norms dynamics. Indeed, when EGT concepts, which have thus far been mainly applied in biology to analyze animal behavior, are applied to the socioeconomic context they are mostly used to study the development of social norms in society. As Mailath (1998: 1348) explains: *Since evolutionary game theory studies populations playing games, it is also useful for studying social norms and conventions. Indeed, many of the motivating ideas are the same.*

EGT does not assume optimizing behavior per se, though it does retain the idea that individuals adjust their behavior in response to persistent differentials in material incentives. In other words, while agents do pursue individual material payoffs, which in these models represent evolutionary success, i.e., fitness, they are not always in a position to obtain straightaway the payoffs an optimizing agent would obtain. This may be due to *social norms of behavior* restricting the course of action of individuals, in such a way as to prevent them from adjusting their behavior toward the optimal strategy immediately (it takes time to change a social norm), or it may be just because individuals do not realize what is the best strategy at once. However, if this situation persists in time, some individuals will start adopting the more efficient strategy and therefore receiving a higher payoff than the rest of

the population. In the long run, the rest of the population will start imitating this more profitable course of action. Thus, the incumbent norm will be replaced by this new, more successful, strategy, which in time will be adopted as the new norm of behavior in the population. *In this sense, evolutionary models can be interpreted as models of learning*, where individuals learn about the game on a trial-and-error basis, and where more efficient behavior, in evolutionary terms, tends to be imitated.

The evolutionary approach to social norms has proved to be complementary to the extensive economic and sociological literature on norms. In particular, the concepts of Evolutionary Stable Strategy (ESS) and Replicator Dynamics (RD) are the more basic tools used in the analysis of social norm dynamics. A typical framework in which these concepts are applied is one where individuals are *repeatedly drawn at random from a large population* to play a symmetric two-person game. An ESS is a strategy, which, if adopted by a population of agents, cannot be invaded by any alternative strategy that is initially rare. An ESS is an equilibrium refinement of the Nash equilibrium (NE). Hence, an ESS is an NE which is "evolutionarily" stable, meaning that once it is fixed in a population, natural selection alone is sufficient to prevent alternative (mutant) strategies from successfully invading.

The criterion of evolutionary stability emphasizes the role of mutations in an evolutionary process – a mutation mechanism. However, a selection mechanism is also required that favors some varieties over others. This is precisely the role of *the RD*, which does not embrace any mutation mechanism at all. Robustness against mutations is indirectly taken care of by dynamic stability criteria. The replicator permits the analysis of a genuinely diverse range of behavior (i.e., a polymorphic profile of strategies) as opposed to the concept of ESS, which makes good theoretical sense only when it represents a monomorphic situation.

In order to better exemplify the modeling of social norms using EGT, let us now formalize the concept of replicator dynamics. Let us consider a game with n pure strategies. If an agent playing strategy i meets an agent adopting strategy j, the payoff to i is π_{ij}. Assuming that $p = (p_1, ..., p_n)$ is the probability of meeting each type in the population, the expected payoff to an i-player is then $\pi_i(p) = \sum_{j=1}^{n} p_j \pi_{ij}$. Hence, the average payoff in the game becomes $\overline{\pi}(p) = \sum_{i=1}^{n} p_j \pi_i(p)$. Consequently, in this setting the RD in a polymorphic population is given by

$$\frac{dp_i}{dt} = p_i(\pi_i(p) - \overline{\pi}(p)) \quad \text{(all } i), \tag{1}$$

where $\overline{\pi}(p)$ denotes the average fitness of the population. Equation 1 is called the replicator equation.

From Eq. 1 it transpires that according to the replicator equation, the strategies that grow are those that perform better than average, and that generally the best performing strategies grow the fastest. In this framework, an NE is a stationary point of the dynamic system. On the other hand, each stable stationary point is an NE and an asymptotically stable fixed point is a perfect equilibrium. Moreover, evolutionary stability becomes a sufficient (but not necessary) condition for asymptotic stability if only pure strategies can be inherited.

In what follows we present a simple application of the concept of RD in the modeling of social norms.

Cooperative Versus Noncooperative Social Norms

Let us consider a doubly symmetric two-player game with two pure strategies and payoff matrix:

$$A = \begin{array}{c} \\ C \\ NC \end{array} \begin{array}{c} C \quad NC \\ \begin{pmatrix} 6 & 0 \\ 4 & 3 \end{pmatrix} \end{array} \tag{2}$$

Since C-C > NC-C and NC-NC > C-NC, we have that this game is a coordination game. We can think of this game, for example, as a two-person common property resource game in which the common resource is an inshore fishery exploited by two fishermen, and that each agent can exploit the fishery choosing between two different levels of effort, e.g., fishing effort might be measured by the number of standardized vessels operating in a fishery during a particular day. In particular, here we consider a low fishing effort, C, which we call cooperative, and a high fishing effort, NC, which we call noncooperative. From the payoff matrix it can be inferred that if both players choose the cooperative fishing effort, they will be better off than if both players use the noncooperative fishing effort, i.e., a payoff of 6 against one of 3. This could be the case if both players adopt the large fishing effort, the stock

could be harvested to a level where extraction gets more difficult and therefore not as profitable as in that case where both fishermen use the low fishing effort giving thus more time to the stock to recover. Playing in a cooperative manner is not without its risks, since if one plays cooperatively and the other noncooperatively the player can end up receiving nothing while his/her opponent gets a payoff of 4. In terms of our example this makes sense, since, as we have assumed here, cooperation means using a lower effort to exploit the resource, which, depending on the relation between efforts, can imply that the other individual using a larger effort can be able to harvest the stock down to a level where it is not more profitable for individual 1 to continue in business or even can harvest the entire stock and there will then be nothing left for individual 1. In any case the cooperative individual will lose revenue by using a lower effort than the other individual who uses a larger effort. Finally, if considering the risk of playing cooperative both players decide to use the noncooperative fishing effort then they get a return of 3, which is lower than that obtained if both players decide to play cooperative, getting a return of 6.

Consequently, according to the basic principles of traditional game theory, it is evident that here both players (strictly) prefer the strategy profile C-C, which gives payoff 6 to each player. Indeed, C-C is a strict NE. However, the pure strategy profile NC-NC is also a strict NE, resulting in payoff 3 to each player. If one player expects the other to play strategy NC with sufficiently high probability, then his or her unique optimal action is to play strategy NC as well. The game has a third Nash equilibrium, which is mixed. This corresponds to the symmetric pair (x, x) where $x = 3/5, 2/5$, the payoff to each player in this equilibrium being 18/5. All Nash equilibria are clearly perfect: Two are strict, and one is interior.

Now we suppose that within the population there is a proportion of players using the cooperative strategy C, and other of players adopting the noncooperative strategy NC which we denote p_1 and p_2 respectively. We also have the identity $p_1 + p_2 = 1$. Thus, we get the following replicator equation:

$$\dot{p}_1 = p_1(1 - p_1)(5p_1 - 3). \tag{3}$$

In order to see how solutions of (3) change over time, let us draw the associated phase portrait.

Hence, it is clear that the steady states $p_1 = 0$, and $p_1 = 1$ are asymptotically stable, while $p_1 = 3/5$ is unstable. In other words, if one starts to the left of 3/5, i.e., where the population playing C, cooperative, is a rather small proportion of the total population, the system tends to the steady state $p_1 = 0$, i.e., the cooperative population is wiped out. If one starts anywhere to the right of 3/5, the system tends to the steady state $p_1 = 1$, i.e., the population adopting the noncooperative strategy is wiped out. The unstable equilibrium at $p_1 = 3/5$ is the boundary, or separatrix, between the region of attraction of $p_1 = 0$ and that of $p_1 = 1$.

In this example we have used the concept of the RD to analyze the evolution of a population where there is a proportion of players using the cooperative strategy C, and other of players adopting the noncooperative strategy NC. We can interpret these two strategies as two different *social norms*, one cooperative and the other noncooperative. The result presented here clearly shows that in this particular example, the emergence of one social norm as the dominant one depends on the initial number of people who subscribe to each norm of behavior. In particular, if, initially, less than 60% of the total population adheres to the cooperative social norm, then the noncooperative one will become the dominant in the long run and people adopting the cooperative strategy will be wiped out. Otherwise, the cooperative social norm will become the dominant and the population adopting the noncooperative strategy will be wiped out. This clearly points to the importance of initial conditions, which somehow determine future developments, and to the relevance of studying the historical context when analyzing social norms in specific settings.

From this simple example it can also be inferred that there can be some conflicts between social norms and that some norms of behavior are not always positive in terms of society's welfare. Indeed, it can be noted that the RD does not reject the socially inefficient

profile NC-NC, i.e., where players use the noncooperative fishing effort. In this sense a socially inefficient norm of behavior, e.g., always use strategy NC when meeting, may be evolutionarily (asymptotically) stable. Certainly, depending on the initial population adhering to the cooperative social norm, the noncooperative convention can become the dominant in the long run and people adopting the cooperative strategy will be wiped out.

Important Scientific Research and Open Questions

Finally, there are many interesting research projects related to learning and the evolution of social norms that could be highlighted: (a) the *"economic anthropology"* of Herbert Gintis and Samuel Bowles, which is based mainly on EGT tools, reviewing topics such as *the importance and origins of reciprocity, fairness and cooperation in primitive societies, and the measure of social norms and preferences using experimental games* (see Bowles 2004; Gintis 2000); (b) the work on the *"evolution of preferences"* as developed by Werner Güth (see Heifetz 2005); (c) the study of the *"evolution of social norms in specific economic settings"* – an excellent example here is provided by the work of Sethi and Somanathan (1996) which examines the problem of the exploitation of a common property resource within an evolutionary game theoretic framework– and (d) the *"evolution of rationality,"* where social norm-guided behavior, which is associated with a nonrational conduct, is contrasted with rational, optimizing, behavior (see Banerjee and Weibull 1994) (see Vega-Redondo 1996: 85).

Cross-References

▶ Cultural Learning
▶ Learning and Evolutionary Game Theory
▶ Social Construction of Learning

References

Bowles, S. (2004). *Microeconomics: Behavior, institutions, and evolution.* Princeton: Princeton University Press.
Gintis, H. (2000). *Game theory evolving.* Princeton: Princeton University Press.
Heifetz, A., Shannon, C., & Spiegel, Y. (2007). The dynamic evolution of preferences. *Economic Theory, 32*(2), 251–286.
Horne, C. (2001). Sociological perspectives on the emergence of social norms. In M. Hecheter & K. D. Opp (Eds.), *Social norms.* New York: Russell Sage.
Mailath, G. J. (1988). Do people play nash equilibrium? Lessons from evolutionary game theory. *Journal of Economic Literature, 36*(3), 1347–1374.
Sethi, R., & Somanathan, E. (1996). The evolution of social norms in common property resource use. *The American Economic Review, 86*(4), 766–788.
Vega-Redondo, F. (1996). *Evolution, games, and economic behavior.* New York: Oxford University Press.
Villena, M. G., & Villena, M. J. (2004). Evolutionary game theory and Thorstein Veblen's evolutionary economics: Is EGT Veblenian? *Journal of Economic Issues, 38*(3), 585–610.
Voss, T. (2001). Game theoretical perspectives on the emergence of social norms. In M. Hecheter & K. D. Opp (Eds.), *Social norms.* Nueva York: Russell Sage Foundation.
Weibull, J. (1996). *Evolutionary game theory.* London: MIT Press.
Young, H. P. (1998). *Individual strategy and social structure: An evolutionary theory of institutions.* Princeton: Princeton University Press.

Learning and Evolutionary Game Theory

LUIS R. IZQUIERDO[1], SEGISMUNDO S. IZQUIERDO[2], FERNANDO VEGA-REDONDO[3]
[1]Departamento de Ingeniería Civil, University of Burgos, Burgos, Spain
[2]University of Valladolid, Valladolid, Spain
[3]European University Institute, Florence, Italy

Synonyms

Theory of games

Definition

Game: A formal abstraction of a social interaction where: (a) there are two or more decision makers, called players, (b) each player has a choice of two or more ways of acting, called actions or (pure) strategies, and (c) the outcome of the interaction depends on the strategy choices of all the players.

Game Theory: The formal theory of interdependent decision-making.

Classical Game Theory: Branch of game theory devoted to the formal analysis of how rational players should behave in order to attain the maximum possible payoff.

Evolutionary Game Theory: Branch of game theory that studies the evolution of large populations of

individuals who repeatedly play a game and are exposed to evolutionary pressures (i.e., selection and replication subject to mutation).

Learning Game Theory: Branch of game theory that studies the dynamics of a group of individuals who repeatedly play a game, and who adjust their behavior (strategies) over time as a result of their experience (through, e.g., reinforcement, imitation, or belief updating).

Theoretical Background

This entry gives a comparative overview of Learning and Evolutionary Game Theory within the broader context of noncooperative game theory. We make a clear distinction between game theory used *as a framework* (which makes no assumptions about individuals' behavior or beliefs), and the three main branches of noncooperative game theory as we know them nowadays, namely classical game theory, evolutionary game theory, and learning game theory.

Game theory as a *framework* is a methodology used to build models of real-world social interactions. The result of such a process of abstraction is a formal model (called *game*) that typically comprises the set of individuals who interact (called *players*), the different choices available to each of the individuals (called actions or *pure strategies*), and a *payoff* function that assigns a value to each individual for each possible combination of choices made by every individual (Fig. 1). In most cases, payoffs represent the preferences of each individual over each possible outcome of the social interaction. The notable exception is evolutionary game theory, where payoffs often represent Darwinian fitness.

		Player 2	
		Player 2 chooses LEFT	Player 2 chooses RIGHT
Player 1	Player 1 chooses UP	3 , 3	0 , 4
	Player 1 chooses DOWN	4 , 0	1 , 1

Learning and Evolutionary Game Theory. Fig. 1 Payoff matrix of a two-player two-strategy game. For each possible combination of pure strategies there is a corresponding pair of numbers (x, y) in the matrix whose first element x represents the payoff for player 1, and whose second element y represents the payoff for player 2

Game theory is particularly useful to model social interactions where individuals' decisions are interdependent, i.e., situations where the outcome of the interaction for any individual player generally depends not only on his own choices, but also on the choices made by every other individual. Thus, several scholars have pointed out that game theory could well be defined as "the theory of interdependent decision-making."

Game theory *used as a framework* provides a formal description of the social setting where the players are embedded. Importantly, it does not account for the players' behavior, neither in a normative nor in a positive sense. It is just not the realm of game theory *as a framework* to do so. It is only when different assumptions about the precise meaning of payoffs and about how players behave – or should behave – are included in the framework, that game theory gives rise to its different branches. Here we outline the main features of the three most developed branches of noncooperative game theory at this time.

Classical Game Theory (CGT)

Classical game theory was chronologically the first branch to be developed (Von Neumann and Morgenstern 1944), the one where most of the work has been focused historically, and the one with the largest representation in most game theory textbooks and academic courses.

In CGT, payoffs reflect preferences, i.e., the payoffs for each player effectively define a preference ordering over the set of possible outcomes. Naturally, the specific properties of this ordering constrain the type of analysis that one can meaningfully undertake. Thus, the most basic assumption about payoffs is to assume that they merely represent a total ordering of preferences, e.g., "Worst, Average, Best" (so arithmetic operations on payoffs would not be meaningful). However, most often payoffs in CGT are interpreted as von Neumann–Morgenstern utilities and, when this is the case, payoffs embody players' attitudes to risk, and thus one can use expected utility theory to evaluate probability distributions over possible outcomes of the game. This allows for the analysis of *mixed strategies*, which are strategies that assign a certain probability to each possible pure strategy. Importantly, note that if no further assumption is made, comparisons of payoffs across players are completely meaningless.

(This contrasts with the interpretation of payoffs made in evolutionary game theory, where payoffs represent reproduction or survival rates and it is the relative differences in payoffs among players what actually drives the dynamics of the process.)

In CGT, players are assumed to be rational, meaning that they act as if they have consistent preferences and unlimited computational capacity to achieve their well-defined objectives. The aim of the theory is to study how these instrumentally rational players would behave in order to obtain the maximum possible payoff in the formal game. The main problem in CGT is that, in general, assuming rational behavior for any one player rules out very few actions, and consequently very few outcomes, in the absence of strong assumptions about other players' behavior. Hence, in order to derive specific predictions about how rational players would behave, it is often necessary to make very stringent assumptions about everyone's beliefs and their reciprocal consistency. With these assumptions in place, the outcome of the game is a Nash equilibrium, which is a set of strategies, one for each player, such that no player, knowing the other players' strategies in that set, could improve his expected payoff by unilaterally changing his own strategy.

Given the strength of the assumptions usually made in CGT, it is not surprising that when game theoretical solutions have been empirically tested, disparate anomalies have been found. To make matters worse, even when the most stringent assumptions are in place, it is often the case that several possible outcomes are possible, and it is not clear which – if any – may be achieved, or the process through which this selection would happen. Thus, in general, the direct applicability of CGT is limited. A related limitation of CGT is that it is an inherently static theory: It is mainly focused on the study of end-states and possible equilibria, paying hardly any attention to how such equilibria might be reached.

Evolutionary Game Theory (EGT)

Some time after the emergence of classical game theory, biologists realized the potential of game theory as a framework to formally study adaptation and coevolution of biological populations, particularly in contexts where the fitness of a phenotype depends on the composition of the population (Hamilton 1967). The main assumption underlying evolutionary

thinking is that the entities which are *more successful* at a particular time will have the best chance of being present in the future. In biological and economic contexts, this assumption often derives from competition among entities for scarce resources or market shares. In other social contexts, evolution is often understood as *cultural* evolution, and it refers to dynamic changes in behavior or ideas over time.

In general, a model is termed evolutionary if its laws of motion reflect the workings of three mechanisms: *selection*, *replication*, and *mutation*, appropriately interpreted for the context in hand. The mechanism of *selection* is a discriminating force that favors some specific entities rather than others. Within the context of game theory, this selection is based on payoffs, so players that have obtained higher payoffs are selected preferentially over those with relatively lower payoffs. The *replication* mechanism ensures that the properties of the entities in the system (or the entities themselves) are preserved, replicated, or inherited from one generation to the next at least to some extent. Within the context of evolutionary game theory, the *replication* mechanism ensures that the strategies of selected players are adequately inherited, or transmitted, across consecutive generations. *Selection* and *replication* are two mechanisms that work very closely together, since *being selected* means *being selected to be preferentially replicated*.

In general, the workings of selection and replication tend to reduce the diversity of the system. The generation of new diversity is the job of the *mutation* mechanism, which is a process that works alongside (and in opposition to) the homogenizing mechanisms of selection and replication to preserve the heterogeneous nature of the system, i.e., the everlasting presence of different strategies. This mutation process by which new entities or new patterns of behavior appear is often called experimentation or innovation in socioeconomic contexts.

EGT is devoted to the study of the evolution of strategies in a population context. In biological systems, players are typically assumed to be preprogrammed to play one given strategy, so studying the evolution of a population of strategies becomes formally equivalent to studying the demographic evolution of a population of players. By contrast, in socioeconomic models, players are usually assumed capable of adapting their behavior within their lifetime,

switching their strategy in response to evolutionary (or competitive) pressure. However, the distinction between players and strategies is irrelevant for the formal analysis of the system in either case, since it is strategies that are actually subjected to evolutionary pressures. Thus, without loss of generality and for the sake of clarity, one can adopt the biological stand and assume that players may die and each individual player uses the same particular fixed strategy all throughout his finite life.

Thus, to sum up, EGT is devoted to the study of a population of agents who repeatedly interact to play a game. Strategies are subjected to selection pressures in the sense that the relative frequency of strategies which obtain higher payoffs in the population will increase at the expense of those which obtain relatively lower payoffs. The aim is to identify which strategies (i.e., type of players or behavioral phenotypes) are most likely to thrive in this "evolving ecosystem of strategies" and which ones will be wiped out by selective forces. In this sense, note that EGT is an inherently dynamic theory, even if some of its equilibrium concepts are formulated statically (e.g., the concept of evolutionarily stable strategy).

In EGT, therefore, payoffs are not interpreted as preferences, but as a value that measures the success of a strategy in relation to the others; this value is often called fitness, and in biological contexts it usually corresponds to Darwinian fitness (i.e., the expected reproductive contribution to future generations). Thus, in stark contrast with classical game theory, payoffs obtained by different players in EGT will be compared and used to determine the relative frequency of different types of players (i.e., strategies) in succeeding generations. These interpersonal comparisons are inherent to the notion of biological evolution by natural selection, and pose no problems if payoffs reflect Darwinian fitness. However, if evolution is interpreted in cultural terms, presuming the ability to conduct interpersonal comparisons of payoffs across players may be controversial.

Once the evolutionary dynamics of the game is precisely defined, the emphasis in EGT is placed on studying which behavioral phenotypes (i.e., strategies) are stable under such evolutionary dynamics, and how such evolutionarily stable states may be reached (Weibull 1995). Despite having its origin in biology, the basic ideas behind EGT – that successful strategies tend to spread more than unsuccessful ones, and that fitness is frequency dependent – have extended well beyond the biological realm. In fact, nowadays there are a number of formal results that link several solution concepts in EGT (which were conceived as the result of the workings of evolution) with solution concepts in CGT (which were derived as the outcome of players' introspective rational thinking) (see, e.g., Chap. 10 in Vega-Redondo 2003).

Learning Game Theory (LGT)

As in classical game theory, players' goal in most LGT models is to obtain the maximum possible payoff. However, LGT abandons the demanding assumptions of classical game theory on players' rationality and beliefs, and assumes instead that players learn over time about the game and about the behavior of others (e.g., through reinforcement, imitation, or belief updating).

The process of learning in LGT can take many different forms, depending on the available information, the available feedback, and the way these are used to modify behavior. The assumptions made in these regards give rise to different models of learning. In most models of LGT, and in contrast with CGT, players use the history of the game to decide what action to take. In the simplest forms of learning (e.g., reinforcement or imitation) this link between acquired information and action is direct (e.g., in a stimulus–response fashion); in more sophisticated learning, players use the history of the game to form expectations or beliefs about the other players' behavior, and they then react optimally to these inferred expectations.

The following is a brief list of some models of learning studied in LGT. We present these in ascending order of sophistication according to the amount of information that players use and their computational capabilities.

Reinforcement Learning

Reinforcement learners rely on their experience to choose or avoid certain actions based on their immediate consequences. Actions that led to satisfactory outcomes in the past tend to be repeated in the future, whereas choices that led to unsatisfactory experiences are avoided. In general, reinforcement learners do not use more information than the immediately received payoff, which is used to adjust the probability of the

conducted action accordingly. Reinforcement learners may well be presumed unaware of the strategic nature of the game.

Learning by Imitation

Imitation occurs whenever a player – the imitator – adopts the strategy of some other player – the imitated. The definition of a particular imitation rule dictates when and how imitation takes place. Some models prescribe that players receive an imitation opportunity with some fixed independent probability; in other models the revision opportunity is triggered by some internal event (e.g., player's average payoff falling down below a certain threshold). When given the chance to revise his strategy, the imitator selects one other player to imitate; this selection is most often influenced by the payoff obtained by the other players in previous rounds, and it often leaves room for experimentation (i.e., adoption of a randomly selected strategy).

Interestingly, models of learning by imitation and evolutionary models are closely related: One can always understand an evolutionary model in learning terms, by reinterpreting the death–birth process as a strategy revision–imitation process conducted by immortal individuals. With this view in mind, one could argue that LGT actually encompasses EGT. However, if not essential in purely formal terms, the distinction between EGT and this particular subset of LGT is clear in the way models are formulated and interpreted, and also in the type of formal models studied in each discipline. A common difference between imitation models in the LGT literature and models in EGT is the level at which dynamic processes are defined. Models in LGT describe how players *individually* adapt through learning, and it is this learning process that is *explicitly* modeled. By contrast, many models in EGT are aggregate in the sense that they impose a dynamic process at the population level, abstracting from the micro-foundations that could give rise to such population dynamics.

Static Perceptions and Myopic Response

In this family of learning models, each player is assumed to know the payoff that he would receive in each possible outcome of the game and the actions that every player selected in the immediate past. When making his next decision, every player assumes that

every other player will keep his current action unchanged (i.e., static perception of the environment). Working under such assumption, each player can identify the set of strategies that would lead to an improvement in his current payoff. At this point different models posit different rules. *Better-response rules* assume that players select one of these payoff-improving strategies probabilistically, while the more demanding *best-response rule* assumes that players select a strategy which would have yielded the highest payoff. Thus, in these models players assume that their environment is static and deterministic, and respond to it in a myopic fashion, i.e., ignoring the implications of current choices on future choices and payoffs.

Fictitious Play

As in the previous class of models, players in fictitious play (FP) models are assumed to have a certain model of the situation and decide optimally on the basis of it. The higher level of sophistication introduced in FP models concerns the (still stationary) model of the environment that players hold. An FP player assumes that each of his counterparts is playing a certain mixed strategy, and his estimation of this mixed strategy is equal to the frequency with which the counterpart has selected each of his available actions up until that moment. Thus, instead of considering the actions taken by every other player only in the immediately preceding time-step (as in the models explained in the previous section), FP players implicitly take into account the whole history of the game. After forming his beliefs about every other player's strategy in such a frequentist manner, an FP player responds optimally (and myopically) to such beliefs.

Rational Learning

The most sophisticated model of learning in LGT is often labeled "rational learning" – see Kalai and Lehrer (1993). Players in this model are assumed to be fully aware of the strategic context they are embedded in. They are also assumed to have a set of subjective beliefs over the behavioral strategies of the other players. Informally, the only assumption made about such beliefs is that players cannot be *utterly surprised* by the course of the play, i.e., players must assign a strictly positive probability to any strategy profile that is coherent with the history of the game. Finally, players are assumed to respond optimally to their beliefs with the

objective of maximizing the flow of future payoffs discounted at a certain rate.

Other Models

Note that all the models presented above embody some sort of rationality in the sense that players try to attain the maximum possible payoff, given certain constraints on the available information and on the formation of beliefs about other players. There are, however, other learning models in the literature which are not built upon the assumption that players respond optimally, but rather attempt to describe how humans actually play games (which does not always seem to be very rational). These learning models are inspired by empirical evidence and by research in cognitive science, and many of them are collected under the umbrella of Behavioral Game Theory (BGT). BGT *is about what players actually do. It expands analytical theory by adding emotion, mistakes, limited foresight, doubts about how smart others are, and learning to analytical game theory* (Camerer 2003). Models in BGT are assessed according to how well they fit empirical (mostly experimental) data.

Important Scientific Research and Open Questions

Both EGT and LGT are very lively fields of research. Understandably, much research on mainstream EGT is founded on assumptions made to ensure that the resulting models are mathematically tractable. Thus, much research assumes infinite and homogeneous populations where players use one of a finite set of strategies and are randomly matched to play a two-player symmetric game. The analysis of richer and more realistic systems (which consider, e.g., finite populations, multiplayer games, simultaneous mutations, and structured populations) has advanced a lot in recent years and is benefiting as well considerably from the advancement of computer simulation.

As for LGT, a common weakness of most models in the literature is that they almost invariably assume that every player in the game follows the same decision-making rule. This seems to be the natural first step in exploring the implications of a decision-making rule; however, it is clear that in many of these models the observed dynamics are very dependent on the fact that the game is played among "cognitive clones." Confronting the investigated learning algorithm with other decision-making rules seems to be a promising second step in LGT studies. As a matter of fact, the inclusion of different learning rules within the same model opens up a promising avenue of interaction between LGT and EGT: The evolution of learning rules, i.e., what type of learning rules may survive and spread in an evolutionary context?

There is also a lot of research to be done on the relation between CGT, EGT, and LGT. A topic of much interest lies in studying the conditions under which the solution concepts derived in each of these fields coincide, e.g., When does a certain learning rule converge to a Nash equilibrium? Under what conditions evolution favors rational behavior? Are the dynamics of a certain evolutionary process formally equivalent to those obtained when the game is played by individuals who learn to play the game?

Another lively area of research concerns the *computational complexity* of the problems we encounter in game theory. Any problem posed in the context of game theory requires some sort of computation. This does not only apply to LGT (where it is clear that learning algorithms have to compute the strategy to use as a function of the available information and feedback) but to the whole field of game theory in general. The identification of best-response strategies, Nash equilibria, evolutionarily stable strategy, or of any other solution concept, are computational problems in the sense that they require an algorithm, a procedure to compute the results. Computational complexity theory studies the inherent difficulty of computational problems, i.e., how hard the problems are, measured as a function of the amount of computational resources needed to solve them. Knowing the computational complexity of a problem can be of utmost significance, and it can crucially influence the applicability of its solution.

Finally, there is clearly a lot to gain from the interaction of game theory with other disciplines. Traditionally, game theory has developed almost entirely from introspection and theoretical concerns. While the work developed in game theory up until now has proven to be tremendously useful, it seems clear that game theory will not fulfill all its potential as a tool to analyze real-world social interactions unless greater attention is paid to empirical evidence and concrete real-world problems. Empirical research (both experimental and fieldwork) can also suggest exciting and relevant

avenues where theoretical research may be most needed. In this way, empirical and theoretical work can usefully drive, shape, and benefit from each other.

Cross-References

References

Camerer, C. (2003). *Behavioral game theory: Experiments on strategic interaction.* New York: Russell Sage.

Hamilton, W. D. (1967). Extraordinary sex ratios. *Science, 156*(3774), 477–488.

Kalai, E., & Lehrer, E. (1993). Rational learning leads to Nash equilibrium. *Econometrica, 61*(5), 1019–1045.

Vega-Redondo, F. (2003). *Economics and the theory of games.* Cambridge: Cambridge University Press.

Von Neumann, J., & Morgenstern, O. (1944). *Theory of games and economic behavior.* Princeton: Princeton University Press.

Weibull, J. W. (1995). *Evolutionary game theory.* Cambridge: MIT Press.

Learning and Fluid Intelligence Across the Life Span

Tracy Packiam Alloway
Centre for Memory, University of Stirling, Stirling, UK

Synonyms

IQ; Learning disability; Working memory

Definition

Fluid intelligence (Gf) is a complex cognitive skill that helps us solve problems, adapt to changing situations, and exhibit flexibility in thinking. Fluid intelligence (Gf) together with crystallized intelligence (Gc) are constructs of general intelligence. Fluid intelligence is measured using tests of problem-solving, pattern matching, and reasoning, while crystallized intelligence (Gc) is evaluated using tasks that measure knowledge and experience and is related to verbal ability, language development, and academic success.

Theoretical Background

The growth and decline of fluid intelligence is associated with brain structural changes. For example, development of fluid IQ is associated with cortex thickness during the critical period between 6 and 12 years old. On the other end of the life span, poor performance in cognitive functioning is attributed to a decrease of frontal gray matter density in elderly populations. In particular, there is a sharp decline in fluid IQ scores after 65 years of age. In 80-year-olds, a decline 15 standard points (1SD below the average) in IQ tests is reported, which reflect levels of cognitive impairments (Kaufman 2001).

There is substantial evidence that fluid intelligence (Gf) and working memory share neural substrates, such as the prefrontal and parietal cortices (Gray et al. 2003). However, there are distinctive patterns in the trajectory and decline of working memory skills that suggest that while working memory and fluid intelligence may share neural substrates, they have dissociable cognitive profiles across the life span. Compared with IQ, the growth of working memory occurs more rapidly and the decline more slowly. For example, there is a reported growth of 23 standard points on average between 5 and 19 years of age. This growth tails off and between 20 and 39 years of age, there is only an average of a 4 standard point increase. In contrast to IQ scores, the rate of decline in working memory skills is less dramatic and people in their sixties tend to perform at a similar level to those in their twenties. Verbal working memory skills are better preserved than visuospatial working memory skills.

There are two opposing positions regarding the theoretical relationship between working memory and IQ. One view is that these two constructs are so highly correlated that they could be considered as isomorphic properties (Colom et al. 2004). An alternative account is that working memory shares psychometric properties with IQ, yet is dissociable (Alloway et al. 2004). In a recent meta-analysis, Ackerman et al. (2005) pointed out that working memory and general fluid intelligence (Gf) share on average 20% of their variance. This modest overlap suggests that these two constructs are not synonymous.

Fluid Intelligence and Learning

Fluid intelligence is typically measured using IQ tests, which incorporate tasks assessing both verbal and

spatial cognitive skills. There is a long history of using IQ tests to identify school performance, with IQ scores explaining about 25% of the variance in grades. When IQ tests were first devised at the turn of the twentieth century, their primary function was to identify students who were falling behind their peers. Today, IQ tests are still used to identify those with learning disabilities (or learning disorder) using a discrepancy criterion between IQ and achievement scores. This criterion is based on the view that if a student performs within an average range in an IQ test, then their learning scores should also be within an average range. However, for 10–20% of students, there is a discrepancy between these two scores – they may have an average IQ score, yet perform below age-expected levels in learning outcomes. Thus, their academic performance is not commensurate with their IQ score, which indexes fluid intelligence.

The use of a discrepancy criterion to identify students with learning disabilities is not without its critics, largely because it is not always reliable. For instance, a student may have an IQ score in the above-average range and learning outcomes in the average range, and yet would be classified as having a learning disability because their academic performance is not in the above-average range as well. The discrepancy criterion also fails to identify students who have a "flat" cognitive profile, with below-average scores in IQ and academic tests.

Fluid intelligence can also be measured using working memory tests. There is substantial evidence that working memory is linked to learning in a range of subjects, including reading and math. In reading, scores on working memory tasks, which require a combination of storing and processing information, predict reading achievement independently of measures of verbal short-term memory or phonological awareness. It may take considerable working memory capacity to keep in mind the relevant speech sounds and concepts necessary for successfully identifying words and comprehending text. Working memory is also closely linked to mathematical skills. For example, visuospatial memory functions as a mental blackboard to support number representation, such as place value and alignment in columns, in counting and arithmetic tasks.

Working Memory

Working memory skills have also been linked to learning disabilities. In a screening study of over 3,000

children, 10% of those in mainstream classrooms were identified with working memory impairments. Inspection of their learning profiles indicates that two-thirds achieved standard scores below age-expected levels (<86) in reading and math (Alloway et al. 2009). Without appropriate intervention, these students lag behind their peers. Recent research has also confirmed that working memory predicts learning outcomes 6 years later (Alloway and Alloway 2010). This suggests that working memory impairments are associated with low learning outcomes and constitute a high risk factor for educational underachievement for children. Common characteristics of working memory impairments in the classroom include failing to remember instructions and difficulty completing learning activities, thereby jeopardizing future academic success.

Poor working memory is found in students with learning disabilities such as dyslexia, ADHD, and motor difficulties. However, each of these groups present a unique working memory profile. For example, students with dyslexia are characterized by a weakness in verbal working memory, while individuals with ADHD and motor difficulties display a specific weakness in visuospatial working memory. In each instance, their poor working memory is linked to their struggle in the classroom and their inability to keep up with their peers' academic progress.

Knowing the strengths and weaknesses of a student's cognitive profile is vital in providing appropriate intervention. One approach to supporting working memory impairments is to introduce changes to the student's environment to reduce the detrimental effects of memory overload. Suggested ways include simplifying the processing demands of classroom activities and providing effective learning strategies. Studies on strategy use in the classroom offers some support in using such complimentary methods to help students with working memory deficits.

While targeted classroom strategies can be useful, there is growing evidence on the efficacy of brain training. However, caution must be exercised as some methods only demonstrate task-specific gains and transfer gains to other tasks are rare or nonexistent. Furthermore, in some instances, gains in IQ tests are often purported to be the result of practice effects due to the similarities between the training task and the secondary task.

One promising approach is adaptive working memory training, where the intensity and difficulty of working memory sessions are individually customized to the aptitude of the child. Studies to date have established that gains are evident in ADHD samples, those with intellectual disability, and in those with poor working memory. Research in college students has demonstrated transfer effects to IQ, which may be the result of sharing neural substrates, such as the prefrontal and parietal cortices. Recent trials with students with dyslexia have found transfer effects from working memory training to IQ and learning outcomes as well.

Important Scientific Research and Open Questions

The theoretical relationship between working memory and IQ has important implications for learning. Given the strong links between working memory and learning, one key question is whether working memory is simply a proxy for IQ with respect to academic attainment. Some researchers have suggested that the key factor underlying the relationship between working memory and learning is IQ. Contrasting evidence suggests that working memory shares unique links with learning after IQ has been statistically accounted. In a recent longitudinal study, working memory skills at 5 years of age was a better predictor than fluid intelligence of literacy and numeracy 6 years later (Alloway and Alloway 2010). It is possible that working memory plays a critical role in predicting learning outcomes when children are young as they have very little knowledge-based resources to draw on to support learning. As children get older, they build up more knowledge and thus, tests that tap crystallized intelligence, such as vocabulary, might be better predictors of learning outcomes.

Cross-References

▶ Attention Deficit and Hyperactivity Disorder (ADHD)
▶ Intelligence, Learning, and Neural Plasticity
▶ Multiple Intelligences and Learning Styles

References

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin, 31*, 30–60.
Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*, 20–29.
Alloway, T. P., Gathercole, S. E., Willis, C., & Adams, A. M. (2004). A structural analysis of working memory and related cognitive skills in early childhood. *Journal of Experimental Child Psychology, 87*, 85–106.
Alloway, T. P., Gathercole, S. E., Kirkwood, H. J., & Elliott, J. E. (2009). The cognitive and behavioural characteristics of children with low working memory. *Child Development, 80*, 606–621.
Colom, R., Rebollo, I., Palacios, A., Juan-Espinosa, M., & Kyllonen, P. C. (2004). Working memory is (almost) perfectly predicted by g. *Intelligence, 32*, 277–296.
Gray, J. R., Chabris, C. F., & Braver, T. S. (2003). Neural mechanisms of general fluid intelligence. *Nature Neuroscience, 6*, 316–322.
Kaufman, A. S. (2001). WAIS-III IQs, Horn's theory, and generational changes from young adulthood to old age. *Intelligence, 29*, 131–167.

Learning and Human–Computer Interaction

▶ Human–Computer Interaction and Learning

Learning and Instinct

Michael Domjan
Department of Psychology, The University of Texas at Austin, Austin, TX, USA

Synonyms

Learned versus innate

Definition

The concept of learning has been contrasted with instinct both historically and in folk biology. Learning was intended to emphasize aspects of behavior and cognition that are the result of experience and training, whereas instinct was intended to emphasize genetically preprogrammed mechanisms that emerge without special environmental input. This distinction was related to distinctions between what is learned and what is innate or inherited. However, all such distinctions have come under serious theoretical and empirical challenge and are no longer considered valid.

Theoretical Background

During much of the twentieth century, scientists studying learning were distinct from those studying

instinct in their intellectual heritage and orientation, in their methods of inquiry, and in their geographical location. Studies of learning were pursued by American scientists in the behaviorist tradition who assumed that behavior is highly flexible and easily modified by environmental experience or training and that the rules of learning are universal and equally applicable to a variety of species and behavioral situations. To discover these general rules of learning, investigators focused their attention on a few species (rats and pigeons) and laboratory situations in which the experience of the animals could be carefully controlled and subjected to precise experimental manipulations. The data of primary interest were how behavior changed as a result of the specific training or conditioning experiences that were provided, irrespective of the evolutionary or natural history of the species.

In contrast to the studies of learning pursued by American psychologists, instinct was the primary interest of European biologists who founded the field of ethology (e.g., Tinbergen 1951). Their interests were rooted in evolution. They sought to elucidate the evolution of behavior across species, in much the same way that Darwin and his successors studied the evolution of morphological traits such as the structure and size of limbs by comparing the limbs of various species. To make comparisons across species, ethologists had to identify behavioral units that varied more between species than within a species. Thus, they focused on species typical behaviors that were exhibited by members of a species of similar age and sex – behaviors that were more generally called "instincts."

In his seminal volume, *The study of instinct,* Niko Tinbergen, who with Konrad Lorenz founded the field of ethology, characterized the basic behavioral unit for the study of the evolution of behavior as the "fixed action pattern." A fixed action pattern is a species typical behavior (such as feeding in sea gulls) that is elicited by a particular stimulus (a "sign stimulus") that is a feature of the physical or social environment. Ethologists identified fixed action patters involved in feeding, mating, aggression, parental care, and other areas critical to biological success. These behaviors occurred in much the same way across individuals of a species (assuming similarity in age and sex) and appeared to be adaptive in that they helped the animal survive and reproduce.

Given their interest in evolution and adaptive function, ethologists eagerly studied a variety of different species in the tradition of Darwin. Their starting point for an investigation was a detailed observation of behavior in the field under natural conditions. Bringing animals into the laboratory for examination of proximate causal mechanisms was undertaken as a follow-up to field studies rather than as a starting point, in contrast to the approach of American behaviorists.

The concept of instinctive behavior and the distinction between learning and instinct came under serious attack shortly after the publication of Tinbergen's *The study of instinct.* The charge was led by a brash young American comparative psychologist, Daniel Lehrman, who published a scathing attack on the concept of innate or instinctive behavior (Lehrman 1953). Lehrman's basic argument was that labeling a behavior as an "instinct" is not useful because it does not tell us anything about the developmental or physiological processes that are responsible for the behavior. Furthermore, simply because a behavior is species specific and occurs with little variation between members of a species does not prove that it has not been learned. This line of argument suggested that the term "instinct" is uninformative at best and may in fact be misleading.

Lehrman's criticism was the beginning of a major assault on the distinction between learning and instinct and the notion that behavior can be genetically determined independent of environmental influences (Bateson and Mameli 2007; Marler 2004). The controversy soon led to the abandonment of the term "instinct" by most psychologists and biologists. There were two major reasons for this. First many students of animal behavior, including Tinbergen, came to accept that just because a behavior is species typical and varies little among members of the same species does not mean that the behavior is innate and not learned. Individuals of the same species not only have similar genes but they also share common rearing and environmental histories. These common experiences can lead to the learning of common behaviors. Thus, behaviors that may appear to be "instinctive" could in fact be the result of common learning experiences.

The second major reason scientists have abandoned the learning/instinct and learned/innate distinctions is that these distinctions were based on an untenable

view of how genetics produces behavioral and other phenotypic outcomes or endpoints. Genes do not act directly to produce a behavioral or physiological characteristic. Rather genes or DNA has to be transcribed or expressed before it can have an impact, and gene expression is determined by environmental factors (Champagne and Curley 2009). For example, genes that determine bone and muscle density operate differently in different gravitational environments, leading to different outcomes for organisms that are raised on earth as opposed to the moon. Development of behavior and physiology is now regarded to involve an epigenetic interplay between genetic and environmental variables that cannot be considered independently (Champagne and Mashoodh 2009). Although these considerations led to the abandonment of the concept of instinct among psychologists and biologists, the concept retains currency in folk biology, promoting the fiction that one can distinguish learned from instinctive or inherited behavioral characteristics.

Although the learning versus instinct distinction is no longer tenable on the basis of the importance of experiential input, this does not mean that behavior is totally malleable given the right environmental experiences, as originally proposed by the behaviorists. Studies have shown that some things are learned much more easily than other things, suggesting both biological constraints and adaptive specializations in learning. How can we understand these phenomena (and the processes of learning in general) without drawing distinctions between learning and instinct or learned versus innate behavior? An approach that remains useful can be built on Pavlov's distinction between conditioned and unconditioned stimuli and responses. An unconditioned response is one that is elicited without prior training by the experimenter, as in salivation to meat powder. In contrast, a conditioned response is one that develops only as a consequence of a special training procedure. Whereas dogs salivate unconditionally to the presentation of meat powder, they only salivate to a tone if the tone has been paired with the meat powder. Thus, the conditioning of the tone requires the use of the unconditioned properties of the meat powder in a special conditioning procedure.

As in Pavlovian conditioning, much of the outcome of specific learning or training procedures can be considered to be the result of how these training procedures are built on and modify the preexisting behavioral repertoire of the organism. This preexisting behavioral repertoire is no doubt the result of epigenetic developmental processes that involve genetic information and gene expression shaped by the environmental context. To the extent that the subjects under investigation do not vary in their developmental trajectories, studies of learning can focus on the specific training procedures of interest. However, one must be always cognizant of the fact that the preexisting behavioral organization of the subject can shape the impact of specific training procedures.

Important Scientific Research and Open Questions

Modern epigenetic views of development make a strict distinction between learning and instinct untenable but they do not invalidate questions about the relationship between learning and genetics (Marler 2004). In fact, rather than regarding behavior as being either learned or innate, the modern view considers all behaviors to be result of processes that include both genetic factors and experiential input. The critical question then becomes how genetic and experiential processes interact to produce significant behavioral changes. The challenge for future research will be to integrate modern genetics and molecular and cellular biology with what we know about conditioning and learning procedures to better understand the roots of learning processes in the evolutionary history of organisms. In addition to elucidating how gene transcription and expression operates in different environmental contexts to shape learning processes, such studies may also show us how specialized learning mechanisms have evolved to solve specific challenges to survival and reproduction.

Cross-References

▶ Behaviorism and Behavioral Learning Theories
▶ Biological Constraints on Learning
▶ Classical Conditioning
▶ Comparative Psychology and Ethology
▶ Lorenz, Konrad (1903–1989)
▶ Pavlov, Ivan P. (1849–1936)
▶ Tinbergen, Nikolaas (1907–1988)

References

Bateson, P., & Mameli, M. (2007). The innate and the acquired: Useful clusters or a residual distinction from folk biology? *Developmental Psychobiology, 49*, 818–837.

Champagne, F. A., & Curley, J. P. (2009). Epigenetic mechanisms mediating the long-term effects of maternal care on development. *Neuroscience and Biobehavioral Reviews, 33*, 593–600.

Champagne, F. A., & Mashoodh, R. (2009). Genes in context: Gene-environment interplay and the origins of individual differences in behavior. *Current Directions in Psychological Science, 18*(3), 127–131.

Lehrman, D. S. (1953). A critique of Konrad Lorenz's theory of instinctive behavior. *The Quarterly Review of Biology, 28*, 337–363.

Marler, P. (2004). Innateness and the instinct to learn. *Anais da Academia Brasileira de Ciências, 76*(2), 189–200.

Tinbergen, N. (1951). *The study of instinct*. Oxford: Clarendon.

Learning and Loss of Memory

Learning and Masculinity and Femininity

Learning and Memory in Hypnotic Trance, Hypnotic Hypermnesia/Posthypnotic Amnesia

Learning and Paradoxes

Learning and Performance Goals

Learning and Recall Under Hypnosis

ULRIKE HALSBAND
Neuropsychology, Department of Psychology,
University of Freiburg, Freiburg, Germany

Synonyms

Learning and memory in hypnotic trance, hypnotic hypermnesia/posthypnotic amnesia

Definition

A major problem in defining hypnosis is the ambiguity of the term. "Hypnosis" was derived from the Greek word "πνος" (hypnos) meaning sleep. However, neurophysiological findings clearly indicate distinct differences between hypnosis and sleep. Numerous electroencephalography (EEG) studies showed that sleep is characterized by K-complexes producing sleep oscillations ranging from 11 to 16 Hz and delta waves. In contrast, significantly greater activity in high alpha (11.5–13.45 Hz), beta (16.5–25 Hz), and high theta (5.5–7.5 Hz) band was reported in high hypnotizable subjects. From a neurobiological point of view, hypnosis can be interpreted as a modified state of consciousness which reflects a dynamic change of brain activity and is characterized by focused attention, a heightened compliance with suggestion, and an increased awareness of internal images (Rainville et al. 2002; Halsband 2009).

Learning can occur consciously (explicit) or without conscious awareness (implicit) and is characterized by the acquisition of new knowledge, behaviors, skills, and values. Memory refers to an individual's ability (1) to encode (processing of received information), (2) to store (creation of a record of the encoded information), and (3) to recall or to retrieve the information (spontaneously or in response to some external cue) (e.g., Squire 2004).

Theoretical Background

Focusing and directing of attention are key characteristics of a hypnotic induction. Hypnosis is a social interaction in which one person, called the subject, acts on suggestions from another person, called the hypnotist. This special rapport between the hypnotist and the hypnotized person as well as the absorption of

the voice of the hypnotist plays a key role. Subjects under hypnosis respond to suggestions from the hypnotist involving alterations in perception and memory. Sensory processing is limited and determined by suggestions. Hypnotic trance is accompanied by a heightened suggestibility, in which suppressed memories may be experienced. In hypnotic trance, age-regression or age-progression can be used therapeutically to allow the subjects to experience or reexperience all forms of inner sensory, perceptual, or emotional events. *Hypnotic hypermnesia* refers to the capacity of hypnotized subjects to present with an increased memory ability and to recover memories of past experiences long forgotten and inaccessible in the waking state. Traumatic, painful, and forgotten experiences may result in serious personality disturbances that are accessible under hypnosis. A foundation laid in hypnotic trance allows for their later integration into the waking life of the patient (Rossi et al. 2008). However, based on individual case histories it has been controversially discussed whether the phenomenon of *hypnotic hypermnesia* may have the potential to enhance eyewitness memory and criminal responsibility in forensic investigations. A major problem is that hypnosis alters expectations about what can be remembered and makes memory more vulnerable to false recollection. One may argue that enhanced memory improvements are of illusory nature: Hypermnesia suggestions may increase the subjects' confidence in both true and false memories. Furthermore, repeated retrieval effort and not hypnosis itself could be responsible for hypermnesia effects.

In contradistinction to hypnotic hypermnesia is the phenomenon of *posthypnotic amnesia* which refers to the subject's difficulty in remembering the events and experiences that transpired while they were hypnotized. After a deep hypnotic trance, subjects may experience a more or less complete amnesia for all trance events. The amnesia can be controlled by the hypnotist through instruction to the subjects and impairs explicit memory for the events and experiences during hypnosis (Rossi et al. 2008). The functional amnesia is of profound importance in hypnotherapy since it permits the therapist to deal with painful or traumatic memories without arousing waking resistance and defense reactions. It was argued that posthypnotic amnesia seems to involve a disruption of retrieval processes similar to the functional amnesias observed in clinical dissociative disorders (Kihlstrom 1997).

Experimental laboratory studies addressed the key question how hypnosis can modify learning and recall of information and tried to disentangle the underlying plasticity changes in the brain.

Important Scientific Research and Open Questions

It is well known that the use of *implicit* memory and information processing play a key role in hypnotherapeutic interventions. When using implicitly learned abilities, some aspects of perception may be separated from the subjects intended voluntary actions and are subconsciously registered and performed. Hypnosis can have a direct influence upon different aspects of implicit memory. In addition to motor skills, implicit memory tasks include priming tasks, simple associations based on the principles of conditioning, nonassociative learning, proactive and retroactive interference, repetition priming in word-stem completion, and semantic priming on free association and category generation tasks. Interestingly, from a neurobiological perspective there is a significant overlap of the neural circuits that play a decisive role in implicit memory processing and in attention.

First attempts to experimentally quantify *explicit* learning performance in trance can be found among the studies of Gheorghiu (1984). He observed an improved recollection of detailed structures in the drawing of animals in several subjects under positive hypnotic suggestion. In a separate study the author examined the ability to retrieve objects in the waking state, in trance, and in autogenic training. Results show a better recollection in hypnotic trance as compared to autogenic training. According to Gheorghiu the increase in amnestic performance in hypnotic trance could be the result of an affective unblocking due to hypnotic relaxation. Alternatively, the findings could be interpreted as a more pronounced representation of high-imagery objects under hypnosis.

Bongartz (1985) investigated the effect of hypnosis on learning and recollection in high and low suggestible subjects. Nouns with high (e.g., sun) or low imaginary content (e.g., thought) were presented. Subjects received a recognition list which contained the original nouns paired with either an acoustically similar distracter (e.g., gun–sun, function–junction) or a semantically similar distracter (e.g., shovel–spade, thought–idea). Results indicate that high hypnotizables

made significantly less errors when a high-imagery noun was paired with a rhyming distracter. It was concluded that highly hypnotizable subjects under hypnosis encode verbal material predominantly in an imaginable form.

More recent findings confirm that high hypnotizables benefit from hypnosis when they have to acquire word-pairs with high-imagery content (e.g., monkey–candle). It was found that high hypnotizable subjects show a better learning performance of high-imagery word-pair associations than do low hypnotizable subjects. In contrast, the ability to retrieve abstract word-pair associations (e.g., wisdom–moral) strongly decreased when encoding took place in hypnotic trance (Halsband 2006) (see Fig. 1).

A major breakthrough in the study of learning and memory during hypnosis is the use of modern brain imaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Subjects allowed to listen to pleasant autobiographical memories under hypnosis showed significant brain activations in a complex neural network including occipital, parietal, precentral, prefrontal, and cingulate cortices (Maquet et al. 1999). The study by Halsband (2006) examined the question whether verbal memory processing in hypnosis and in the waking state is mediated by a common neural system or by distinct cortical areas. During encoding subjects were visually presented high-imagery word-pairs.

Afterward, the subjects were asked to retrieve the corresponding word-pair associate after having been randomly presented the first of the two words of each word-pair. Word pairs were semantically unrelated and therefore difficult to associate (e.g., monkey–candle). During the encoding phase in hypnosis, a most pronounced occipital activation and an increased prefrontal activity were observed. When word-pairs were retrieved previously learned under hypnosis, a stronger activation in the prefrontal cortex and cerebellum, as well as an additional bilateral activation in the occipital lobe were reported (see Fig. 2). These results have therapeutic implications and are relevant for our understanding of the perception of reality under hypnosis.

As yet, the neural mechanisms underlying learning and recall in hypnosis remain poorly understood. In future studies an integrative working program, PET and/or fMRI could be used to measure regional activation effects in combination with neurophysiological recordings of the brain (electroencephalography, EEG/magnetoencephalography, MEG). This ensures simultaneously a high spatial (fMRI, PET) and a high temporal resolution (EEG, MEG) in the range of milliseconds. Another interesting future perspective is the integration of the analysis of neurochemical changes, e.g., stress hormones (cortisol, β-endorphin) and neurotransmitters with functional brain imaging techniques. Recently, a new system was introduced (MR-PET) which is capable of performing

Learning and Recall Under Hypnosis. Fig. 1 Correct answers in % by high hypnotizable subjects compared to low hypnotizable subjects, when retrieving high-imagery word-pair associations as compared to abstract word-pair associations. The word-pairs were encoded either during hypnotic trance or in the waking state

Learning and Recall Under Hypnosis. Fig. 2 Positron emission tomography (PET) activation during encoding and retrieval of high-imagery word-pairs. Hypnosis condition: (**a**) encoding, (**b**) retrieval. Waking condition: (**c**) encoding, (**d**) retrieval

simultaneously measurements of anatomy, functionality, and biochemistry. Future studies hold great promising to use MR-PET for differentiating the functional and biochemical basis of learning and recall under hypnosis.

Cross-References

▶ Amnesia and Learning
▶ Association Learning
▶ Associative Learning
▶ Complex Declarative Learning
▶ Conditions of Learning
▶ Declarative Learning
▶ Human Learning
▶ Imagery and Learning
▶ Memory Codes and Neural Plasticity of Learning
▶ Memory Structure
▶ Mental Imagery and Learning
▶ Mental Models Improving Learning
▶ Neuropsychology of Learning
▶ Pair-Associated learning
▶ Procedural Learning

References

Bongartz, W. (1985). Encoding of high-and low-imagery nouns during hypnotic age regression. *Experimentelle Klinische Hypnose, I*, 143–151.

Gheorghiu, V. A. (1984). *Hypnose und Gedächtnis: Untersuchungen zur hypnotischen Hypermnesie und Amnesie.* München: Wilhelm Goldmann.

Halsband, U. (2006). Learning in trance: Functional brain imaging studies and neuropsychology. *Journal of Physiology – Paris, 99*, 470–482.

Halsband, U., Mueller, S., Hinterberger, T., & Strickner, S. (2009). Plasticity changes in the brain in hypnosis and meditation. *Contemporary Hypnosis, 26*, 195–215.

Kihlstrom, J. F. (1997). Hypnosis, memory and amnesia. *Philosophical Transactions of the Royal Society: Biological Sciences, 352*, 1727–1732.

Maquet, P., Faymonville, M. E., Degueldre, C., Delfiore, G., Franck, G., Luxen, A., & Lamy, M. (1999). Functional neuroanatomy of hypnotic state. *Biological Psychiatry, 45*, 327–333.

Rainville, P., Hofbauer, R. K., Bushnell, M. C., Duncan, G. H., & Price, D. D. (2002). Hypnosis modulates activity in brain structures involved in the regulation of consciousness. *Journal of Cognitive Neuroscience, 14*, 887–901.

Rossi, E. L., Erickson-Klein, R., & Rossi, K. L. (2008). *The collected works of Milton H. Erickson: The nature of therapeutic hypnosis* (Vol. 1). Phoenix: The Milton H. Erickson Foundation Press.

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning and Memory, 82*(3), 171–177.

Learning and Sexual Categories

► Gender, Learning, and Social Practice

Learning and Sexual Characteristics

► Gender, Learning, and Social Practice

Learning and Thinking

Norbert M. Seel
Department of Education, University of Freiburg, Freiburg, Germany

Synonyms

Learning by thinking; Learning to think; Reflective learning and reasoning

Definition

▶ *Learning without thinking is useless*
 Thinking without learning is dangerous
  Confucius

In cognitive psychology, it is possible to find a strong relationship between learning and thinking inasmuch as thinking skills are considered to be of central importance to higher-order cognitive learning. For instance, conceptions of model-based learning often presuppose processes of mental simulations of complex systems aiming at thought experiments. However, it is possible to consider learning without thinking (e.g., learning by rote or by accident) as well as learning with thinking in order to produce new knowledge.

In general, the relationship between learning and thinking can be broken down into *learning about thinking* and *thinking about learning.* Another distinction can be made between learning by thinking and learning to think.

Learning by thinking refers to the construction of cognitive artifacts (such as conceptual models and theories about the physical world) and mental models of both simple and complex systems. They aim at the explanation and simulation of transactions in a complex system and thus lead to thought experiments. Learning by thinking transcends immediate experiential and associative learning and is closely related to inferential learning and reasoning.

Learning to think has long been a popular concept in educational psychology and is often compared to critical thinking, which means correct thinking in the pursuit of relevant and reliable knowledge about the world. Alternatively, critical thinking can be conceived of as reasonable, reflective, responsible, and skilful thinking that helps individuals decide what to believe or do in a given situation.

The conceptions of learning by thinking and learning to think both correspond to German philosopher Martin Heidegger's (1968) assertion that *thinking is learning to think.* In other words, in order to be capable of thinking, we need to learn it first.

Theoretical Background

Cognitive psychology is concerned with the principles of human *thinking* and the development of cognitive capabilities. Therefore, thinking skills are at the heart of cognitive learning in that they make higher-order

learning and problem solving possible (Mayer 1992). Issues such as critical and creative thinking and reflective learning are aspects of human thought studied by cognitive psychologists. Accordingly, learning is generally understood as the process of acquiring new knowledge and of modifying prior knowledge, skills, habits, or tendencies through experience, practice, exercise, or observation. To *learn* means that something that was not previously known to a person becomes personal knowledge. From a psychological point of view, learning includes not only associative processes, discrimination of sense data, psychomotor and perceptual learning, imitation, and concept formation, but also – at higher levels of cognition – problem solving and insight. Whereas low-level learning might simply entail memorization and the functional incorporation (internalization) of information, higher-order learning requires the active and intentional manipulation of knowledge and is by definition a conscious act involving critical and creative reflection. Accordingly, it is reasonable to distinguish between learning without thinking (as in the case of memorization) and learning with thinking that produces new knowledge often without any reference to the internalization of external information.

Interestingly, the relationship between learning and thinking has been discussed extensively by Heidegger (1968), who asked whether there is a way of thinking which has its purpose in itself, i.e., which is self-referential and verified through itself and not necessarily through concrete experiences. Heidegger distinguishes between two ways of thinking (or cognition): The first allows individuals to experience something and its nature in itself. This corresponds to ▶ experiential learning, whereas the other way of thinking challenges nature and makes it capable of being manipulated through logical reasoning. Heidegger (1968) argues that humans learn to think by directing their mind toward that which there is to think about. In a simplified sense, thinking can be equated to knowledge plus critical reflection. Of course, the products of thinking are also memorized and the new knowledge is not merely absorbed from other information sources. However, thinking can only generate new knowledge if knowledge is already available to serve as the "raw material" of content-extending thought processes.

Thinking always *creates new knowledge* on the basis of existing knowledge. In other words, it is not necessary for individuals to fall back on additional information from their surroundings to learn something. For example, someone who knows the entire series of fives on the multiplication table has learned them at some point (possibly by memorizing them); on the other hand, someone who knows that $2 \times 5 = 10$ and uses this knowledge to conclude that the product of 4×5 must be twice as much or 20 has reflected on the matter and has also learned something. Individuals can construct knowledge simply by executing thinking operations. The knowledge they acquire in this manner does not necessarily need to have any connection to their experiences, although it originates in them. The thinking operations involved in this process are inferential and content extending. Such thinking forms the basis of a kind of learning which transcends immediate experience. It corresponds to Heidegger's (1968) verdict that t*hinking is learning to think.*

Important Scientific Research and Open Questions

In contemporary education literature, it is common to emphasize the fact that students must develop intellectual and practical skills for lifelong learning in order to master the demands of an increasingly complex and interconnected world (Paul and Elder 2002). Accordingly, students need to learn and transfer complex cognitive skills to a varied set of complex settings and contexts. In other words, students should become "expert learners" who posses not only metacognitive capabilities (discussed here in terms of learning to think) but also the capability of learning to think and learning by thinking.

In cognitive psychology, the area of learning by thinking is usually related to the construction of cognitive artifacts, such as mental models and conceptual models, as well as proof learning in mathematics. In addition, it is of course also the subject of research on inferential learning and reasoning.

The learning of proofs is one of the most active research agendas in mathematics education (Mariotti 2006). In addition to analyzing the particular role of proofs in mathematics curricula, research has focused mainly on students' conceptions of proofs and their ability to construct them as well as on teaching experiments to teach students to do proofs. Other research on proof learning is related to the use of new technologies in teaching and learning mathematics.

Another major field of research on learning by thinking is concerned with the construction of cognitive artifacts, which represent complex phenomena of the physical world, and of "thought models," which operate as qualitative process models of complex systems that often have no correspondence to the external world but rather "exist" only in the human mind. Good examples of the quality of thought models can be easily found in the area of natural sciences (e.g., Rutherford's atomic model, models to explain black holes and phenomena of quantum mechanics, and so on). Indeed, there is a long tradition of research on model-building activities for specific subjects. This research emphasizes design-based modeling in the context of guided discovery and exploratory learning in different subjects, such as mathematics and physics (Lesh and Doerr 2000; Penner 2001). Another line of research on thought models is concerned with the simulation of processes of complex and dynamic systems. This occurs when a learner interacts with elements of a complex system in order to manipulate them mentally in such a way that the cognitive operations simulate specific transformations of these elements that may occur in real-life situations. These *simulation models* operate as thought experiments which produce qualitative inferences with respect to the situation to be mastered (Greeno 1989).

Whereas the area of learning by thinking is concerned with the construction of cognitive artifacts which serve to model the physical world, learning to think is traditionally linked with the idea of critical thinking. Due to the fact that critical thinking traditionally has been considered an important and vital topic in education, there is an abundance of guidebooks for improving critical thinking inside and outside of the classroom. A nice example from the nineteenth century is the guidebook by Abbott (1856) while good examples of current guides to critical learning are those by Cromley (2000) and Halpern (1997). Although an abundance of ideas has been generated for improving critical thinking skills, there remains a significant lack of empirical evidence that the critical thinking skills of students can be enhanced by any specific instructional method (Wolcott et al. 2002). Empirical research on critical thinking is either descriptive and focuses on student-characteristics or correlational and investigates the relationships between instruction, student-characteristics, and outcomes. After reviewing numerous studies, Wolcott et al. conclude that – due to

weaknesses in methodology – it is difficult to draw conclusions with regard to the effectiveness of treatments and educational efforts on critical thinking.

Cross-References

▶ Cognitive Artifacts, Technology and Physics Learning
▶ Critical Thinking and Learning
▶ Dynamic Modeling and Analogies
▶ Models and Modeling in Science Learning

References

Abbott, J. (1856). *The little learner. Learning to think*. New York: Harper & Brothers.

Cromley, J. (2000). *Learning to think, learning to learn: What the science of thinking and learning has to offer adult education*. Washington, DC: National Institute for Literacy (NIFL).

Greeno, J. G. (1989). Situations, mental models, and generative knowledge. In D. Klahr & K. Kotovsky (Eds.), *Complex information processing* (pp. 285–318). Hillsdale: Lawrence Erlbaum.

Halpern, D. F. (1997). *Critical thinking across the curriculum. A brief edition of thought and knowledge*. Mahwah: Erlbaum.

Heidegger, M. (1968). *What is called thinking?* New York: Harper & Row.

Lesh, R., & Doerr, H. M. (2000). Symbolizing, communicating, and mathematizing: Key components of models and modeling. In P. Cobb, E. Yackel & K. McClain (Eds.), *Symbolizing and communicating in mathematics classrooms. Perspectives on discourse, tools, and instructional design* (pp. 361–383). Mahwah, NJ: Erlbaum.

Lesh, R., & Doerr, H. M. (Eds.). (2003). *Beyond constructivism. Models and modelling perspectives on mathematics problem solving, learning, and teaching*. Mahwah: Lawrence Erlbaum.

Mariotti, M. A. (2006). Proof and proving in mathematics education. In A. Gutiérrez & P. Boero (Eds.), *Handbook of research on the psychology of mathematics education* (pp. 173–204). Rotterdam: Sense Publishers.

Mayer, R. E. (1992). *Thinking, problem solving, cognition* (2nd ed.). New York: W.H. Freeman.

Paul, R., & Elder, L. (2002). *Critical thinking: Tools for taking charge of your professional & personal life*. Upper Saddle River: Prentice-Hall.

Penner, D. E. (2001). Cognition, computers, and synthetic science: Building knowledge and meaning through modeling. *Review of Research in Education, 25*, 1–35.

Wolcott, S. K., Baril, C. P., Cunningham, B. M., Fordham, D. R., & Pierre, K. St. (2002). Critical thought on critical thinking research. *Journal of Accounting Education, 20*(2), 85–103.

Learning and Training (L&T)

▶ Learning and Training: Activity Approach

L

Learning and Training: Activity Approach

Gregory Z. Bedny[1], Hansjörg von Brevern[2],
Kateryna Synytsya[3]
[1]Essex County College, Essex, NJ, USA
[2]School of Informatics/Centre for Human Computer
Interaction Design, City University, London, UK
[3]International Research and Training Center for
Information Technologies and Systems, Kiev, Ukraine

Synonyms

Activity theory (AT); Learning and training (L&T);
Systemic-structural theory of activity (SSAT); Zone of
proximal development (ZPD)

Definition

In this chapter, we concentrate on the study of learning
and training (L&T) in relation to industrial, occupa-
tional, and professional education, and the evolution of
the human subject for system design. One of the most
important aspects in this area of study is the relation-
ship between theory and the ability to apply theory in
practice.

Theoretical aspects of learning are considered in
terms of their ability to be utilized in training. Forma-
tion of domain-specific skills and knowledge is seen as
a result of work activity, which is a product of socio-
cultural–historical development (Vygotsky 1962).
Vygotsky posited that learning precedes development
within sociocultural and historical contexts. Scientific
or theoretical concepts, which are systematically learnt
at school, exceed everyday ones, which are empirical
generalizations of individual experience. Development
takes place in a dynamic and interchangeable sphere
between everyday concepts and the application of
scientific ones; between a social, cultural, and historical
domain; the individual; and collectively relates to the
nature of human thinking, consciousness, and system-
atization. In the zone of proximal development (ZPD),
intellectual development is based on scientific con-
cepts, which can be changed and moderated with the
help of a more advanced and matured peer like a
teacher. Vygotsky's views are therefore not only suitable
for L&T but are equally valid for applied engineering
research.

Labor and mediating tools play a critical role in
mental development. The study of human labor is a
main concern in the activity-based approach. Mediat-
ing tools (e.g., signs, speech, and images) can be inter-
nal or external and are socially, functionally, and
contextually critical to a human subject. From socio-
cultural–historical angles, the relationship between
external and internal components of activity is impor-
tant for studying L&T and can be considered as the
process of internalization. This concept therefore also
plays a critical role in understanding L&T.

The sociocultural–historical context encapsulates
activity and is a fundamental ground of activity theory
(AT). The structural theory of activity (SSAT) is
applied AT with an evolution in research of more than
one century. This brief chapter will therefore inter-
changeably discuss issues from AT and SSAT
perspectives.

From the standpoint of SSAT, internalization is not
the transformation of external into internal, but rather
a changeable and dynamic interrelationship between
the internal and external in human activity (Bedny and
Karwowski 2007). More specifically, internalization is
the continuous process of a mutual influence between
internal and external activity through feedforward and
feedback loops and the gradual development of mental
components. Internal mental activity is constructed
from mechanisms of self-regulation. As such, internal-
ization cannot be reduced to separate psychological
processes and memorization in particular. It is the
very process by which the formation of internal mental
operations and actions based on mechanisms of self-
regulation is provided. Emotionally motivational
processes play a critical role in self-regulation and
mental development. All told, these facets are tightly
associated with the goal of activity, which is a cognitive
mechanism of activity regulation. Activity is therefore
"a goal-directed system, in which cognition, behavior,
and motivation are integrated and organized by
a mechanism of self-regulation toward achieving a
conscious goal" (Bedny and Karwowski 2007, p. 1).
The vector "motive(s) → goal" endows the process
of self-regulation with goal-directedness. Hence, self-
regulation is a goal-directed process in learning and
knowledge acquisition, which encapsulates conscious
and unconscious components.

Altogether, these are the theoretical perspectives
from which we consider L&T in the following that are

equally applicable and valid for formal and vocational or professional education as well as for instruction.

Theoretical Background

Comparative Analysis of Different Approaches to Learning and Training

American Psychology principally distinguishes between two main approaches to L&T: The behavioral and the cognitive based.

Behaviorism is based on laws and principles according to which learning of human and higher-order (i.e., nonhuman) animals are similar. In itself, behaviorism reduces and simplifies conscious human activity to reflexive behavior. Consequently, differences between psychology and higher-order neural activity are not distinguished. Instead, behaviorism presents a human as a passive reactor to external stimuli. These perspectives differ from AT. Pavlov's classical conditioning is considered a physiological predominantly unconscious level of learning in human beings. While operant conditioning is not considered a possible strategy to study human L&T, the mechanism of conditioned reflex is significantly reconsidered in AT. According to Anokhin (1969), a conditioned reflex should be studied as a complex self-regulative system. In AT, human activity and behavior cannot therefore be viewed as the sum of elementary reflexes. Through evolution, human psychic processes and behavior have experienced an essential reorientation because of language and consciousness. Unlike nonhumans, a human being can easily abstract from concrete situations to anticipate potential consequences of other situations and consciously interpret consecutive events. Another fundamental difference from an AT perspective between humans and nonhumans is that human beings are able to create, keep, intentionally control, manipulate, and metamorphose tools. Nonhumans may create a tool for a specific visually active situation. However, once a tool is utilized, it is then abandoned. On the other hand, a human being can plan for future events and even constitute a tool to be used to create alternative tools. If the classical conditioning in AT is considered as a possible approach to unconscious and involuntarily human L&T, the operant conditioning is considered inadequate for human L&T. The reason for this being that an AT-based approach to human L&T concentrates its efforts on the study of voluntary, conscious, and goal-directed human behavior.

Some scientists inaccurately ignored the fact that purposeful behavior and goal-directed human activity differ. In AT however, a goal always includes consciousness and the ability to interpret events. On the contrary, the basic idea of operant conditioning is simple and is based on positive and negative reinforcements, which are reduced to such methods as "give and take" that are only applicable for animals, which do not possess consciousness and the ability to interpret the situation. One can evaluate this behaviorist paradigm against practical situations. For instance, Ormrod (1990) in her textbook on learning attempts to demonstrate a possibility to utilize operant conditioning in human learning based on the following example: "Many newer cars give a loud buzzer signal if the key is still in the ignition when the driver's door is opened; removal of the key from the ignition is negatively reinforced because the buzzer stops." What happened if instead of a buzzer signal one would use beautiful music? Maybe, the driver would then leave the key and close the door so that such "key-leaving" behavior would be positively reinforced by the beautiful music. Taking the key would entail self-punishment from the behaviorist point of view. Regardless of whether one uses the buzzer or music, the issue is to make certain that the driver removes the key. Therefore, behaviorism fails to understand that the essential element in these concrete actions is the conscious goal of removing the key from the ignition. Moreover, behaviorism and likewise many other theories and models largely ignore the criticality of the human "goal," its inseparability from human activity, and over and above, have an unclear understanding of the concept of the human "goal" per se.

Now, let us consider the options under the angles of behaviorism in another example of a prisoner who is released from jail early thanks to good behavior:

(a) Positive reinforcement
(b) Classical conditioning
(c) Negative reinforcement
(d) Punishment

According to behaviorist literature, this premature release from prison is considered as negative reinforcement of proper behavior. Nonetheless, prisoners who are being released not only remove the negative stimuli of prison, but also at the same time have an

opportunity to reenter society, all of which are very powerful positive incentives. In such cases, behaviorist theories fail to capture the causal dynamics of the practical situation.

Cognitive views of learning started to dominate in psychology since the 1970s. However, the shortcomings of this approach are becoming more and more apparent particularly when L&T is largely reduced to the processes of memorization while motivational processes are not considered. Finally, cognitive learning processes are not considered in unity with external behavior. It is only the AT-based approach that can overcome these shortcomings because, as discussed earlier, activity is regarded as a goal-directed, self-regulated system that integrates cognition, behavior, and motivation.

Altogether, the activity-based approach stresses on the transition from a learner's relatively passive reception of information to his/her active participation in the course of L&T, which makes this approach particularly relevant to vocational education and training.

General Characteristics of Learning and Training from Activity Perspectives

There are two major vocational training systems. One is the "operational-complex" system of vocational training. The other is the "problem-analytical" system.

The major notions of the "operational-complex" system are single technical operations and their complexes. At the first stage of training, learners acquire isolated technical operations that are associated with skills, which are involved in the performance of separate elements of production task (i.e., the operational stage). At the final stage of training, learners perform holistic production operations or tasks (i.e., the complex stage) and learn how to perform various production operations in changing conditions.

The "problem-analytical" system is used in educating operators who regulate process control and other automated manufacturing facilities. In this system, the major training elements are not production operations but rather problem-solving tasks. First, trainees study such tasks theoretically, thereafter use simulators, and finally move on to a real production environment. So, training is organized as a multilevel process.

Leaning is considered as a self-regulated process. At the low level, learning is performed according to principles of self-regulation of conditioned reflexes. The next higher level of learning (i.e., the cognitive level) involves conscious activity, which is a goal-directed, self-regulated process. These two levels of learning are interdependent. The cognitive level involves analysis of the logical relationship between elements of situation and consequences of actions (i.e., particular ↔ general, concrete ↔ abstract, class ↔ subclass) and the functional relationship (goal ↔ tools, cause ↔ consequence, quality ↔ quantity, and actions ↔ result). In other words, we are talking about an understanding and interpretation of the relationships among objects, events, actions, consequences, and phenomena in general when and where symbolic systems play a particular role. This being the case, a designated system of symbols and various elements for an L&T situation and its operations becomes particularly important.

L&T conjoins with the sociocultural–historical theory of mental development (Vygotsky 1962). In the course of a learner operating on objects in time and space, a learner does not only discover essential but also hidden associations and relationships within a specific L&T situation. These situated operations can be performed not only externally but also internally using images and concepts.

The activity approach to L&T clearly distinguishes between mental operations or mental actions and knowledge. The ability to utilize mental operations or actions in combination with existing knowledge provides the human subject (i.e., the learner) with an opportunity to solve new and therefore previously not yet encountered problems. Correspondingly, AT adverts instruction to make a learner execute conscious instead of unconscious mental operations in situ, wherever and whenever necessary.

Training is the transformation of instruction into a learner's internal plane of self-instruction (Landa 1976). Applying AT to instruction equips learners during training with the ability for self-regulation and self-control (Bedny and Karwowski 2007). Solving a practical problem is based on the process of transformation of not only material objects but also knowledge (e.g., concepts and images) by means of cognitive operations or actions, because practical and mental actions and operations are tightly interdependent. This explains and leads to the important principle formulated by Rubinshtein, which is known as the principle of the unity of cognition and behavior.

The comprehension of the cognitive level of learning strongly differs between Western theories and AT, which envisions tight connections between human cognition, behavior, and motivation. In AT, cognition is not only a process but also as a system of cognitive actions. SSAT has brought forth a method to extract cognitive and behavioral actions, discern, and classify them. In SSAT, an associative level of learning is considered as a subordinated component of the cognitive level of learning. Associations are formed as a result of self-regulation of activity at conscious and unconscious levels (Bedny and Karwowski 2007). As a whole, this can be seen as a hierarchically organized process, which might also involve incidental learning. For example, a person who performs a certain task occasionally learns how to perform a different set of actions without voluntary effort to. Although this unpremeditated learning may, in some cases, be effective, in most cases however, premeditated (i.e., goal-directed) learning is more efficient.

Main notions used in the study of learning in AT are the task, problem-solving task, action, goal, motive, feedback, self-regulation, self-control, human algorithm, heuristics, strategies, and the like. Concepts like stimulus, response, reinforcement, and reward are rarely or not used at all in AT.

Withal, AT emphasizes on the situated character of the learning process because activity is organized and based on principles of self-regulation (Bedny and Karwowski 2007). Accordingly, knowledge and skills can only be acquired through the holistic system of human cognitive and behavioral actions. From this follows that learning is always accompanied by the doing i.e., training in time and space.

Another critical principle of L&T is individualization, which builds on the concept of individual style of performance. This recognition plays a leading role in AT.

In AT, mental development is not only a mere "knowledge-absorbing process" but encapsulates the ability of the human subject to independently acquire knowledge and skills. Their achievement utilizes principles of developmental education e.g., from discovery learning, algorithmization, internalization, the unity of cognition and behavior, and self-regulation.

Discovery learning rests on constructivism and primarily relies on a learner's "learn by doing" pursuit. Problem-solving situations require a learner to search for unknown laws, methods of actions, and applicable rules. A problem-solving task involves the discovery of the discrepancy between task conditions, a learner's knowledge, and task requirements. The mantra of discovery learning is that a learner's resolve should arise from the discrepancy between discovering new information and its practical application.

In contrast to discovery learning, Landa (1976) developed the Algo-Heuristic Theory of instruction (AHT) for problem-solving in L&T. AHT utilizes an algorithmic concept that describes human algorithmic and heuristic problems, processes, and instructions and, as such, is applicable to resolve a particular class or classes of (algorithmic or heuristic) problem-solving tasks. The critical argument behind AHT is the algorithmic and heuristic discovery and decomposition of logically and systematically organized (cognitive and behavioral) operations and actions for both L&T and instruction. The logical and systematical organization of operations and actions can be compared to flowcharts, which are very often used for L&T and instruction. In most cases, however, flowcharts fail to describe a human algorithm and thus lack the precise description of human actions. According to Landa (1976), flowcharts cannot fully and satisfactorily specify or determine the actions and operations that need to be performed by a learner. Flowcharts can be imprecise and ambiguous descriptions of a learner's performance, thereby leading to potential errors in performance by the learner. On the contrary, AHT engages in the full complement of cognitive operations and actions. AHT therefrom provides a flexible and effective description of the logical organization of cognitive operations and actions into a system that can be fully and accurately performed by the learner.

Generally, various algorithms for instruction and analysis of L&T can impose different degrees of generality. While there are some algorithms that are applicable and limited to a specific problem-solving task, other algorithms are capable of describing a more general method and can resolve a wider range of problems. Overall, both types of algorithms are therefore important tools for professional and general thinking.

With this respect, we need to distinguish between the concepts of knowledge and thinking. Knowledge circumferences a subject's mental construct of objects and phenomena, while thinking encompasses operations on knowledge. Hence, the continuous acquisition

of various types of human algorithms and heuristics shapes the general strategies of thinking.

More specifically, SSAT (Bedny and Karwowski 2007) has introduced methods of activity and strategies that describe the use of probabilistic algorithms, which in turn allow in-depth and formal studies of flexible aspects of activity. Eo ipso, SSAT not only exercises verbal but also formalized methods to delineate L&T activity at different degrees of granularity and from multiple perspectives. For example, qualitative analysis precedes an algorithmic description of a learner's activity. Moreover, SSAT embraces qualitative descriptions of strategies of learners' activity at various stages throughout L&T.

In SSAT, learning is a transformation process from less effective to more effective strategies. On one hand, the more complex the learning situation is, the more intermediate strategies will be chosen by a learner. On the other hand, the more efficient the training process is the less intermediate strategies will be adopted. A description of learning activity is carried out in terms of cognitive actions and operations that can be mental and practical. Such stage of analysis can be supplemented by cognitive analysis of activity.

The most complex aspect of an algorithmic description of a learning activity is its association with cognitive components of activity. One of the basic procedures of an algorithmic description is the breaking down of complex, unobservable cognitive processes into more elementary, yet unobservable cognitive actions or operations that could be unambiguously described by an instructor and executed by a learner at a particular stage of skill acquisition. As a matter of fact, there are no easy methods for achieving this. Landa (1976) therefore emphasized on the importance to study experts' strategies and their subsequent algorithmic description, which allows learners to acquire such strategies. However, experts' strategies are not always available to the learner without foremost using intermediate strategies at certain stages of L&T (Bedny and Karwowski 2007). With regard to this, Bedny and Landa described some qualitative techniques for analysis of possible strategies of task performance e.g., the verbal protocol, cross-examining experts and novice task performance, observation of acquisition processes, errors analysis, and uncovering encountered difficulties.

Another stance of analysis reflects on the conditions of task performance, inclusion, and elimination of particular task elements when observing novice and experts. Nevertheless, these methods do not always suffice to satisfactorily describe experts or learners' mental actions and operations in the course of problem-solving. SSAT has therefore introduced and expounded a new method that decodes eye movements, helps the discovery of mental actions and operations, and ultimately serves algorithmic descriptions (Bedny and Karwowski 2007). Altogether, this particular technique is a highly precise method to better penetrate "experts or learners' minds" during task performance.

In summary, algorithms and heuristics are instructional-based models that formally describe a logical and well-structured organization of material and subjective mental actions or operations. An in-depth knowledge of algorithms and heuristics, task performance, and cognizance of problem-solving behaviors facilitates the formation of required mental operations, which are altogether necessary for L&T. While AT has brought forth a philosophical and psychological framework, SSAT has evolved from AT and built the grounds for systemic structural principles, models, and methods of analysis for instruction and L&T.

Conclusion

From AT perspectives, the main purpose of L&T is the formation of adequate cognitive and behavioral actions, operations, and their systemic and structural organization into strategies. Such strategies are based on mechanisms of self-regulation. In this regard, not only cognitive and behavioral actions and operations but also motivational processes are important. Motivation is directly involved in forming cognitive strategies during L&T processes. While AT does not deny the role of associations, it regrettably fails to reduce L&T processes to such mechanisms. However, associations are considered as a result of an active self-regulative process that cannot be reduced merely to pairing stimulus and response in time or space. Associations are thus often a result of an automated, unconscious, and self-regulative process. However, the activity of self-regulation during L&T is mainly goal directed and includes both conscious and unconscious levels. The more complicated acquired skills and knowledge are, the more intermittent strategies are developed during self-regulative processes.

Based on the principles of AT, theories of L&T are intimately related to cognitive psychology, but at the

same time AT focuses not only on stages of information processing and its reorganization in memory but also on goal formation and motivation, on determining content of each action, and strategies of performance. Consequently, L&T is treated as a nonlinear, recursive process and, in particular, special attention needs to be paid to the thinking process of the individual human subject.

A combination of the discovery of L&T and algorithmization, self-regulation, and interdependence of external and internal activity is the base to realize and develop education principles.

Important Scientific Research and Open Questions

To develop L&T systems, we need a better understanding of task requirements of the L&T activity because analogous activities mutually affect each other.

We posit that methods from SSAT provide us with a better formal understanding of system requirements for modular content, requirements from dynamic strategies of probabilistic algorithms, and requirements that result from the ZPD between the roles of a learner, a more mature peer, and an L&T system. Moreover, the aspect of development coupled with the extended views of the ZPD gives rise to rethinking how to design help systems coupled with the learning curve of complex computer-based systems.

Moreover, the accord of informal tasks is difficult when we do not have an elucidate picture of the object of study. However, this deficiency is not uncommon in organizational environments. Therefore, if we want to ameliorate organizational performance, we need to know the precise foci on objects of study. Its tasks are then subject to task decomposition (von Brevern and Synytsya 2006).

Cross-References
▶ Activity Theories of Learning
▶ Cognitive Self-Regulation
▶ Constructivist Learning
▶ Sociocultural Research on Learning

References
Anokhin, P. K. (1969). Cybernetic and the integrative activity of the brain. In M. Cole & I. Maltzman (Eds.), *A handbook of contemporary soviet psychology* (pp. 830–856). New York/London: Basic Book Publishers.
Bedny, G., & Karwowski, W. (2007). *A systemic-structural theory of activity: Applications to human performance and work design.* Boca Raton: Taylor & Francis.
Landa, L. M. (1976). *Instructional regulation and control: Cybernetics algorithmization and heuristics in education.* Englewood Cliffs: Educational Technology Publication.
Ormrod, J. E. (1990). *Human learning theories, principles and educational applications.* New York: Macmillann.
von Brevern, H., & Synytsya, K. (2006). A systemic activity based approach for holistic learning and training systems. *Educational Technology & Society, 9*(3), 100–111 (Special issue on next generation e-learning systems: Intelligent applications and smart design).
Vygotsky, L. (1962). *Thought and language.* Cambridge: MIT Press.

Learning and Understanding

Gabriele Kern-Isberner
Department of Computer Science, TU Dortmund, Dortmund, Germany

Synonyms
Acquiring and using (generic) knowledge

Definition
Learning is a crucial prerequisite for intelligent behavior in that it enables agents or actors to react adaptively to their environment and to make successful use of their experiences. Understanding goes beyond learning, as it requires the agent/actor to see through superficial similarities and analogies, and to challenge what he or she is being told. While an agent/actor may learn simply by mimicking a behavior that he or she evaluated to be successful, an understanding agent/actor would *know why* he or she expects a decision to be successful, and would be able to *explain* what he or she observes. So, in order to perform learning it might be enough to adopt *factual, situation-based knowledge*, whereas understanding aims at acquiring and using *generic knowledge*, in particular *causal and conditional knowledge* that may establish links between isolated pieces of information.

Theoretical Background
In artificial intelligence (AI), learning has been extensively studied in the area of machine learning which is

not only concerned with the problem of making computational systems adapt new knowledge but also with strategies and techniques to support human learning and understanding (Michalski et al. 1983). Indeed, most learning methods in AI aim at extracting generic knowledge from factual data in order to provide the human user with intelligible connections that help him or her understand the problem domain under consideration, or maybe even the world. For example, decision tree learning returns graphical models that present such connections in a catchy way, and concept learning generates abstract logical descriptions of observed phenomena. The inductive nature of such computational learning methods makes proper generalizations possible and therefore supports the transition from factual, situation-based information to generic knowledge.

Logic plays a major part for learning and understanding, as it offers broad and powerful frameworks not only to describe and represent what has been learned, but also means to express and use generic knowledge. However, the term *logic* goes far beyond propositional and first-order predicate logic here and includes such approaches as default logics, causal and conditional logics, probabilistic logics, and other forms of commonsense logics. In particular, these latter ones (that usually build on classical logics) are of principal importance for understanding the real world as they allow for dealing with uncertain and incomplete information. Most of our knowledge on the real world is uncertain and incomplete, and subject to change. Even solid statements like "Water boils at 100°C" are only quite a good approximation to what holds in the real world, but not certain knowledge, as they depend on local conditions like the level of elevation.

Uncertainty and incompleteness pervade human knowledge about the world, and although strict rules like classification rules help us to order our information and provide basic insights, a deeper understanding can only be provided by more flexible structures. Conditional statements like "If A then B" have proved most adequate to encode such flexible links of a very generic nature (Nute and Cross 2002). Human beings make vast use of conditionals in their everyday lives, but also scientific knowledge is often based on (axiomatic) systems of conditional statements. Conditionals can be taken as qualitative entities, like in default logics (Russell and Norvig 2003), or be annotated with quantitative information, like in probabilistic logics

(Pearl 1988). So, learning can only lead to understanding if the aim of learning is to extract and adopt conditional structures from given information.

More sophisticated approaches to learning can be obtained when prior knowledge of the user has to be taken into account when adopting new information. Dealing with such problems is the major topic of *belief revision*, an area that has emerged from philosophy and artificial intelligence (Hansson 1999). Such kind of learning is particularly interesting in the realm of learning and understanding, as it may enhance an understanding of the world that is actually present in an agent/actor by incorporating more and refining information. Hence, belief revision aims at improving understanding by further learning.

Finally, understanding can be used to *explain* the phenomena observed in the world, or to *justify* decisions. This is a crucial feature of rational agents/actors that they may apply to optimize their behavior. Moreover, explanations can also be communicated between agents/actors and may initiate learning (and understanding) processes in other agents/actors. *Argumentation theory* investigates the art of coming up with conclusive explanations (or even more general statements) that hold out against dialectical, attacking statements (Besnard and Hunter 2008). So, while conditional rules may provide the basic building blocks for understanding, argumentation theories indicate ways of using such rules successfully in argumentative structures to obtain an evaluable picture of the world.

Important Scientific Research and Open Questions

The major challenge in the field of learning and understanding is to study the connections between all disciplines mentioned above and further disciplines from philosophy and psychology in order to design a comprehensive picture of human learning and understanding. Although unifying approaches between different disciplines are most intensively investigated, the current research does not aim at coming up with a unique optimized approach. Rather the diversity of methods and views is most appreciated, and the comprehensive picture should contain as many of these different facets as possible. Nevertheless, unifying structures are searched for on a deep, methodological level so that coherence of approaches can be shown while not touching their characteristics. From a more

pragmatic point of view, cross-fertilizations between various disciplines are expected to provide a better understanding and further enhancement of methods.

Topics of current research work are, for instance, the connection between machine learning and logic, in order to improve the understandability and usability of outcomes of machine learning processes. Another very active domain of research is to investigate cross-fertilization between belief revision and argumentation theory, on the one hand, and between belief revision and learning approaches, on the other. Finally, the nature and role of causal reasoning which pervades all mentioned disciplines has been a major topic of research at least for decades, if not centuries.

Cross-References
► Abductive Learning
► Abductive Reasoning
► Argumentation and Learning
► Concept Learning
► Conditional Reasoning
► Default Reasoning
► Human Causal Learning
► Human Information Processing
► Inductive Reasoning
► Logical Reasoning and Learning
► Machine Learning

References

Besnard, P., & Hunter, A. (2008). *Elements of argumentation.* Cambridge, MA: MIT Press.

Hansson, S. O. (1999). *A textbook of belief dynamics.* Dordrecht: Kluwer.

Michalski, R. S., Carbonell, J. G., & Mitchell, T. M. (Eds.). (1983). *Machine learning: An artificial intelligence approach.* Palo Alto: Tioga.

Nute, D., & Cross, C. B. (2002). Conditional logic. In D. M. Gabbay & F. Guenther (Eds.), *Handbook of philosophical logic* (2nd ed., Vol. 4, pp. 1–98). Dordrecht: Kluwer.

Pearl, J. (1988). *Probabilistic reasoning in intelligent systems.* San Mateo: Morgan Kaufmann.

Russell, S., & Norvig, P. (2003). *Artificial intelligence – A modern approach* (2nd ed.). New Jersey: Prentice Hall.

Learning Approaches

► Learning Styles

Learning as a Side Effect

Joost Breuker[1], Stefano A. Cerri[2]
[1]Leibniz Center for Law, Universit of Amsterdam, Amsterdam, the Netherlands
[2]Montpellier Laboratory of Informatics, Robotics, and Microelectronics (LIRMM), Montpellier, Cedex 5, France

Synonyms
Implicit learning; Incidental learning; Informal learning; Unconscious learning; Unsupervised learning

Definition
All learning processes are autonomous processes whose nature and content is dependent on activities and experiences. From a psychological perspective, learning ths the side effect of activities and experiences.

Theoretical Background
From a psychological perspective, all learning is the side effect of activities; whether these activities are undertaken with the intention to learn or not, i.e., learning *is* a side effect. We may be able to control what activities are undertaken, but we have no direct control over the learning processes themselves. (There is a growing doubt whether we really have control over our cognitive processes in general. Strong evidence for the fact that conscious control may be an illusion can be found in Wegner [2002].) These learning processes are autonomously active, storing information and association. *What* will be learned is dependent on the kind of activities – problem solving, interpreting discourse, experiencing events, etc. – and its semantic content. Three kinds of basic learning processes are accountable for our learning, and all three operate in parallel with our activities and experiences. They are in the first place identified by the kinds of information they select, store in, and retrieve from long-term memory.

1. Episodic memory allows us to remember events which are time/place dated and are viewed as records of occurrences (instances).
2. What we have understood may give rise to the acquisition of new concepts and the correction of misconceptions. These knowledge structures, consisting of generic concepts which are meaningfully related, are maintained in "semantic memory."

3. Associative patterns that link regularly co-occurring structures reflect the acquisition of skills. These associations constitute some associative memory.

The distinction between memories of events and semantic structures, i.e., between *episodic* and *semantic* memory in psychology is well known (for an overview see Tulving 1991). However, where episodic and semantic information keep links within their own structures, associative links appear to be made between contingent experiences and are "reinforced" by repetition, recognition, and attention.

This view of learning as consisting of autonomous processes and as the side effect of other controllable mental activities does not play an explicit role in educational learning theories (see http://tip.psychology.org/ for an overview of about 50 of these theories). Educational learning theories are not theories that model the learning processes themselves (see below), but describe or prescribe the content and nature of the learners' activities, and thus indirectly influence the effectiveness of learning, i.e., these theories are about the conditions for learning. In this context, the effects of these autonomous learning processes become more directly observable when there is no explicit intention to learn. Intentional learning is then contrasted with "incidental" (implicit, unconscious) learning. Intentions may be explicitly, institutionally formalized in an educational setting. This "formal" learning is contrasted with "informal learning"; the latter being strongly associated with incidental learning (for a review of research on formal versus informal learning, see Sefton-Green (2004)). The differences in effect between incidental learning and intentional learning are due to the focusing on specific content and/or the accumulations (or reinforcements) due to repetition in the latter condition. Because incidental learning lacks this planning of activities (and a related organization of the environment), its results are diffuse and less predictable (and therefore hard to measure). A meta-analysis of about 30 experiments shows that the amount of learning is the same in an incidental versus intentional paradigm, but – as to be expected – in the incidental condition, less "goal-related" information is retained (Klauer 1984). The same basic learning processes are playing roles in intended learning and in incidental learning.

Important Scientific Research and Open Questions

Most research on incidental learning has been performed between the 1960s and 1980s, in particular in the context of vocabulary learning of first and second language (McLaughlin 1965), (McLaughlin et al. 2006). More recent research on "implicit" learning has been focused on semantic memory (also using neural evidence) (Smith 2008) and text understanding (McGeorge 1990). A serious problem in empirical research that aims at showing similarities between incidental and intentional learning is the fact that in a "pure" incidental learning setting no test can be designed before the activities are performed and experienced. Therefore, a test to measure learning results cannot be the same for incidental learning as for intentional learning. This may explain the fact that interest in "incidental" learning is rather low in educational research, despite the fact that it accounts for the bulk of the knowledge and skills we have acquired in life. It should be noted that new media, in particular the Web, are rather evaluated in the context of formal and intentional learning (e.g., in distance education, but also in "serious games" settings) than in the informal and "incidental" learning opportunities these media provide.

Cross-References

▶ Adaptation and Unsupervised Learning
▶ Autonomous Learning and Effective Engagement
▶ Incidental Learning
▶ Informal Learning

References

Klauer, K. J. (1984). Intentional and incidental learning with instructional texts: A meta-analysis for 1970–1980. *American Educational Research Journal, 21*(2), 323–339.

McGeorge, P., & Burton, A. M. (1990). Semantic processing in an incidental learning task. *The Quarterly Journal of Experimental Psychology, 42A*, 597–609.

McLaughlin, B. (1965). Intentional and incidental learning in human subjects: the role of instructions to learn and motivation. *Psychological Bulletin, 63*, 359–376.

McLaughlin, B., Rossman, T., & McLeod, B. (2006). Second language learning: an information processing perspective. *Language Learning, 33*, 135–158.

Sefton-Green, J. (2004). Literature review in informal learning with technology outside school, NESTA FUTURELAB, report 7, www.nestafuturelab.org/research/reviews/07_01.htm.

Smith, E. E. (2008). The case for implicit category learning. *Cognitive, Affective & Behavioral Neuroscience, 8*, 3–16.

Tulving, E. (1991). Concepts of human memory. In L. Squire, G. Lynx, N. M. Weinberger, & J. L. McGaugh (Eds.), *Memory: Organization and locus of change* (pp. 3–32). Oxford: Oxford University Press.

Wegner, D. (2002). *The illusion of conscious will*. Cambridge, MA: Bradford Books/MIT Press.

Learning as Effective Action

Learning as Meaning Making

Tania Zittoun[1], Svend Brinkmann[2]
[1]Institute of Psychology and Education, University of Neuchâtel, Neuchâtel, Switzerland
[2]Department of Communication and Psychology, Aalborg University, Aalborg, Denmark

Synonyms

Meaning construction; Sense-making

Definition

"Meaning making" designates the process by which people interpret situations, events, objects, or discourses, in the light of their previous knowledge and experience. "Learning as meaning making" is an expression emphasizing the fact that in any situation of learning, people are actively engaged in making sense of the situation – the frame, objects, relationships – drawing on their history of similar situations and on available cultural resources. It also emphasizes the fact that learning involves identities and emotions.

Theoretical Background

To learn something means to acquire knowledge, skills, or dispositions that enable the learner to act, think, and feel in ways that are recognized as important by oneself or others. A number of significant educational, psychological, and philosophical perspectives have emphasized the idea that learning in this sense is best conceived as meaning making. These perspectives include cultural-historical psychology, pragmatism, constructivism, and social constructionism. According to these perspectives, to learn something means to establish a meaningful relation to the subject matter so that it makes sense to the learner. Learning to read means learning to see the letters as forming meaningful sentences, and learning to play house means learning the overarching system of meanings that involves a mother, father, children, and cultural ideas about the family. If learning is not conceptualized in mechanical terms and extended to such things as computers and machines, then it seems that there is an element of meaning making in most if not all processes of learning.

If learning involves meaning making, we need to address that which is made, that is, meaning. In a minimal sense, human action, thought, or cultural products are considered meaningful when they cannot be adequately described in purely physical terms. Thus, the same physical movement of a human eye, a wink for example, can express different meanings (flirtation, a signal of conspiracy, etc.) depending on the purpose and context of the wink. But the meaning of the movement cannot be found in its physical properties as such.

In this sense, meaning involves two aspects: intentionality and normativity. Intentionality is sometimes called "aboutness" and signifies the fact that things that are meaningful extend beyond themselves by referring to or pointing to something else. The wink of the eye is meaningful because it is a signal, and the letters on this page are meaningful because they are about certain theories of learning. Normativity refers to standards of correctness, which is to say that meaningful actions are subject to normative appraisal. A wink can only be meaningful because there are more and less correct ways of using this sign, and letters, words, and sentences are meaningful because there are right and wrong ways of using language.

This view of meaning, as a composite of intentionality and normativity, is related to both classic and contemporary theories of the mind in social and cultural psychology. In *Democracy and Education*, Dewey came close to defining mental phenomena in terms of meaning, for instance in the following quote: "The difference between an adjustment to a physical stimulus and a *mental* act is that the latter involves response to a thing in its *meaning*; the former does not." (Dewey 1916, p. 29). Nothing, for Dewey, has meaning in itself, but only on the background of a larger social practice,

which accentuates the importance of context in understanding anything meaningful (and psychological). In *Acts of Meaning*, Bruner (1990) argues that we cannot understand human beings without understanding how experience and action are formed by the mind, and we cannot understand the mind without taking cultural systems of meaning into account.

We propose to distinguish between three levels of meaning (semantic, pragmatic, and existential) all of which are relevant in relation to learning:

1. *Semantic meaning* concerns the meaning of language, signs, and symbols. Acquiring an understanding of the world involves establishing conceptual relations to the world, and this is a process of meaning making that predominantly takes place in social situations. Dewey observed the following in *Democracy and Education*: "the sound h-a-t gains meaning in precisely the same way that the thing "hat" gains it, by being used in a given way." (Dewey 1916, p. 15). The child learns the semantic or conceptual meaning of the sound "hat," because the sound is part of certain activities that involve this object. This context is social, for "the thing and the sound are first employed in a *joint activity*, as a means of setting up an active connection between the child and a grown-up." (p. 15). On a semantic level, learning as meaning making involves being socialized into cultural-discursive systems of meaning. This idea was further developed by Vygotsky (1986) in his reflection of the relationship between language and thinking: Meaning making appears as the process by which socially given and shared words organize thinking and how thinking gives life to words. Vygotsky's work has also highlighted the tension taking place between the socially shared meaning of a word and the more subjective sense it can acquire for a person, in a given place and moment.

2. *Pragmatic meaning* concerns the social practices of a culture. Culture is comprised of social practices that are constantly performed and reconstructed, and learners must acquire the capacity to participate adequately in these social practices. A useful analytic approach to these processes is found in studies of situated learning and apprenticeship (Lave & Wenger) and cultural approaches to apprenticeship in thinking (Rogoff). Building on anthropological studies of tailors, midwives, and other forms of activity in social practice, such studies suggest that learning involves acquiring an identity in a given community of practice. Thus, newcomers to a practice will begin at a peripheral position in the community of practice, but if they see a meaningful trajectory ahead of them, and if their activity is acknowledged by others, they will often be able to work hard to attain a more central position. The basic idea is that meaning motivates, and that there is a process of meaning and identity construction in any complex form of learning.

3. Finally, we will point to an *existential level* of meaning making in learning. Here, learning is considered as located within a person's life trajectory, and, as it is often triggered by situations of rupture or uncertainty, it might question or reshape his or her whole perspective on her past and future possibilities – that is, a life-meaning. This existential aspect has been emphasized in studies in adult learning (as in Mezirow's transformative learning). From a semiotic perspective, meaning making can also designate the processes by which emotionally laden life experiences acquire a semiotic shape, which makes them thinkable and communicable. As such, these processes contribute to, or impede, the actual processes of learning about an object, others, or the world (see for instance Zittoun, in press, 2011).

Important Scientific Research and Open Questions

The idea of learning as meaning making has been very useful in deepening our understanding of teaching–learning dynamics. Current studies have used it to deepen three main lines of inquiry: The first describes and analyzes teaching–learning settings; the second develops didactic means to improve these; and the third aims at improving theoretical understanding of thinking.

Current descriptions of the teaching–learning situation identify parameters that contribute to the learner's meaning making processes (see Perret-Clermont et al. 2004). First, studies have identified aspects of the *frame* of the teaching–learning activity – the didactic contract, the shared definition of the situation – that guides the learner's meaning making. Mediating artifacts, such as tools, books, and new technologies, also support and shape these meanings.

Second, other studies emphasize the processes of negotiation of intersubjectivity and the construction of shared understanding. Third, some researches insist on the role of the subjectivity of learners, which, depending on personal histories and sociocultural trajectories, might shape meaning making processes in learning situations (Rochex 1998). One of the questions recurrently emerging from such studies is that of the generality of meaning making: If learning depends on meaning making, and the latter is situation-specific, how is it possible to use knowledge developed in a given situation in another one? Is learning through meaning making more likely to take place when learning and teaching settings look similar to everyday situations?

Other studies use the idea of learning as meaning making to solve a pragmatic question: How to improve learning conditions? These tend to focus on the development of means that might support or mediate adequate meaning making: Computer software likely to give an everyday or playful flavor to school tasks; strategies that facilitate learners' capacities to listen to others' arguments and to formulate one's own, as in current research on argumentation; forms of mediation that might facilitate externalization of thinking and affect, and subsequent reflectivity through verbal elaboration, such as in techniques of life story in adult education, etc.

Theoretical advancement is based on the idea of learning as meaning making is deeply linked to authors' specific understandings of "meaning." In the field outlined here, open questions include: What are the psychological processes by which meaning making takes place? If, as some authors admit, meaning making requires "relating" discrete experiences, what are the modalities of these relationships (e.g., analogies, metaphors, reasoning by proximities, etc.)? If personal sense and socially shared meaning can be differentiated, how can these processes and their mutual relationship be described? If meaning making is a way of turning new or uncertain experiences into a person's self-narrative, by which processes does it occur? More generally, the emphasis on meaning making has tended to background classical questions related to the nature of reasoning and thinking (such as in Piaget). However, if it has been a step forward to show that a learner can solve a mathematical problem only if he or she has conferred meaning to it (see two points above), it might not be enough to account for the actual processes of reasoning involved. If this is so, how can we describe the relationships between processes of meaning making and other processes of arguing, reasoning, etc.?

Cross-References
► Adult Learning/Andragogy
► Argumentation and Learning
► Bruner, Jerome S (1915-)
► Communities of Practice
► Dewey, John (1858–1952)
► Identity and Learning
► Jack Mezirow on Transformative Learning
► Meaningful Learning
► Piaget, Jean (1896–1980)
► Socio-cultural Research on Learning
► Vygotsky, Lev (1896–1934)

References

Bruner, J. S. (1990). *Acts of meaning*. Cambridge: Harvard University Press.

Dewey, J. (1916). *Democracy and education. An introduction to the philosophy of education*. New York: Macmillan.

Perret-Clermont, A.-N., Carugati, F., & Oates, J. (2004). A socio-cognitive perspective on learning and cognitive development. In J. Oates & A. Grayson (Eds.), *Cognitive and language development in children* (pp. 303–332). Milton Keynes/Oxford: The Open University & Blackwell Publishing.

Rochex, J. (1998). *Le sens de l'expérience scolaire*. Paris: Presses universitaires de France.

Vygotsky, L. S. (1986). In A. Kozulin (Ed.), *Thought and language*. Cambridge: MIT Press.

Zittoun, T. (in press, 2011). Lifecourse. In J. Valsiner (Ed.), *Handbook of culture and psychology*. Oxford: Oxford University Press.

Learning as Natural Process

► Natural Learning in Higher Education

Learning at Play

NEGIN DAHYA
Faculty of Education, York University, Toronto, ON, Canada

Synonyms

Education; Games; Ludology; Play

Definition

This section on "learning at play" will discuss the importance of play in the process of learning and education. "Play" can be described as a wide range of activities defined by the engagement of the subject in procedural, semi-structured, and/or unbounded activities. Examples of play include role play (e.g., "make-believe," theater) and the creative restructuring of existing physical or conceptual spaces (e.g., design, puzzles). People also "play" with ideas, reconfiguring knowledge to alter experiences and perceptions of the world. Children, in particular, engage in playful activities to familiarize themselves with the rules and regulations of their local and global environments. Though often associated with leisure and amusement, play can be serious, competitive, and creative and has an important role in the development of society and culture (Caillois 1961; Huizinga 1960). All play (for children and adults) is metaphor: competitive sports, children's games, ceremonial and religious rituals, videogames, and playful engagements with art, scholarship and design reflect complex sociocultural significance beyond the acts of play themselves (Huizinga 1960). Learning at play occurs as a result of players' interactions with activities or tasks during which time knowledge, identity, community, and skill are developed alongside the rules of engagement.

Theoretical Background

Research in the field of videogames for education offers a clear, accessible way to understand the relationship between learning and play. "Learning through play can be a meaningful experience for players because they can subjectively interpret the multimodal procedures that create a game as they relate specifically to the player's preexisting 'real-world' knowledge" (Crawford 1982). Games and play provide safe ways to experience, to some extent, something that might otherwise not be experienced in the physical world.

There is a close relationship between play and games. All games are "closed formal systems" with "two-sided representational relations" (Crawford 1982). The structure of the game world does not change because it is preprogrammed into the game's design. At the same time, the relationship between the player and what is represented in the game is subjective. Although other forms of play may be less structured than most games, the relationship of representation between

subject and any form of play is similar to what occurs in games: the player's experience is based on a combination of the decisions the player makes and her preexisting knowledge; human imagination works with playful choices to mix the representational lines between the "real" and imaginary. As a result of the player's engagement with the play system, the experience of play is meaningful even if the game/play world is make-believe. It is precisely because play is make-believe that it provides "safe" spaces in which the player can make (right or wrong) choices and experience the consequences of those decisions without permanency (though not without affect). In most forms of play, players can *try* over and over again until they get it right. The same cannot be said for actions in the real world, despite a common understanding that as humans, we so often learn from our mistakes.

The value of learning at play is recognized by contemporary game theorists who assert that it is possible to tell stories through the virtual worlds of videogames with real effects on game players, to explore and develop identities through avatars, to read cultural rhetoric through games, and to use videogames for the purpose of education in formal and informal settings. Various forms of literacy are explored by game players as they read instructions, communicate with other players, and discover new ways of engaging with game/play worlds. These assertions all point to one important element of learning at play, referred to as "situated meaning," "situated cognition," "situated learning," or meaningful play: immersed in virtual or physical play environments, the player makes choices related to her own experience and preexisting knowledge, implicitly (if not explicitly) finding meaning and relevance to her own life and interests. Learning can occur through experience, interaction, game design, and/or playful engagement, and may be more contextualized in play compared to the so often decontextualized "fact" based structure of prescribed education. Rather than learning information mandated by an educator, play creates space for learning to occur organically and interactively; players' master one level or mode, which contributes to the desire to play more and, as a consequence, to learn more. Even in unstructured play settings, the learner is practicing a skill or engaging with knowledge toward the goal of mastering how to enact that role. During the play experience, the player is autonomous in her role enactment and learns through the direct consequences of her actions in the game.

Discussions around meaningful learning in situated contexts are not new. In the early twentieth century, Jean Piaget explored how play contributed to children's ability to make sense of the world around them, concluding that children develop an understanding of the world through active engagement (by *doing*). Piaget diverged from the idea that learning only occurs in formal educational settings and instead questioned how meaningful experiences contribute to personal and intellectual growth. Around the same time, Lev Vygotsky also explored the question of how children learn. For Vygotsky, personal and social experiences could not be separated and the experience of living was shaped by family, community, class, education, culture, etc., with playful interaction acting as a major component of knowledge construction across these sociocultural spaces. Piaget and Vygotsky's ideas are foundational to the development of contemporary theories of learning at play.

Important Scientific Research and Open Questions

Contemporary videogame and educational scholars are exploring how games and play, particularly in their electronic and online varieties, are and can be used for education. In many cases, existing games and game world communities are being studied to better understand how and why they are such popular play spaces and what kinds of social and cognitive learning is underway during the play process. Massive multiplayer online games (MMOGs) such as *EverQuest* exemplify how situated learning can extend beyond the game world into a culturally relevant social practice with a community of learners/players (Steinkuehler 2004). Studies of MMOGs demonstrate how game players, who are often seemingly uninterested in formal "learning," engage in reading, writing, and various game-related challenges of their own accord. In addition, socialization and critical discussion about game worlds are abundant in online MMOG communities (Steinkuehler 2004). The role enacted by players online is complex and closely related to their engagement with other people, popular culture, and other physical-world realities in which learning takes place.

Another example of current uses of games/play for learning includes the use of strategy games in formal education. One example is the game *Civilization*, which gives players the opportunity to develop their own

civilizations through diplomacy, discovery, development, war, and colonization. This game replicates historical patterns and by playing *Civilization* students experience history instead of memorizing decontextualized and often limited curricula (Squire and Jenkins 2003). Although a game such as *Civilization* may not "teach" students about "the history" of the world (as though there were only one), gameplay allows players to learn about the progress of civilization over time through their own construction of a make-believe environment (Squire and Jenkins 2003). MMOGs and games such as *Civilization* demonstrate how games are inherently educational and engage students in playful roles for the purpose of education. As this reality about the educational value of games becomes more widely accepted, designers, researchers, and educators are working to develop games for education that meet curricular requirements.

To approach learning at play more broadly, other recent studies have exposed important identity and gender inequities surrounding technology and education. One study suggests that the seemingly gendered divisions in the "boy-culture" of the videogame world are very much the result of girls not having access to game consoles (Jenson and de Castell 2008). In this case, access to play impacts student engagement with technology, in a world where access to technology is an indicator to students' choice to pursue information and communications technologies and science-based professions. Interestingly, given the opportunity, the differences in children's desire to play, which are frequently (still) attributed to gender, emerged in this study as differences related to novice versus expert skill levels. Differences in play styles and time spent at play was largely attributed to accessibility to consoles and free time for children to play at home, where girls were still expected to do more housework and were generally only given chances to play videogames when their male siblings and other male family members were not playing. Given the chance to play console-based videogames in an after-school club, girls developed an interest in gameplay and demonstrated attributes typically associated with their male peers, such as competitive play (Jenson and de Castell 2008). "Learning" here goes beyond curriculum and addresses, on a broader scope, the social and gender relations shaping the lives of children and the future career options they have, paved in many ways from the social roles children play starting in childhood.

As this interest in the educational function of games and play grows, there are a multitude of questions researchers are looking to answer: How do we harness the power of play for education? What are the implications of learning in virtual environments and through online role-play games? How do we understand questions of individual identity as they are portrayed and experienced at play in the digital and physical world? What are the learning outcomes of game production versus consumption? To what extent can role-play and gameplay engage players/learners in "serious" experiences and with social and political content? How much does play need to be scaffolded to be effective and how should this scaffolding occur (i.e., within game design, by teachers/educators or parents)? What is the evaluation process for understanding the impact of play (and do we need one)? These are but a few of the questions under consideration in the area of learning at play.

Cross-References

References

Caillois, R. (1961). *Man, Play and Games* (trans: Barash, M.). New York: Free Press.

Crawford, C. (1982). *The art of computer game design.* Vancouver: Washington State University Press.

Huizinga, J. (1960). *Homo ludens: A study of the play-element in culture.* Boston: Beacon.

Jenson, J., & de Castell, S. (2008). Theorizing gender and digital gameplay: Oversights, accidents and surprises. *Eludamos, Journal for Computer Game Culture, 2*(1), 15–25.

Squire, K., & Jenkins, H. (2003). Harnessing the power of videogames in education. *Insight, 3*, 5–33.

Steinkuehler, C. A. (2004). Learning in massively multiplayer online games. In Y. B. Kafai, W. A. Sandoval, N. Enyedy, A. S. Nixon, & F. Herrera (Eds.), *Proceedings of the sixth international conference of the learning sciences* (pp. 521–528). Mahwah: Erlbaum.

Learning Attitude

Learning Beyond the Classroom

Learning Blockage

Learning by Acquaintance

Learning by acquaintance refers to the process of acquiring knowledge through perceptual observation, in contrast with learning through description.

Learning by Chunking

Stephen B. Fountain, Karen E. Doyle
Department of Psychology, Kent State University, Kent, OH, USA

Synonyms

Abstraction; Concept formation; Grouping; Information processing; Learning by recoding; Mnemonics; Parsing; Rule learning; Sorting

Definition

Learning by chunking is an active learning strategy characterized by *chunking*, which is defined as cognitive processing that recodes information into meaningful groups, called *chunks*, to increase learning efficiency or capacity. Chunks of information are generally composed of familiar or meaningful sets of information that are recalled together. In this way, the organism is able to decrease the amount of information that must be held in working memory by increasing the amount of information per chunk. Learning by chunking increases working memory capacity by reducing memory load and facilitates acquisition or recall by organizing long-term memory for information in perceived stimuli, motor sequences, or cognitive representations. Chunking also extends the ability to recognize or recall

information or perform tasks at a later time. Common learning strategies involving chunking processes include learning by employing mnemonics such as forming acronyms or acrostics, grouping of digits in a phone number, or using the method of loci. Other forms of learning by chunking include concept formation, rule learning, and other forms of abstraction.

Theoretical Background

George Miller (1956) adopted the term *chunk* as a cognitive term in his influential paper entitled, "The magical number seven, plus or minus two: Some limits on our capacity for processing information." Learning by chunking is the idea that animals and humans process information cognitively instead of simply learning the characteristics of the stimuli they are presented. That is, they recode familiar information into chunks which can be represented in memory more efficiently than maintaining the information as it was originally experienced. When presented with sets of unidimensional information to remember (such as a variety of light wavelengths or tone frequencies), human capacity in short term or working memory tasks appeared to Miller to have a limited capacity of approximately seven pieces of information. However, this limitation could be overcome when elemental information was recoded into chunks. Miller believed that chunking increased memory capacity because capacity was dependent on the number of chunks instead of the total number of items making up the chunks. An example of this process given by Miller is that of a person initially learning Morse code. Early in acquisition, each *dit* and *dah* is maintained individually in memory. As the information becomes more familiar, however, several dits and dahs can be organized into letters and then later into words and phrases.

Simon (1974) questioned how much information can be represented in a single chunk. Because information is diverse in type and dimensionality (e.g., digits, words, syllables, colors, directions), Simon sought to determine the capacity of memory in short term and working memory tasks as well as the capacity of individual chunks. To demonstrate chunk size and the importance of organization, for example, Simon (1974) offered this list of words to be remembered: "Lincoln, milky, criminal, differential, address, way, lawyer, calculus, Gettysburg." It is generally rather difficult to recall randomly associated words when listed in this way, but when organized into more familiar chunks the list of seven words may be organized into four chunks:

- Lincoln's Gettysburg Address
- Milky Way
- Criminal lawyer
- Differential calculus

Organized in this manner, the information is learned quickly and recalled with ease. These chunked phrases, however, are also limiting when more information is added within the phrase. Where one may easily remember multiple two word phrases, recall of larger sentences limits the amount of chunked sentences that can be recalled. However, under proper training conditions and with practice, more and more information may be added via chunking, and memory capacity in short term or working memory tasks can be increased to a remarkable degree (Ericsson et al. 1980).

Another general type of recoding in chunking seems to be common, namely, recoding by rule learning. For example, some kinds of sequentially presented stimuli are thought to encourage learning by chunking, those with *structure*. The defining property of such a sequence, known as a *serial pattern*, is the ordinal or interval nature of an *alphabet*, or ordered set or dimension of stimuli, from which the elements of the sequence are drawn (Jones 1974). Most generally, an alphabet consists of a set of stimuli which (1) are discriminable from one another and (2) have the properties, at a minimum, of an ordinal scale (Jones 1974). This means that the elements of a serial pattern are all drawn from the same stimulus dimension and that they are related in some quantifiable way, for example, some elements of the pattern are larger or smaller, brighter or dimmer, more to the left or right, greater than or less than others. The elements of serial patterns are quantitatively different, and can thus be related to each other by quantitative descriptions such as "greater than," "less than," "+1," or "1." These kinds of quantitative descriptions are one kind of rule that the learner can use to encode information about the pattern beyond the qualitative identity of each list element. Also, some instructional descriptions, such as "alternate," "repeat," "reverse," or "transpose" may be used as rules to describe the relationships of whole subsets of pattern elements. A *rule*, then, is a principle for establishing a relationship among the elements of a set of stimuli,

a set drawn from an alphabet in the present case. The view that serial patterns of stimuli may be built by the action of rules operating on alphabets has been developed earlier in several detailed, related theoretical forms.

Formal structure is a systematic relationship or set of relationships among rules relating pattern elements, such as the repeated occurrence of a single rule or of a set of rules always found in the same order. Rules that relate pattern elements are called lower order rules. In addition, because some sets of rules recur or can be derived from earlier sets, they may be summarized by higher order relational rules. Rules that relate whole sets of rules, and thus whole sets of pattern elements, are called higher order rules. In the formally simple pattern 1 2 3 4 5 6, for example, the lower order "+1" rule adequately describes the relationships between all pairs of successive pattern elements. This type of formal structure is the simplest that can be devised. Formal structure becomes more complex as the number of different rules needed to describe a pattern is increased. The highest order rules relate the largest number of pattern elements and sets of elements, with lower order structure nested within the higher order structure. Some patterns may be perfectly symmetrical with lower order rules completely nested within higher order rules, forming *structural trees*; other patterns may have incompletely nested rule structures. Whatever the form, the presence of any formal structure provides a potential means of reducing memory load via learning by chunking, and the learner needs only to have the capacity and predilection to use it to substantially increase pattern-learning efficiency. This memory load hypothesis assumes that the learner actively searches for simple or recurring structures of patterns that can be encoded by abstracting and learning a representation of formally simple rule structures. When simple structures are found, the learner may choose to use a rule-learning strategy if doing so substantially reduces the total amount of information that must be committed to memory to learn the pattern. The difficulty of a pattern is assumed to be directly related to pattern complexity, but may be affected by many other, often conflicting, factors. Among the factors that are likely to contribute to pattern difficulty are pattern length, element discriminability, and the relative and absolute timing of events that compose the pattern. Each of these factors may affect an organism's

choice of strategy in pattern learning, namely, learning by chunking versus associative strategies.

Grouping related items into chunks during learning facilitates encoding in both humans and animals. For example, Terrace (1987) required pigeons to learn lists of five pictures which were either unorganized or organized by clustering related list items together into chunks. Pigeons learned chunked lists faster than lists without organization. Terrace (1987) suggested that the pigeons were able to impose a "self-generated organizational scheme" on the sequential elements to form chunks in memory and this allowed for better acquisition and reproduction of the organized lists.

Evidence of learning by chunking patterns in terms of pattern structure and phrasing has also been demonstrated in animals (Fountain et al. 1984). For both humans and animals in such tasks, pattern structure is a better predictor of sequence difficulty than associative structure, effects of phrasing cues depend on their correspondence with chunk boundaries, and elements of interleaved patterns (such as: 1A2B3C4D...) are cognitively *sorted* into their component subpatterns to simplify learning.

Important Scientific Research and Open Questions

Chunking is most famously used as a technique to increase memory in a learning environment and is stressed in the form of mnemonics, acrostics, acronyms, and the method of loci. Students are taught to increase memory by actively organizing information within STM. Research continues on how best to employ learning by chunking to facilitate learning in academic settings. Similarly, research on areas of rhythm, intonation, and pauses between words (prosody) and language acquisition examine how the chunking of verbal information may be used to better acquire a language. Although clear differences may be seen in the use of prosody across age groups, it is still unclear whether an inability to use prosody to organize information results in retarded acquisition of a language. Prosody has also been studied in birds in the acquisition of bird song.

Some open questions regarding learning by chunking include: the role of practice on memory capacity, whether or not working memory capacity is the same for all sensory modalities or types of information, the age of developmental onset of chunking ability, and the extent and nature of chunking abilities

in diverse animal species. Recent evidence suggests that working memory capacity may not be equal for different sensory modalities and types of information within the same sensory system. There has also been evidence that infants and a growing number of nonhuman animals may use chunking strategies.

It is generally agreed that learning by chunking plays a role in sensory pattern recognition and motor pattern acquisition, speech perception and production, reading and writing, music perception and production, and working memory and long-term memory. One important open question is the extent to which the chunking processes observed in each of these domains share common psychological and neural processes.

Cross-References

► Chunking Mechanisms and Learning
► Rule Learning
► Sequential Learning

References

Ericsson, K. A., Chase, W. G., & Faloon, S. (1980). Acquisition of a memory skill. *Science, 208*, 1181–1182.

Fountain, S. B., Henne, D. R., & Hulse, S. H. (1984). Phrasing cues and hierarchical organization in serial pattern learning by rats. *Journal of Experimental Psychology: Animal Behavior Processes, 10*(1), 30–45.

Jones, M. R. (1974). Cognitive representations of serial patterns. In B. Kantowitz (Ed.), *Human information processing: Tutorials in performance and cognition*. Hillsdale: Erlbaum.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81–97.

Simon, H. A. (1974). How big is a chunk? *Science, 183*(4124), 482–488.

Terrace, H. S. (1987). Chunking by a pigeon in a serial learning task. *Nature, 325*(7000), 149–151.

Learning by Design

Kwaku Frederick Sarfo
Department of Educational Leadership, University of Education, Winneba - Kumasi Campus, Kumasi-Ashanti, Ghana

Synonyms

Learning by doing; Learning through creating

Definition

The word *learning* comes from an old English word "Leonian" or Middle English word "Lernen" which means *to be informed, or to gain knowledge and skills*. Learning as a noun based on this origin means *the acquiring of knowledge and skills; the act, process, or experience of gaining knowledge and skills; the acquired knowledge and skills*. Learning, in Psychology, can be defined as the process by which a relatively permanent change in behavior occurs as a result of practice and experience. In learning and instructional sciences, learning can be defined as "relatively outward change of external capabilities which are constructed internally (in the mind) as the individuals engaged in both mental and social activities". The word *design* comes from Middle English word "designen," meaning *to mark out, or to define, or to make original plan, sketches, and patterns*. Design as a noun based on this origin means *plan, scheme, to work from*. In design education, design can be defined as conscious effort to create an artifact or something that is both functional and aesthetically pleasing. Learning by design in sciences of learning can therefore be defined as construction of knowledge and skills (in the mind) as a result of learners making conscious effort to create an external artifact (such as table, toy, advert) which is both functional and aesthetically pleasing and meaningful to them. In other words, learning by design is designing to learn.

Theoretical Background

Research on how to improve students' learning has received a significant recognition and attention in various fields in education (such as medical education, mathematics education, agriculture education, science education), more especially in the learning sciences and psychology. One of the emerging learning needs of learners required by modern aims of education indicates that learners should be helped to construct higher level skills or more specifically: (1) general problem-solving skills, (2) domain-specific problem-solving skills, and (3) domain-specific knowledge simultaneously as a result of creating an external artifact in the classroom. This calls for learning by design in the classroom. It is important to note that *learning by design or designing to learn* as we have in sciences of learning and instruction is not the same in meaning as *learning to design* as we have in design education. However, the meaning of the word "design" in sciences

of learning is similar to the meaning of the word "design" in design education. The word "design" in learning sciences can be traced back to design education. In design education, learners learn to design external artifacts. The person designing is called a designer. A designer is also a term used for people who work professionally in one of the various design areas, such as fashion designer, building designer. One can design by constructing an object or an artifact. A designer's sequence of activities is called design process. According to Dorst (2004), design processes can be described in terms of two fundamentally different paradigms: the rational problem-solving paradigm (objectivist epistemology) introduced in the early 1970s by Simon; and the reflective practice paradigm (phenomenological epistemology) introduced in the early 1980s by Schön. The rational problem-solving paradigm as design process indicates that problem solving takes place within a problem space that is structured by the elements of the task environment which, in turn, determines the methods that can be used for the designing. In contrast, Schön (1983) reported that technical rational problem-solving paradigm impedes the training of practitioners in design enterprise. This is because in the rational problem-solving paradigm, no attention is paid to the structure of design problems and the crucial problem of linking process and problem in a concrete design structure. Based on the advantages and disadvantages of the two paradigms, research in design education reveals the following as design methods:

- Exploring possibilities and constraints
- Using critical thinking skills to research and define the problem space for creating artifacts
- Brainstorming
- Working collaboratively to achieve a goal
- Redefining the specifications
- Managing the process of exploring, defining, creating artifacts continuously
- Reviewing and repeating practice

These design methods, according to Dost (2004), are responsible for the development of the following practice behaviors or cognitive processes of designers:

- Use basic structured concepts, rules, and principles of domain knowledge.
- Use conceptual or functional reasoning on the domain knowledge.
- Use rules of thumbs, self-reflective strategies, and problem-solving strategies when designing an artifact.
- Use basic domain principles or rule-based behaviors (e.g., application of standards) and reflective strategies simultaneously.
- Use analysis, evaluation, synthesis, and explicit strategies.

These cognitive processes are similar to cognitive processes – as reveals in research on students' learning in learning and instructional sciences and psychology – responsible for development of higher-level skills. In *learning by design* from the perspective of sciences of learning, where learners *design to learn*, learners engage in creating external artifacts (such as toy, teaching material) in the classroom. By so doing, they construct a highly structured cognitive schemata (or higher-level skills); in other words, they construct: (1) general problem-solving skills, (2) domain-specific problem-solving skills, and (3) domain-specific knowledge simultaneously which enable them to become competent problem solvers and reflective practitioners in real-life situation (Balasubramanian and Wilson 2007; Han and Bhattacharya 2001). Thus, learners become co-designers and coproducers of knowledge. As pointed out by Dijkstra and van Merrienboer (1997), the cognitive construct that would result from learning by design will enable learners (as designers) to create, invent, and construct contextualized knowledge and skills. The concept "learning by design" based on constructionist learning theory (Papert, 1993) is recently used in the literature. Constructionism is built on constructivism theories of Jean Piaget (Han and Bhattacharya 2001), proposing that learners construct knowledge and skills as they actively engage in mental and social activities. Constructionism suggests that new ideas are most likely to be created as learners are actively engaged in building some type of external artifact that they can reflect upon and share with others. In this regard, learning by design emphasizes the value of learning through creating, programming, or participating in other forms of designing. The design process creates a rich form of learning (Han and Bhattacharya 2001). In learning-by-design process, according to Han and Bhattacharya (2001), the learner chooses a topic or a task, in line with the subject of interest, which is based on real-life application and

meaningful to him/her. Then the learner describes the audience. The choice of the audience guides the learner as he/she designs the specific artifact. Once the artifact is created, the learner will pilot it. At this point, he/she should receive feedback from the facilitator and peers. The learner then reflects on the artifact created and the feedback to evaluate his/her work. The learner therefore modifies the artifact based on this evaluation. While doing all these, the notion is that the learner cognitively reasons, reflects, evaluates, and restructures the conceptual and functional principles as well as cognitive rules of the external artifact created. Consequently, the learner constructs contextualized knowledge or an integrated set of knowledge and skills (general problem-solving skills, domain-specific problem-solving skills, and domain-specific knowledge) simultaneously that would make him/her a competent problem solver in the real world. The entire design process is overseen by the facilitator who is represented by the "eye in the sky". It is argued that the design process, as described above by Han and Bhattacharya, to some great extent calls for purely discovery method. Mayer (1994), on the other hand, taught LOGO programming in line with learning-by-design process using either a pure discovery or a guided discovery method. In the pure discovery method, students were given a LOGO manual and then engaged in creating several LOGO projects. In guided discovery method, students were given the same project along with explicit modelling of design concepts such as modularization of programs, hints, and feedback about how their programs related to design principles. On subsequent tests, the guided discovery group wrote more elegant programs, made better use of good design principles better than the pure discovery group. This suggests that guided discovery method can better facilitate learning by design than purely discovery method. Researchers (e.g., Han and Bhattacharya 2001; Carvers et al. 1992) have identified the following as the elements which add value to learning-by-design environment and make it worthwhile for productive learning:

- Authenticity: tasks based on real work
- Multiple contexts for design activities
- A balance of constrained, scaffolded challenges with open-ended design tasks
- Rich, varied feedback for designers
- Discussion and collaboration

- Experimentation and explanation
- Reflection

Furthermore, they identified the following as the common goals and important behaviors of learning-by-design environment:

- Extracting essential concepts and skills from examples and experiences
- Engaging learners in learning
- Encouraging question posing
- Confronting conceptions and misconceptions
- Creating a timeline, allocating resources, and assigning team roles
- Developing research skills
- Organizing and presentation
- Encouraging reflection

Research study by Balasubramanian and Wilson (2007) indicates that learning by design enhances science and mathematics students' academic performance. According to their findings, well-designed learning by design in the traditional classroom not only addresses equity issues and increases students' achievement for all subgroups of learners, but it also results in significant learning gains for the Caucasian male students. Furthermore, learning by design was used by Carvers et al. (1992). They considered classroom as a design community in which students design instruction for other students, documentaries for local media, and other exhibits for the community. As they pointed out, "the instructional virtues of these design experiences include the opportunity to develop and coordinate a variety of complex mental skills." The concept "learning by design" looks unique in the literature of sciences of learning and instruction. However, the intention of learning by design from the perspective of the literature is not very exceptional. It is similar to task centered learning, activity-based learning, anchored instruction, 4C/ID model for complex learning, cognitive apprenticeship model, and more especially project-based learning. The basic innovative pedagogical function of all these approaches to learning including learning by design is that they invite the learners to be the co-producers of an integrated set of knowledge and skills by actively participating fully in teaching and learning processes (either in the traditional classroom or electronic learning environment/community). What actually makes learning by design

little different and receives remarkable attention in the literature of sciences of learning and instruction is that learning by design actually stimulates students to create an external artifact and object, that reflect their cognitive artifact (acquired integrated set of knowledge and skills), for their target audience.

Important Scientific Research and Open Questions

Some researchers (e.g., Balasubramanian and Wilson 2007; Mayer 2004) have observed that learning by design disconnected with domain knowledge or students' cognitive activities merely entertains students and results in their inadequate conceptual understanding. For instance, in a study conducted by Balasubramanian and Wilson (2007), students indicated that in learning by design, putting stuff together was easy; they did not have to think as much; not have to write as much; and just had to pay attention instead of having to read a lot of stuff. This demonstrates that in learning by design (some) students either disregard their cognitive activities or do not apply the domain knowledge; and as already said, this may lead to inadequate conceptual understanding. And this can be interpreted to mean that learning-by-design environment just supports some learners to become merely traditional craftsmen instead of competent problem solvers or reflective practitioners. In the same study, some students also reported that engaging in design in course of learning in the classroom might sometimes be hard. This is because you have it the wrong way; write-ups the explanations after the hands-on are sometime hard; not knowing how to solve a problem, thinking about it, measuring it right, making choices, reading a blueprint; sometimes it is frustrating because you cannot figure it out, sometimes your team disagrees about doing things and it is majority. These complaints by students suggest that in learning-by-design environment, learners need sufficient metacognitive skills or learning support to manage their cognitive processes (or limited cognitive resources) appropriately to facilitate construction of an integrated set of knowledge and skills. In addition, one of the fundamental requirements of the learning-by-design environment is that the teacher or the designer makes available the resources and cognitive tools in the learning environments (either electronic or classroom). Learners are supposed to use these resources and cognitive tools in

their design activities to achieve the learning goal. However, a number of studies on students' use of the support devices in electronic learning environments indicate that learners normally do not take the advantage of the opportunities offered them. Number of learning environments have been designed with support devices or cognitive tools included to provide learners the necessary help. Nonetheless, learners do not grasp the learning opportunity, they do not use the support devices, or they do use them in non-beneficial way. These research findings indicate that in learning-by-design learning environments, learners might not use the available tools and devices in their design activities, or they might use them in a way that does not promote their learning processes. And this might handicap the achievement of the design goal. Another issue is concerned with the teachers' ability to design appropriate learning environments to facilitate students' activities, as well as designing appropriate instruments to assess students' learning outcome in the context of learning by design.

Cross-References

► Constructionism
► Constructivism
► Discovery Learning

References

Balasubramanian, N., & Wilson, B. G. (2007). Learning by design: teachers and students as co-creators of knowledge. In K. Kumpulanen (Ed.). *Educational Technology: Opportunities and Challenges*. Oulu, Finland: University of Oulu, 30–51. Retrieved August 30, 2010, from http://herkules.oulu.fi/isbn9789514284069/isbn 9789514284069 pdf

Carvers, S. M., Leherer, K., Connell, T., & Erickson, J. (1992). Learning by hypermedia design: Issue of assessment and implementation. *Educational Psychologist, 27*(3), 385–404.

Dijkstra, S., & van Merriemboer, J. J. G. (1997). Plans, procedures, and theories to solve instructional design problems. In R. D. Tennyson, F. Schott, N. Seel, & S. Dijkstra (Eds.), *Solving instructional design problems, instructional design. international perspective, vol 2* (pp. 23–43). Mahwah: Lawrence Erlbaum.

Dorst, K. (2004). On the problem of design problems – problem solving and design expertise.*The Journal of Design Research*. Retrieved March 7, 2005, from http://jdr.tudelft.nl/articles/issues 2004.02/Arts html

Han, S. & Bhattacharya K. (2001). Constructionism, learning by design, and project based learning. In M.Orey (Ed.). *Emerging perspectives on learning, teaching, and technology*. Retrieved October 7, 2010, from http://projects.coe.Uga.edu/epltt/

Mayer, E. R. (2004). Should there be three-strikes rule against pure discovery learning? The case for guided method of instruction. *The American Psychologist, 59*(1), 14–19.

Retrieved October 2, 2010, from http://www.yourdictionary.com/learning

Retrieved October 2, 2010, from http://www.yourdictionary.com/design

Learning by Doing

BERTRAM C. BRUCE, NAOMI BLOCH
Graduate School of Library and Information Science,
University of Illinois at Urbana-Champaign,
Champaign, IL, USA

Synonyms

Active learning; Experiential learning; Inquiry-based learning; Problem-based learning; Project-based learning

Definition

Learning by doing is the process whereby people make sense of their experiences, especially those experiences in which they actively engage in making things and exploring the world. It is both a conceptual designation applied to a wide variety of learning situations (in fact, as some would argue, to all learning), and a pedagogical approach in which teachers seek to engage learners in more hands-on, creative modes of learning.

Theoretical Background

Learning by doing, in one form or another, is an element of almost all major learning theories – in the West going back at least as far as the Sophists, with their emphasis on mind-and-body and learning. In Vygotsky's (1930) sociocultural theory of learning, novices participate in activity before they have full competence or understanding of it. In this sense, activity (or "doing") precedes development, rather than the reverse. That is, it is not that we learn a thing which ultimately enables us to do something, instead it is that an activity itself creates the possibility for developing new knowledge or learning. Similarly, in behaviorist models of learning, virtually all learning is seen to proceed through action in the world, which has consequences – positive or negative – for the learner. The learner's experience of these consequences leads to conditioned responses or the incorporation of knowledge from that doing (Skinner 2002).

John Dewey's (1938b) idea of inquiry as the transformation of indeterminate situations to form a unified whole also positions active doing as a necessary ingredient of learning. However, for Dewey and other pragmatists, doing or experience alone is not sufficient; reflection upon experience is required in order to solidify and articulate knowledge (Schön 1991). Nevertheless, doing is such a central aspect of Dewey's theory that his pedagogy is often equated to learning by doing. In recent years, a variety of approaches such as problem-based learning, active learning, experiential learning, and service learning similarly conceive of doing as a key component of learning. Work in areas such as computer-supported collaborative learning seeks to organize learning around social communication, again, via a process of learning through activity.

Many thinkers in the East espouse similar ideas. Tsunesaburo Makiguchi (1871–1944), a Japanese educator and philosopher, put forward the idea of learning through value creation, that is, the discovery and formation of "beauty, gain, and good," which benefits not just the individual, but humanity as a whole. He called for a fusion between school and community, learning and life – even proposing that students spend only half the day in school, with the other half engaged in community and vocational pursuits. Nobel-prize-winning Bengali poet, artist, and educational reformer Rabindranath Tagore (1861–1941) likewise advocated a creative, hands-on pedagogical approach in which students connect learning to their local environment and the natural world. Tagore's ideas continue to influence educators far beyond Indian and Bengali culture (Hansen 2007).

A fundamental argument for promoting learning-by-doing approaches within formal learning settings is that ultimately we expect learners to participate fully in the world beyond the classroom. It seems highly implausible that the learner can participate successfully without some opportunity in the formal learning experience to do some form of the activities they are expected to do in the real world. This is why, for example, professional learning programs typically involve internships, workplace observations, and other means for engaging in the doing of the

profession. Lave and Wenger (1991) argue that across a wide range of learning situations, successful learners have the opportunity for legitimate peripheral participation (LPP). This means that while they are not given full responsibility for the task they are learning, they are nevertheless engaged with experts who allow them to do things in a way that is valued and plays a role in the larger activity. As they see their own activity embedded within a larger situation, they are able to understand both the part they play and the greater whole. In this model, the learner makes a transition from an initial minor role of observation, to one of carrying out small designated tasks, to more significant tasks, to ultimately assuming more responsibility for the larger task and eventually to independence in that activity.

Important Scientific Research and Open Questions

Despite the broad-based consensus that doing is important for learning, there remain many important questions. To what extent is learning based on doing? Surely we learn through reading, exploring the Web, talking with others, and so on. Are these best conceived as forms of doing as well? If we take doing very broadly, are we saying anything at all by the phrase "learning by doing," or are we simply equating learning and doing? Even in the cases where doing seems to be most salient, what other processes are needed in order to make the learning process most effective (e.g., reflection)?

In some curricular areas, the role of doing has been widely recognized and appears very central. For example, modern science education places great emphasis on hands-on investigation (Duckworth et al. 1990). Lab work, exploring natural environments, examining specimens – these appear to be clear cases of learning by doing. Should we expect that same method to be valid in all areas of the curriculum? What is the role of learning by doing in areas such as the study of ancient civilizations, the study of religion, aspects of philosophy, or the study of government?

Many educators would argue that every area of the curriculum could benefit from a learning-by-doing approach, however it certainly seems the case that in some areas, where we are reduced to simulations (e.g., the model UN program in which youth act the role of UN ambassadors), the learning situation must be seen as only at best an approximation of the real situation. This leads to another question: How important is the match between the doing and the topic of the inquiry? If young people, for example, dress up as their ancestors and reenact some events from history or legend, might we introduce as many misconceptions as deeper understandings of the phenomenon in question?

There are also a set of very practical policy questions deserving further study. In general, learning-by-doing activities may be more expensive, more time-consuming, more subject to legal and other policy restrictions, and even more physically dangerous than the conventional classroom model of learning from the textbook. If learning by doing is important, perhaps even necessary, then how do we find ways to make it safe, affordable, and manageable in the modern context of schools, which may be overcrowded with limited funding and limited resources?

The general notion that learning by doing is valuable is not always supported by evaluation studies, especially those keyed to traditional modes of learning (Kirschner et al. 2006). One reason is that while learning by doing may help students to understand holistic connections about a phenomenon or deal with unexpected occurrences in the process of doing (Knowles et al. 2005; Katz and Chard 1989; Kolb 1984), these positive effects, even if warranted, are unlikely to be demonstrable with conventional evaluation techniques. Another practical challenge is that learning by doing, especially when it involves larger scale longer term projects, may be more difficult to manage, particularly for a teacher who has difficulties dealing with complexities and unexpected occurrences. Accordingly, successful learning-by-doing models invariably call for a view of the teacher as learner and for a different model of the teacher–student relationship – one in which the teacher plays more of a role as coach and facilitator (Means and Olson 1994).

Doing has to be conceived not just as the activity itself. Most researchers would argue that we need to intrinsically view the concept of learning by doing as comprising not just the activity, but also the learner's reflection upon that process. For example, students learning about floating and sinking in a science classroom might do an experiment in which they fold a piece of paper to make a boat and see how many coins it can carry. This kind of activity may be fun and engaging. The students may well learn how to make boats out of paper. They may also have learned something about collaboration and other things as well.

However, if the activity stops at that point, it is unlikely that the learning can extend much or provide tools for further learning.

On the other hand, if the students can reflect upon their boatbuilding experience and connect that to their other experiences (e.g., with other hands-on floating and sinking experiments), they can amplify the effects of that experience. As they articulate those experiences and connect one to another, they are actually constructing new knowledge that can be applied to subsequent experiences. Thus the doing, in the sense of "hands-on" science, can be extended from the isolated doing to what some might call "minds-on" science investigation. The process just described for primary-level science learning may be similar to that encountered across wide areas of the curriculum for a wide variety of learners. However, the extent to which this model applies is something deserving of further research and study.

Across a broad range of domains, activity appears to fundamentally involve collaboration (Dillenbourg 1999). As such, the doing of the activity is enabled by the work of collaborators, while at the same time successful doing requires learning how to collaborate. This means that learning by doing is almost inseparable from the social context. Learning by doing thus means not only learning to do a task, but also learning how to coordinate one's activity with others and learning from others. The LPP mentioned above is typically seen to operate in a community of practice, in which people may not conceive of what they are doing as both teaching and learning, even though they are in fact learning not only from each other but from the community dynamic as a whole.

The inquiry cycle model (Bruce and Davidson 1996; Bruce and Bishop 2002) is one way to characterize these ideas. In this model, learning involves doing through active investigation of phenomena, and through building or creating products. It also involves collaboration or dialogue, in which learners again learn from others and also about others through their interactions with them. And finally, the cycle calls for reflection as a way of making sense of that doing and connecting it with other experiences.

Perhaps one of the biggest questions for conceiving of learning by doing is that doing tends to be situated; it is embodied and tied to a particular, ultimately idiosyncratic, time and place. Yet the learning that is often most valued is a more general, transferable, broad-based kind of understanding. If, as C. S. Peirce (1868) says, we can learn only through our personal experiences, and if learning is always tied to situation, then how can we possibly develop knowledge and skills that can be shared with others, applied to new and unexpected situations, and which become part of developing a common base of knowledge? How do we move from personal inquiry to community inquiry?

Kanfer et al. (2000) present this as the problem of moving from embedded knowledge to mobile knowledge. How do we make embedded knowledge mobile? John Dewey argued that it is ultimately impossible to create fully mobile, transferable knowledge that prepares us for the complex and uncertain world in which we live. Instead, he argued, we need to find ways of engaging fully in the doing experience. This is captured in Dewey's well-known quote, "We always live at the time we live and not at some other time, and only by extracting at each present time the full meaning of each present experience are we prepared for doing the same in the future" (1938a, p. 51). According to Dewey, what we do by living fully in each moment is to create the capacity to develop new embedded knowledge in new situations.

Cross-References

► Action-Based Learning
► Active Learning
► Activity Theories of Learning
► Cognitive Skill Acquisition
► Experiential Learning; Experiential Learning Theory
► Inquiry Learning
► Learning by Design
► Open Learning
► Openness to Experience
► Play, Exploration, and Learning
► Playful Learning Environments: Effects on Children's Learning

References

Bruce, B. C., & Bishop, A. P. (2002). Using the web to support inquiry-based literacy development. *Journal of Adolescent and Adult Literacy, 45*(8), 706–714.

Bruce, B. C., & Davidson, J. (1996). An inquiry model for literacy across the curriculum. *Journal of Curriculum Studies, 28*(3), 281–300.

Dewey, J. (1938a). *Experience and education.* New York: Macmillan.

Dewey, J. (1938b). *Logic: A theory of inquiry.* New York: Henry Holt.

Dillenbourg, P. (1999). *Collaborative learning: Cognitive and computational approaches.* New York: Elsevier Science.

Duckworth, E., Easley, J., Hawkins, D., & Henriques, A. (Eds.). (1990). *Science education: A minds-on approach for the elementary years.* Hillsdale: Erlbaum.

Hansen, D. (Ed.). (2007). *Ethical visions of education: Philosophies in practice.* New York: Teachers College Press.

Kanfer, A. G., Haythornthwaite, C., Bruce, B. C., et al. (2000). Modeling distributed knowledge processes in next generation multidisciplinary alliances. *Information Systems Frontiers, 2*(3/4), 317–331.

Katz, L. G., & Chard, S. C. (1989). *Engaging children's minds: The project approach.* Norwood: Ablex.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 46*(2), 75–86.

Knowles, M. S., Holton, E. F., & Swanson, R. A. (2005). *The adult learner.* Burlington: Elsevier.

Kolb, D. A. (1984). *Experiential learning.* Englewood Cliffs: Prentice Hall.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Means, B., & Olson, K. (1994). The link between technology and authentic learning. *Educational Leadership, 51*(7), 15–18.

Peirce, C. S. (1868). Some consequences of four incapacities claimed for man. *Journal of Speculative Philosophy, 2,* 140–157.

Schön, D. A. (1991). *The reflective turn: Case studies in and on educational practice.* New York: Teachers Press, Columbia University.

Skinner, B. F. (2002). *Beyond freedom & dignity.* Indianapolis: Hackett.

Vygotsky, L. (1930). *Mind in society.* Cambridge, MA: Harvard University Press.

Learning by Doing Versus Learning by Thinking

C.-J. Olsson[1], Lars Nyberg[2]
[1]Department of Surgical and Perioperative Sciences, section for Sports Medicine; UFBI (Umeå centre for Functional Brain Imaging), Umeå University, Umeå, Sweden
[2]Department of Integrative Medical Biology, physiology; Department of Radiation Sciences, Radiology; UFBI (Umeå centre for Functional Brain Imaging), Umeå University, Umeå, Sweden

Synonyms

Imagery; Mental training; Visualization

Definition

Learning by doing may be the most efficient way to acquire new motor skills, but it is not the only way to enhance motor performance. An additional way to improve motor performance is through mental training. The original definition of mental training was offered by Richardson (1967); "the symbolic rehearsal of a physical activity in the absence of any gross muscular movements." Hence, instead of physically performing an action, it is instead imagined. Imagining actions can be done either from a first-person perspective (internal), when emphasis is on feeling as the action is performed, or from a third-person perspective (external), similar to observing the action. For motor performance, the first-person perspective is more beneficial.

Theoretical Background

Since the beginning of the 1900s mental training has been a subject for research. Moreover, mental training has also interested athletes, since under circumstances in which participation in physical training is difficult or impossible, e.g., during injury, mental training has been used instead or as a complement. Indeed, several studies in various sports such as golf, high jump, gymnastics, diving, etc., have shown that mental training is positively associated with performance improvements, yet not as efficient as regular motor training (for overview see Driskell et al. 1994). A key underlying assumption behind mental training is that during imagery of motor actions (motor imagery) the corresponding brain regions are recruited as during the actual physical performance of the same action. Consequently, the underlying neural mechanisms for mental training should largely be the same as for motor training. However, the assumption of underlying similarities between mental and motor activity has to be qualified. Recent neuroimaging studies have shown that our ability to recruit motor regions during motor imagery depends on our ability to perform the action physically. If we, in fact, do not have action specific physical experience motor imagery will recruit the frontal or visual/parietal cortex instead of the motor cortex. Thus, during motor imagery of actions with no prior task specific physical experience, the third-person perspective is used instead of the first person perspective (Olsson et al. 2008b; Olsson and Nyberg 2010; Olsson and Nyberg, 2011).

Important Scientific Research and Open Questions

Investigations into the underlying neural representations following training have increased in the last 15 years, much thanks to the development of advanced imaging techniques such as functional Magnetic Resonance Imaging (fMRI). After a period (4 days) of mental training on a complex finger-tapping task, general training related effects are seen that are similar to those following motor training. More specifically, a reduction of activated brain regions was seen along with a more dominant role of motor structures. In addition, after 4 days of mental training a training-specific activation was seen with extra recruitment of secondary visual cortex. By contrast, motor training resulted in training-specific brain pattern with additional activations in the supplementary motor area (SMA) and in the cerebellum (Nyberg et al. 2006). Moreover, extending the mental training period from 4 days to 6 weeks resulted in engagement of the fusiform cortex which is a region specialized for object representations. Correspondingly, extending motor training led to a more robust representation in the ventral pre-motor cortex, which is specialized for hand movements (Olsson et al. 2008a). Thus, mental training is reflected within the neural system partly differently than motor training with distinct neuroplastic changes related to motor performance improvements.

This leads to at least two possible consequences when complementing or adding mental training to regular motor training that needs to be addressed in future studies. The first possibility is that the extra representation created in the visual system may facilitate learning since performance can be based on both motor and non-motor representations. An alternative possibility is that the extra representation may interfere with learning and, thus, affect performance negatively. As a result, even though it has been proven that mental training can affect motor performance, athletes and coaches should be aware about that the performance improvements are based on partly different systems of the brain. Thus, future research should focus on under what specific circumstances mental training could affect motor performance positively, and when mental training would be more time consuming than effective.

Cross-References

► Action Learning
► Imagery and Learning
► Learning by Doing
► Mental Imagery
► Mental Representation

References

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *The Journal of Applied Psychology, 79*, 481–492.

Nyberg, L., Eriksson, J., Larsson, A., & Marklund, P. (2006). Learning by doing versus learning by thinking: An fMRI study of motor and mental training. *Neuropsychologia, 44*, 711–717.

Olsson, C.-J., & Nyberg, L. (2010). Motor imagery: If you can't do it, you won't think it. *Scandinavian Journal of Science and Medicine in Sports, 20*, 711–715.

Olsson, C.-J., & Nyberg, L. (2011). Brain simulation of action may be grounded in physical experience. Neurocase.

Olsson, C.-J., Jonsson, B., & Nyberg, L. (2008a). Learning by doing and learning by thinking: An fMRI study of combining motor and mental training. *Frontiers in Human Neuroscience, 2*, 5.

Olsson, C.-J., Jonsson, B., Larsson, A., & Nyberg, L. (2008b). Motor representations and practice affect brain systems underlying imagery: an fMRI study of internal imagery in novices and active high jumpers. *The Open Neuroimaging Journal, 2*, 5–13.

Richardson, A. (1967). Mental practice – review and discussion (Part I). *Research Quarterly, 38*(1), 95–107.

Learning by Eliminating

Rūsiņš Freivalds
Institute of Mathematics and Computer Science,
University of Latvia, Riga, Latvia

Synonyms

Co-learning; Learning by elimination

Definition

Learning by eliminating as proposed by Freivalds et al. (1994a) is a class of methods used in inductive inference, a research area started by Gold (1967). We consider learning where an algorithmic device inputs data and produces a sequence of programs such that this sequence can be interpreted as a correct program consistent with the given data. For Gold (1967) the

sequence was supposed to be an infinite sequence such that all of its members (but a finite number of them) equal one correct program. For learning-by-eliminating algorithms the interpretation of the infinite resulting sequence is different. The sequence is to contain all possible programs with one exception. Namely, one correct program is to be missing.

Theoretical Background

Learning by eliminating means the process of removing potential hypotheses from further consideration thereby converging to a unique hypothesis which will never be eliminated. This hypothesis has to be a correct solution to the actual learning problem.

This approach is motivated by similarities to both human learning or, more general, human problem solving, as well as automated problem solving. Actually, in solving a problem we mostly find out several "nonsolutions" to that problem first, contradicting the data we have or explaining them unsatisfactorily. Of course, we then will exclude these nonsolutions from our further consideration and keep only a more or less explicitly given remaining set of potential solutions. Often, at any time of the solving process we have an actual "favored candidate" among all the remaining candidates for a solution which, though, up to now cannot be proved to be really a solution and which also may change from time to time. Our "favored candidate" will be stable from some point on, it is really a solution, but we are not absolutely sure of that.

Learning by eliminating can be applied to learn recursive functions or recursive languages. In all cases, this type of learning is proved more powerful than finite learning. The advantages of learning by eliminating versus finite learning can be seen in an earlier paper by Freivalds (1975) where existence of a total function $N \rightarrow N$ was proved such that it is not a recursive function but a uniform algorithm exists eliminating every wrong value of this function.

Learnability by eliminating of programs in Gődel numberings and in other computable numberings was studied in Freivalds et al. (1994a). A class U of total recursive functions is learnable by eliminating in any Gődel numbering if and only if U is learnable in the limit. For other computable numberings, the characterization of the classes of functions learnable by eliminating is not yet complete.

Freivalds et al. (2002) proved that if a computable numbering is cylindric, then in this numbering learnability by eliminating is as powerful as learnability in the limit. On the other hand, there are computable numberings in which only finite classes can be learnability in the limit.

Jain et al. (1996) studied learnability by eliminating of minimal programs for classes of total recursive functions. Freivalds and Zeugmann (1996) studied learnability by eliminating recursive languages from positive data.

Important Scientific Research and Open Questions

Deep results on learnability by eliminating of recursively enumerable classes were obtained. It was conjectered in Freivalds et al. (1994a) that only finitely learnable classes of total recursive functions are learnable by eliminating in all recursively enumerable numberings. This conjecture was disproved by Freivalds et al. (1994b). Unexpectedly, this research was continued by Kummer (1995). He proved that a recursively enumerable class of total recursive functions is learnable by eliminating all recursively enumerable numberings if and only if all these numberings are equivalent (i.e., reducible one to another). Thus a learning-theoretic solution was given to a long standing problem in recursion-theoretic numbering theory.

Cross-References

▶ Learning by Erasing
▶ Procrastination and Learning

References

Freivalds, R. (1975). On complexity and optimality of computation in the limit. *Theory of Algorithms and Programs*, Vol. 233, pp. 155–173 (in Russian).

Freivalds, R., & Zeugmann, Th. (1996). *Co-learning of recursive languages from positive data* (LNCS, Vol. 1181, pp. 122–133). Berlin/Heidelberg: Springer.

Freivalds, R., Karpinski, M., & Smith, C. H. (1994a). Co-learning of total recursive functions. *Proceedings of the Seventh Annual ACM Conference on Computational Learning Theory (COLT 1994)*, ACM, New Brunswick, pp. 190–197.

Freivalds, R., Gobleja, D., Karpinski, M., & Smith, C. H. (1994b). *Co-learnability and FIN-identifiability of enumerable classes of total recursive functions* (LNCS, Vol. 872, pp. 100–105). Berlin/Heidelberg: Springer.

Freivalds, R., Karpinski, M., Smith, C. H., & Wiehagen, R. (2002). Learning by the process of elimination. *Information and Computation, 176*(1), 37–50.

Gold, E. M. (1967). Language identification in the limit. *Information and Control, 10*, 447–474.

Jain, S., Kinber E. B., & Wiehagen, R. (1996). On learning and Co-learning of minimal programs. (LNCS, Vol. 1160, pp. 242–255). Berlin/Heidelberg: Springer.

Jain, S., Kinber, E. B., & Wiehagen, R. (2000). Language learning from texts: Degrees of instrinsic complexity and their characterizations. *Proceedings of the Thirteenth Annual Conference on Computational Learning Theory (COLT 2000)*, Morgan Kaufmann, Palo Alto, pp. 47–58.

Kummer, M. (1995). A learning-theoretic characterization of classes of recursive functions. *Information Processing Letters, 54*, 205–211.

Learning by Elimination

► Learning by Eliminating

Learning by Erasing

Rūsiņš Freivalds
Institute of Mathematics and Computer Science, University of Latvia, Riga, Latvia

Synonyms

Negative learning

Definition

Learning by erasing as proposed by Lange et al. (1996) is a class of methods used in inductive inference, a research area started by Gold (1967). We consider learning where an algorithmic device inputs data and produces a sequence of programs such that this sequence can be interpreted as a correct program consistent with the given data. For Gold (1967) the sequence was supposed to be an infinite sequence such that all of its members (but a finite number of them) equal one correct program. For learning-by-erasing algorithms the interpretation of the infinite resulting sequence is different. The sequence is to contain all possible programs with some exceptions. Namely, one minimal program among those missing is assumed to be the result.

Theoretical Background

When you have eliminated the impossible, whatever remains, however improbable, must be the truth. The scientific method in problem solving is in the process of putting forth a hypothesis and then testing and validating it. If the hypothesis is found to be false, a new one is generated. The learning-by-erasing algorithm takes the extreme view of having to eliminate all of the potentially possible answers but the correct answer.

This notion of learning is a generalization of the notion "learning by eliminating" introduced by Freivalds et al. (1994). In learning by eliminating, the learning algorithm always constructs an infinite sequence of programs where all possible programs with one notable exception are present. The missing program is considered the result of the learning algorithm. In learning by erasing introduced by Lange et al. (1996) even infinitely many programs may be missing. The result of the algorithm is the minimal missing program. Since minimality can be considered by several nonequivalent definitions of minimality (minimal program in a fixed programming language, program with the least Kolmogorov complexity, etc.) several nonequivalent modifications of learning by erasing are possible. For sets of hypotheses, the following possibilities during the inference process are considered and compared:

1. An arbitrary set of hypotheses may be erased.
2. Exactly all hypotheses less than the least correct one have to be erased.
3. Only incorrect hypotheses may be erased.
4. Exactly all incorrect hypotheses have to be erased.
5. All incorrect hypotheses have to be erased and an arbitrary set of correct hypotheses may be erased, too.
6. All but one hypothesis have to be erased.

An impressive amount of result is presented in Jain et al. (2000). For language learning by erasing, it turns out that this model is sensitive with respect to the particular choice of the hypothesis space, thus nicely contrasting learning in the limit and finite learning. A further interesting result shows that the process of elimination cannot be restricted to incorrect hypotheses for achieving its full learning power. On the other hand, all models of learning by erasing that are allowed to erase correct hypotheses, too, are as powerful as

learning in the limit provided the hypothesis space is appropriately chosen.

Important Scientific Research and Open Questions

Gierasimczuk (2009) compared the possibility of modeling inductive inference (Gold 1967) in dynamic epistemic logic. She analyzed a variety of epistemological notions involved in identification in the limit and match it with traditional epistemic and doxastic logic approaches. Then, she proved that finite identification can be modeled in dynamic epistemic logic, and that the elimination process of learning by erasing can be seen as iterated belief revision modeled in dynamic doxastic logic. These results show that learning theory is incrementally linked to deep problems in mathematical logics.

Cross-References

► Learning by Eliminating

References

Freivalds, R., Karpinski, M., & Smith, C. H. (1994). Co-learning of total recursive functions. *Proceedings of the Seventh Annual ACM Conference on Computational Learning Theory (COLT 1994)*, ACM, New Brunswick, pp. 190–197.

Gierasimczuk, N. (2009). *Learning by erasing in dynamic epistemic logic* (LNCS, Vol. 1181, pp. 362–373). Berlin/Heidelberg: Springer.

Gold, E. M. (1967). Language identification in the limit. *Information and Control, 10*, 447–474.

Jain, S., Osherson, D., Royer, J. S., & Sharma, A. (1999). *Systems that learn* (2nd ed.). Cambridge, MA: MIT Press.

Jain, S., Kinber, E. B., Lange, S., Wiehagen, R., & Zeugmann, Th. (2000). Learning languages and functions by erasing. *Theoretical Computer Science, 241*(1–2), 143–189.

Lange, S., Wiehagen, R., & Zeugmann, Th. (1996). *Learning by erasing* (Tech. Rep. RIFIS-TR-CS-122). Fukuoka: Research Institute of Fundamental Information Science, Kyushu University.

Learning by Examples

► Analogy-Based Learning

Learning by Experience

► Learning in Practice and by Experience

Learning by Experimentation

► Discovery Learning

Learning by Feeling

Lynne Hall, Marc Hall
University of Sunderland, Sunderland,
Tyne & Wear, UK

Synonyms

Social and emotional experiential learning

Definition

Learning by feeling provides the learner with the opportunity to explore strategies for coping with challenging complex socioemotional situations by experiencing the associated emotional dynamics. Learning by feeling is often facilitated by use of role-play and synthetic characters.

Theoretical Background

Social and emotional learning is of increasing importance with the growth of multicultural societies in which cultural, ethnic, and religious groups must live and work together. There is increasing awareness of the need to receive educational support for social and emotional learning with the recognition that not only does social and emotional learning have considerable importance for nonacademic outcomes, such as citizenship and safety, it also plays a critical role in improving academic performance. This is supported through the view that social learning leads to cognitive development, with emotions driving attention, learning, memory, and other important mental and intellectual activities, having a significant affect on cognitive processes.

Personal, social, and health education, dealing with good citizenship, with problems such as drug abuse, with unacceptable behavior such as bullying and racial victimization, and with the complications of personal relationship building and sex can never be achieved by merely knowing the facts. Learning such things has to be achieved using a different approach; this is where learning by feeling really comes into its own.

Cognitive, affective, and behavioral learning is achieved through experience, with knowledge emerging "from the combination of grasping and transforming experience" (Kolb 1984). Experiential learning has made an important contribution to successful social and emotional learning programs. The marriage of experiential learning with emotional engagement gives rise to learning by feeling.

Empathy is essential for social and emotional learning and is both the central mechanism that allows learning by feeling to happen and the cognitive faculty that is to be developed in the process. Empathy can be defined as "an observer being exposed in some way to a target, after which some response on the part of the observer, cognitive, affective, and/or behavioural, occur" (Davis 1994).

One of the fundamental processes for empathy to develop is role-taking: "the attempts by one individual to understand another by imagining the other's perspective" (Davis 1994). Understanding another's perspective can be achieved through role-play, an experiential technique in which attitudes, feelings, and social interaction can be explored. The basic premise of role-play is that it is easier to empathize with how another person might feel under certain circumstances if one has experienced something similar, even symbolically as part of a role-play. It is for this reason that learning by feeling often uses a role-play approach, giving the learner the opportunity to feel what it is like to experience another person's or group of people's situation.

Theater-in-education is often used, in which narrative produces an empathic relationship between characters portrayed as confronting one of these issues and the audience, drawing on empathy and other aspects of the affective loop.

With experiential role-play, social interaction is used as the stimulus for challenging and changing existing beliefs. Role-play is highly relevant for social and emotional learning (Henriksen 2004), resulting in more significant behavioral changes than can be achieved through lecture-style information sessions.

Important Scientific Research and Open Questions

Innovative technology is increasingly being used for educational role-play; however, this typically focuses on language learning, business studies, and industrial/international relations. Where the potential of virtual role-play environments has been explored for social and emotional issues, this has mainly focused on educational drama and storytelling, e.g., Ghostwriter (Robertson and Despa 2006), E-Drama (Zhang et al. 2009), ORIENT (Aylett et al. 2009).

Role-play is particularly appropriate where issues relate to peer-group pressures such as racism, bullying, personal vendettas, and social conformism in general, with the high level of drama in approaches in an immediacy that is more likely to evoke emotion than other learning approaches such as reading. However, supporting experiential role-play typically involves considerable teacher preparation and is particularly demanding within the classroom situation.

Recently, results have highlighted the potential of synthetic characters for empathic engagement (Hall et al. 2004), providing children with a safe environment for experiential social and emotional learning, allowing the user to experience the character's emotions and problems in a distanced way, while being at the same time engaged in what happens to the characters. Empathic engagement can be enhanced through the use of innovative interaction devices to provide children with more intuitive interfaces to express affect.

Cross-References

▶ Emotion Regulation
▶ Emotional Learning
▶ Empathetic Virtual Characters in Narrative-Centered Learning Environments
▶ Experiential Learning
▶ Experiential Learning Theory
▶ Mood and Learning
▶ Mood-Dependent Learning
▶ Play and Its Role in Learning

References

Aylett, R., Lim, M. Y., Kriegel, M., Enz, S., Vannini, N., Hall, L., et al. (2009). Technology-enhanced role-play for intercultural learning contexts. *Lecture Notes in Computer Science, 5709*(1), 73–84.

Davis, M. H. (1994). *Empathy: A social psychological approach*. Dubuque: Brown and Benchmark.

Hall, L., Woods, S., Sobral, D., Paiva, A., Dautenhahn, K., Wolke, D., & Newall, L. (2004). *Designing empathic agents: adults versus kids*. Paper presented at intelligent tutoring systems seventh international conference, ITS 2004. Maceio, Brazil.

Henriksen, T. (2004). On the transmutation of educational role-play. In M. Montola & J. Stenros (Eds.), *Beyond role and play: Tools, toys and theory for harnessing the imagination* (pp. 107–130).

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs: Prentice Hall.

Robertson, J., & Despa, J. O. (2006). Ghostwriter: educational drama and presence in a virtual environment. *Journal of Computer-Mediated Communication, 8*(1). doi: 10.1111/j.1083-6101.2002.tb00159.x.

Zhang, L., Gillies, M., Dhaliwal, K., Gower, A., Robertson, D., & Crabtree, B. (2009). E-Drama: Facilitating online role-play using an AI actor and emotionally expressive characters. *International Journal of Artificial Intelligence in Education, 19*(1), 5–38.

Learning by Practicing

► Cognitive Skill Acquisition

Learning by Recoding

► Learning by Chunking

Learning by Teaching

Ulrike Hanke

Department of Educational Science, University of Freiburg, Freiburg, Germany

Synonyms

Peer tutoring

Definition

The basic idea of learning by teaching, also known as peer tutoring, is that learners take the role of the teacher for a certain time in class. This time period can be a whole lesson or only the time needed for a special activity. During this time period, the learners who take the role of the teacher may present a new subject to the other learners, lead discussions, help each other in solving learning tasks, and so on. There are two basic forms of learning by teaching: In the first form roles are switched, that is, a learner may take the role of a teacher for a special activity but in other respects has the role of the learner. This form is sometimes called horizontal interaction (Hatano and Inagaki 1991). The second way of realizing learning by teaching is by implementing a tutor, that is, an older pupil or student. In this so-called vertical interaction (Hatano and Inagaki 1991), roles are not switched. The older pupil or students stay in the role of the teacher for the entire time of interaction.

Theoretical Background

The advantages of learning by teaching for tutors and tutees are explained by role-model theory, sociolinguistic theory, and cognitive psychology.

The basic idea behind role-model theory is that everyone has expectations toward persons with special social roles. These expectations define the rights and duties of any person inhabiting this social role. When children, pupils, or students take the role of the teacher for a certain time, their "behavior will be constrained by what tutees expect of a teacher" (Goodland 1989, p. 56). They learn to take responsibility for the learning process of their tutees and their self-concept is reinforced because they feel like they are being treated with respect. Another effect is that the tutors begin to sympathize with their teachers, which causes a better atmosphere in class later on (Goodland 1989, p. 58). But role-theory does not only explain the benefits for the tutors: It is suggested that the tutees are more willing to learn from peers because they inhabit a similar world, facilitating communication (Goodland 1989).

Another theory that explains advantages of learning by teaching is sociolinguistic theory. This theory focuses on different speech codes of varying people. Children from the lower classes of society often have a restricted speech code. In taking the role of a teacher, these children are supported in using speech codes of teachers, that is, speech codes with which they are unfamiliar. As the ability to use and understand different patterns of speech has effects on perception, it is supposed that the possibility to learn different patterns of speech also has, in the long run, effects on learning (Goodland 1989).

According to cognitive psychology, learning by teaching should have advantages for the learning of the tutors because of three factors: the expectation of having to teach, the requirement to explain something to others, and the requirement to answer questions of others (Renkl 1997). It is assumed that the expectation of having to teach, the requirement to explain a subject to others and the requirement to answer questions after

the tutorial support the idea that tutors use elaboration strategies in learning and monitor their own learning process in order to diagnose and fill the gaps in their own understanding. When people know that they have to teach a special subject, they have to set goals and make sure that they reach them, because if these goals are not realized, teaching will not occur. In order to be able to explain the subject, the tutors have to learn meaningfully. They have to understand the facts and integrate them and they have to think of examples and analogies. These activities are supposed to cause a deep understanding of the subject and inhibit rote learning. Even while explaining the subject, tutors go on learning, because their own explanations can show inconsistencies in their own argumentation and knowledge. The same is true for the act of answering questions. In order to be able to answer questions, tutors have to have a deep understanding of the subject. In addition, the questions of their tutees may show them their still existing deficits in their knowledge and understanding. All three components proposed by cognitive psychology in order to explain the benefits of learning by teaching explain the benefits by the requirement for the tutors to use elaboration strategies in order to prepare their teaching situation. From the point of view of the tutee, cognitive psychology cannot explain benefits. As the tutors are no professional teachers and as they are no experts in the subject that they are teaching, there is the risk that they will teach in inappropriate ways and even give incorrect explanations. Both aspects can make learning difficult for the tutees or can even inhibit it.

As has been shown, different theories explain the benefits of learning by teaching in different ways and stress different benefits. From the discussion above, it has to be assumed that there should be more advantages of learning by teaching for the tutors than for the tutees.

Important Scientific Research and Open Questions

To test the hypothesis of these different theories about learning by teaching is difficult, as it is hardly possible to control all variables that might have an effect on the outcomes of learning by teaching.

Nevertheless, there are studies that tried to measure the effects of such settings. For an overview, see Renkl (1997) and Goodland (1989).

The studies mostly concern cognitive and affective gains.

Studies concerning cognitive gains seem to be quite clear in respect to the effects for the tutors. It was shown that pupils improved their reading by tutoring as well as they "learned better by tutoring in science-related topics than by studying alone" (Goodland 1989, p. 80). Concerning the cognitive gains of the tutees, results are even more clear-cut. Goodland (1989) sums up by writing "that those tutored can benefit from taking part in tutoring schemes is one of the best-authenticated findings of all" (p. 81). He lists a dozen studies that give evidence for the positive effects of tutoring on reading skills for the tutees. All these studies made use of vertical interaction settings in learning by teaching. Similar effects could be found by studies in mathematics (Goodland 1989, p. 82).

Affective gains of learning by teaching are more difficult to measure. Although there are, according to Goodland (1989), several studies where no evidence for positive effects of learning by teaching on self-concepts was found, there are also studies that were able to find improvement in self-concepts of the tutors (Mainiero et al. 1971). Other studies also give evidence that tutoring increases empathy, altruism, and self-esteem of the tutors and the tutees (Goodland 1989). Mainiero et al. (1971) were able to show for example that the self-concept of 9–11-year olds improved when they were taught by 13-year olds. Other studies show that academic motivation of children can be improved when they are taught by university students (Abidi et al. 1976) and that teacher-rated attitudes and classroom behavior can be improved when being taught by older pupils (Horan et al. 1974).

These studies seem to give quite good evidence for cognitive as well as affective gains for tutors and tutees taking part in tutoring programs.

Renkl (1997) conducted studies with less evidence for positive effects on the tutors. He was able to show that the expectation to teach the tutees induces strain and tension in the tutors, that they did not use other learning strategies and the gains in learning are not influenced by the expectation to teach. The other factor that Renkl believed to have an influence on gains in learning in learning-by-teaching contexts is that the tutors have to explain the learning subject to other subjects. The fact that tutors had to explain something to their tutees caused them to elaborate the learning material in more

detail than without this expectation. However, this did not lead to better results in learning. Renkl explains this by factors like higher fear for failure, the fact that explaining also demands attention for other aspects and that tutors are insecure about their own knowledge. The third factor that is supposed to support learning in learning-by-teaching contexts is that tutors have to answer questions of their tutees. Results from Renkl's studies show that this factor also does not have direct effects on learning outcome, but on learning motivation.

These results give evidence for positive effects of learning by teaching for tutors and tutees in respect to cognitive and affective gains, but Renkl's results also show that these positive effects are not easy to explain for tutors, as the supposed factors do not have direct effects on the learning outcomes.

Cross-References

► Active Learning
► Collaborative Learning
► Cooperative Learning
► Interactive Learning
► Peer Learning and Assessment
► Shared Cognition

References

Abidi, A. A., et al. (1976). *The pimlico connection*. London: Department of Electrical Engineering, Imperial College of Science and Technology.

Gartner, A., Kohler, M. C., & Riessman, F. (Eds.). (1971). *Children teach children. Learning by teaching*. New York: Harper & Rohr.

Goodland, S. (1989). *Peer tutoring: A guide to learning by teaching*. London: Kogan Page.

Hatano, G., Inagaki, K. (1991). Sharing cognition through collective comprehension activity. In L. B. Resuick, J. Levine & S. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 331–348). Washington, DC: American Psychological Association.

Horan, J. J., de Girolomo, M. A., Mill, R.L., & Shute, R. E. (1974). The effect of older peer participant models on deficient academic performance. *Psychology in Schools, 2*, 207–212.

Mainiero, J., Gillogly, B., Nease, O., Heretz, D., & Wilkinson, P. (1971). *A cross-age teaching resource manual*. Ontario: Ontario-Montclair School District.

Renkl, A. (1997). *Lernen durch Lehren. Zentrale Wirkmechanismen beim kooperativen Lernen*. Wiesbaden: Deutscher Universitäts-Verlag.

Learning by Thinking

► Learning and Thinking

Learning Community

► Mental Models and Lifelong Learning

Learning Company

► Learning Organization

Learning Concepts

► Learning Metaphors

Learning Content Management System

► Integrated Learning Systems

Learning Context

► Experiential Learning Spaces
► Perceptions of the Learning Context and Learning Outcomes

Learning Control

► Iterative/Repetitive Learning Control: Learning from Theory, Simulations, and Experiments

Learning Criteria

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Learning Criteria, Learning Outcomes, and Assessment Criteria

Lin S. Norton
Faculty of Education, Liverpool Hope University, Liverpool, England, UK

Synonyms

Achievement criteria; Assessment grid; Assessment matrix; Assessment rubric; Assessment schemes; Criterion-referenced assessment; Grade descriptors; Grading criteria, grading standards; Instructional objectives; Learning criteria; Learning objectives; Learning outcomes; Level descriptors; Marking criteria; Marking grid; Marking matrix; Marking rubric; Marking schemes; Marking standards; Performance criteria

Definitions

Assessment. The noun "assessment" is derived from the verb "assess" which means evaluate or estimate. It also means to set the value of a tax, fine, etc., for a person (or property). [The origin is from Old French *assesser*, from Latin *assidere* "sit by" (later "levy tax")]. The use of the word assessment is relatively new in the context of general education where traditionally terms like testing, examining, and grading were used. However, early in the 1970s the term assessment came to be generally associated with these activities. Before then, the term assessment seems to have been associated with individuals and it was sometimes specifically associated with judgments about children who had specific learning and/or other needs (Heywood 2000).

Assessment criteria. Originally the term was used within the measurement of economic activity and capital expenditure and also in the context of the process of selecting individuals for jobs based upon their skills or the tasks that were to be performed. In education, the earliest the term seems to appear is within a discourse discussing the use of self-instruction materials in programmed instruction (Soles 1963).

Learning is defined in this entry as any action of receiving instruction or acquiring knowledge:

1. To gain knowledge, comprehension, or mastery of through experience or study
2. To fix in the mind or memory; memorize
3. To commit to memory, learn by heart.

Objectives: Something toward which effort is directed: an aim, goal, or end of action; in military terms a strategic position to be attained or a purpose to be achieved by military operation outcomes.

Outcome. That which comes out of or results from something; visible or practical result; effect or product.

Theoretical Background

Assessment in education is a perennially difficult issue which affects sectors at all levels and in different countries across the world. The complex nature of assessment is, in part, derived from the purposes it is required to fulfill. According to the Chartered Institute of Educational Assessors (CIEA) the four most commonly used goals of assessment are:

1. *Diagnostic assessment.* This is when the teacher sets out to "*ascertain the knowledge, skills, strengths, and weaknesses that students already have…the diagnosis should enable the teacher to tailor their forthcoming teaching…validity and reliability are therefore important features of diagnostic assessment.*"
2. *Formative assessment.* This is frequently referred to as assessment *for* learning (Black and Wiliam 1998). Its goal is to enable both learner and teacher to ascertain progress and take action. This means that following feedback, the learner can modify learning efforts and the teacher can tailor teaching accordingly. Formative assessment can sometimes be also used summatively, but more usually it is not counted in any overall grade or measure and tends to be informal with a greater emphasis on validity rather than on reliability.
3. *Criteria.* This is the plural version of the noun criterion meaning a test, principle, rule, canon or standard, by which anything is judged or estimated. [The origin is from the Greek *kriterion* 'a means for judging, test, standard', from *krites* 'a judge'].
4. *Summative assessment.* This may also be referred to as assessment for certification which means that it is a measure of attainment or achievement. Summative assessment is formal and its purpose is to put learners into some rank order of achievement or it may be used to certify that they have reached some

threshold standards in their learning. Since summative assessment is a "high stakes" activity (it has serious consequences for the learner), both validity and reliability are important. Transparency, fairness, and accountability are also associated with this type of assessment.

5. *Evaluative assessment.* This is used to make judgments about the success of a school, or college or university or a particular teacher. The focus is not on what the individual learner can do but on the overall success of the teaching program, so it is a quality measure. An example the CIEA gives is that of key stage tests in UK schools which are used to measure the effectiveness of teaching and learning as well as how individual children are performing in specified subjects.

The following paragraphs focus on summative assessment.

Summative Assessment

To think about summative assessment requires a consideration of its constituent parts which could be loosely construed as the learning element (what is learned), more specifically described as learning criteria or learning outcomes and the assessing element (what is judged as evidence of that learning), more specifically described as assessment criteria. Each of these terms will be described in turn while recognizing that their function and purpose is inextricably interwoven. Learning criteria is a phrase that has been beset with problems of terminology where different educational systems use different terms, for example, learning criteria, objectives, goals, intents, aims, outcomes, tasks, mastery are all terms that are frequently used indiscriminately and often interchangeably. The term learning criteria is no longer widely used and tends to incorporate learning outcomes and learning objectives, both of which are often used interchangeably, but erroneously. Learning criteria originated from a view of learning which is influenced by behavioral psychology where the emphasis is on that which can be measured. Some of the earliest references to learning criteria appear in journals reporting on experimental studies of learning in the 1940s and 1950s where they are specified precisely such as, for example, the number of trials needed, or the number of correct responses to demonstrate that the required learning has taken place.

Not surprisingly, the impact of programmed instruction in the 1950s, which was derived from B.F. Skinner's behaviorism, served to sustain the importance of learning criteria. Programmed instruction presents learners with a carefully designed sequence of learning steps, tests them, and then gives them the answer. Gradually, however, there has been a significant shift from learning criteria to learning objectives and more recently to learning outcomes. In the 1960s, early iterations of learning (instructional) objectives were to break down complex tasks into identifiable smaller components in order to measure each to see if the required standard had been reached. Specification of objectives was critical and heavily influenced by a positivist, technical approach to education with an emphasis on behavior that is observable and measurable, rather than on higher-order thinking processes, which can only be inferred.

By the late 1960s most teachers were writing and using behavioral objectives, but there were those who questioned the wisdom of breaking subject content into its smallest component parts and thus missing the complex understanding of the whole. Eisner (1979) who came from an Arts education perspective argued that outcomes are much broader than objectives with their emphasis on atomized elements of behavior that can be specified and measured. Learning outcomes cannot be articulated with the same degree of specificity and are resistant to being described in purely behavioral terms. Pedagogically speaking, this is their strength as it enables them to address such concepts as understanding, creativity, and developing critical thinking which are fundamental to the aims of education. Learning outcomes are far more complex than learning objectives, but what they both share is a focus on what the learner can do rather than on the content of the curriculum or on the intention of the teacher. They represent what the learner has achieved and they represent what was assessed. Learning objectives and learning outcomes both represent a view of education and learning where an intention to bring about a change in knowledge, skills, and personal development is specified. The emphasis, though, is not on the teaching but on what the learner or student is able to do at the end of the course, or the lesson.

Learning Outcomes

Learning outcomes are integral to learning, teaching, and assessment, the interrelationships of which are

key to curriculum design, according to Spady (1994) who is recognized as one of the key proponents of outcomes-based education, particularly in South Africa and Australia. Once learning outcomes are specified, they need to be assessed and assessment criteria devised, and then learning and teaching methods are designed to bring this about. With the progression in all education sectors to learning outcomes has come a progression in assessment in the expressed ideal that *all* learning outcomes must be assessed. Such insistence has had the unfortunate effect of sometimes encouraging teachers to only focus on conceptually limited learning outcomes which are easy to define and assess. On the positive side, since learning outcomes are required to be achievable, observable, and measurable, they can be used to ensure consistency of delivery across discrete elements of learning and to identify any areas of overlap (e.g., class session, module, course, program). Learning outcomes also help teachers to improve their course design by specifying how learning progression will be incorporated. They encourage teachers to reflect on assessment and the development of assessment criteria and they give a clear picture to the outside world of what has been achieved. The biggest advantage of adopting learning outcomes is, however, in signaling the move from content and what teachers teach to student-centered learning and what students will be able to do. There is currently a positive Europe-wide movement toward the adoption of learning outcomes building on what has already been established in the education systems of the USA, Australia, New Zealand, and South Africa, among others.

Assessment Criteria

Assessment criteria is also a phrase which suffers from a vagueness in terminology, as it is commonly confused with marking criteria, grading criteria, assessment rubric, and marking standards. The term itself has gained in currency and in importance as an answer to the widespread demand that assessment in education should carry greater accountability. As part of that movement, the use of assessment criteria is important not only because of the perceived need to improve marking practices in terms of their reliability and validity, but also to help students to improve their performance. In short, there has been a political imperative which can be summarized as a result of the greater

public demand and the quality assurance movement for accountability and for the assessment process to be demystified. The public demand has come from parent pressure in the schools system and student pressure in the higher education sector where, increasingly, students are paying for their education. The pedagogical imperative comes from the move to student-centered learning with learning outcomes putting the focus on what students will be able to do and assessment criteria enabling them to understand such requirements. The move has not been without its critics. Sadler (2005), for example, has argued that there is no common understanding of what criteria-based assessment means and that teachers still make subjective judgments. He suggests that if teachers were to shift to thinking primarily in terms of standards, with criteria playing a minor role, they would better be placed to meet the real pedagogical aims of this type of approach to assessment.

Underlying the practice of defining and using assessment criteria is the psychometric approach with its emphasis on validity and reliability which has been argued to be the main concern of any assessment process. Put simply, validity can be defined in terms of demonstrating that it measures what it is supposed to measure. If, for example, a learning outcome is that the learner will be able to ride a bicycle, a valid assessment criterion would be the learner can pedal a bike unaided for 2 m. An invalid assessment criterion would be the learner can write two paragraphs summarizing how to balance when riding a bicycle. No amount of theoretical written description would prevent the learner from falling off! At one level, to achieve validity stronger links are needed between learning theories and the latest thinking in testing, which is the psychometric measurement approach. At another level, the more complex learning outcomes, such as higher order thinking, critical analysis, and creativity among others, mean more weight has to be put on the subjective judgment of the assessor, who will infer certain characteristics from the student's performance thus reducing both validity and reliability. If an assessment is unreliable, different results are obtained each time the assessment is used. Reliability can be measured by agreement between two markers, called inter-marker reliability, or by repeated testing, meaning the same marker would give the same grade to a piece of work on two separate occasions, called test–retest reliability.

If assessment lacks reliability, it limits confidence in what can be inferred from the learning outcomes. This is particularly important when the assessment is high stakes and some sort of certification of the learner's achievements is involved. Unfortunately, attempts to increase reliability usually mean a decrease in validity as it only becomes possible when what is to be assessed is stripped down to small component elements, hence mirroring the same issue raised with a psychometric approach to learning objectives and learning outcomes.

Assessment grids or marking rubrics are widely used across all the educational sectors in an attempt to specify to both marker and student what is required and the levels of achievement. Typically this will be a matrix which incorporates the specification of the assessment criteria which should be linked to the learning outcomes together with an associated scale. Sometimes the scale is numerical (e.g., 10–1 where 10 is "perfect" and 1 is "very poor") or categorical (e.g., Grades A–F, where A is "outstanding" and F is failure). In higher education it is common for the letter grades to be translated to a numerical score where A typically represents < 70 marks out of 100 and F represents > 35 marks out of 100. In each of the categories for every criterion will be qualitative verbal descriptors which can cause difficulty when the matrix has too many numerical or grade categories. A simple example would be the essay criterion "addresses the question" in which:

A. the question is completely addressed throughout the essay, by a sophisticated use of content
B. the question is fully addressed throughout the essay, by a competent use of content
C. the question is mainly addressed throughout the essay, with some minor irrelevant content
D. the question is occasionally addressed throughout the essay, but much of the content is irrelevant
E. the question is hardly addressed throughout the essay and most of the content is irrelevant
F. the question is not addressed at all in the essay and all of the content is irrelevant

Immediately, one can see from this small example how quickly such a matrix becomes over-specified and how one struggles to describe the qualitative descriptors in any but the most general of terms. "Addressing

the question" is a broad assessment criterion within which are nested many smaller but interlinked criteria, such as "interpretation," "clarity," "definition," "setting parameters," the list could be almost infinitely extended, so the broad criterion has to act as a proxy for what are much smaller and more subtle criteria all interwoven. Similarly, the descriptors act as a broad indicator of what is to be inferred from the assignment. What, for example, is the difference between "completely" and "fully" or between "sophisticated" and "competent"? One strategy is to use exemplars, but this can sometimes have the unfortunate effect of limiting students' horizons as to what is achievable and perpetuating the misguided idea that there is only one right answer.

Another criticism of assessment grids is that they encourage a tendency for the descriptors to be phrased negatively rather than positively (see C, D, E, and F in the above example). Further difficulties arise in the weighting of assessment criteria as not all will be of equal importance, which can lead to the variability between markers who have their own implicit weightings and mark accordingly. This is not always made apparent to students. Many teachers will use such marking grids if they are compelled to but will then give a holistic mark and adjust the marking grid marks so that they add up to their intuitive overall holistic mark. Despite such reservations, marking grids are common and are promoted as enabling assessment criteria to be clarified. This allows more objective standards to be set and determines the level and focus of assessment criteria and their relationship with marking grades and standards.

Important Scientific Research and Open Questions

The most fiercely contested terrains still center on the measurement aspect of learning objectives, learning outcomes, and assessment criteria. There are two main positions:

1. The technical positivist approach to assessment derived from the psychological branch of psychometrics which is an attempt to measure human behaviors, personality characteristics, attitudes, and, more recently, academic achievement. By adopting such principles, proponents argue that

assessment will be fair and objective. To introduce any other judgments is to compromise the validity and integrity and even the moral responsibility of assessment particularly that which is high stakes and which can have a considerable influence on the paths people take in their lives.

2. The professional/connoisseurship is a reaction against the technical approach and instead champions subjectivity, holistic judgments, and qualitative approaches to assessment. In this position, the assessors' claim to be expert is central. Experts are known to rely less on rules, routines, or expressly articulated deliberations, hence the opposition to learning outcomes and assessment criteria. There is, however, a body of evidence which shows that expert judgment is not always accurate. One example is the study by Newstead and Dennis (1994) which showed how experienced external examiners gave substantially different grades to the same piece of work. Evidence in the literature also shows that assessment by experts is not always superior to that made by novice assessors who do tend to stick more closely to assessment rubrics, rather than relying on heuristics or short cuts.

The latest thinking in the assessment literature suggests there is a middle way which embraces both these positions rather than treating them as oppositional dichotomies This takes a post-structuralist approach and recognizes the notion that assessment is a sociopolitical practice, an approach that originated in school sector with the assessment *for* learning movement, where one of the concepts is that of multiple perspectives rather than single "objective truths." It is too early to say whether this movement will become established and, as yet, there is little evidence for its efficacy, but one question which will continue to engage the assessment community is the need expressed by Sadler, among others, to enable students to develop the ability to judge the quality of their own work, which may involve them negotiating their own learning outcomes and assessment criteria.

Cross-References

► Assessment in Learning
► Diagnosis of Learning
► Evaluation of Student Progress in Learning
► Learning Outcomes

References

Black, P. J., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education, 5*, 7–74.

Chartered Institute of Educational Assessors (2010) Purposes of assessment. http://www.ciea.org.uk/knowledge_centre/articles_speeches/general_articles/purposes_of_assessment.aspx. Accessed 25 April 2010.

Eisner, E. (1979). *The educational imagination.* New York: Macmillan.

Heywood, J. (2000). *Assessment in higher education. Student learning, teaching, programmes and institutions.* London: Jessica Kingsley Publishers.

Newstead, S. E., & Dennis, I. (1994). Examiners examined: The reality of exam marking in psychology. *The Psychologist, 7*, 216–219.

Sadler, D. R. (2005). Interpretations of criteria-based assessment and grading in higher education. *Assessment and Evaluation in Higher Education, 30*, 175–194.

Soles, S. (1963). Educational quackery external to our schools: What is a professional response? *Phi Delta Kappan, 44*, 299–302.

Spady, W. (1994). *Outcome-based education: Critical issues and answers.* Arlington: American Association of School Administrators.

Learning Cycles

AYTAC GOGUS
Center for Individual and Academic Development, Sabanci University CIAD, Istanbul, Turkey

Synonyms

Continuous improvement; The experiential learning cycle; The learning cycle

Definition

The learning cycle is an inquiry-based teaching approach and a philosophy of education/model of instruction that can promote *critical thinking, active learning* and *meaningful learning* (Marek et al. 2003; Sowell 1993). Marek et al. (2003) and Sowell (1993) refer to the three-phase learning cycles that include exploration, invention, and organization. Some researchers argue for additional phases of the learning cycle (e.g., Kolb 1984; Tsai and Lee 2006). Kolb's theory of experiential learning (1984) provides a model called The Kolb Cycle, The Learning Cycle, or The Experiential Learning Cycle. The Kolb Cycle has four phases which includes concrete experience, reflective

observation, abstract conceptualization, and active experimentation.

Theoretical Background

The learning cycle, originally developed by Robert Karplus (1927–1990) to improve teaching of science, views the students as active learners, which is an important part of Piaget's theory of learning (Marek et al. 2003). According to Marek et al. (2003), the learning cycle was derived from Piaget's model of *mental functioning* which refers to the cognitive processes of ► assimilation, ► accommodation, and organization as explained below:

► The Exploration phase of the learning cycle allows learners to *assimilate* the essence of the science concept. In other words, the first steps toward developing concept understanding are to gather pertinent data through direct experiences and to do so until disequilibrated. The Concept Introduction phase is designed to guide learners in the interpretation of their data and experiences resulting in reequilibration and the *accommodation* of the science concept. The Concept Application phase of the learning cycle provides learners with opportunities to relate the newly developed science concept to everyday applications and to other concepts through a cognitive process Piaget called *organization*. (p. 147)

The learning cycle places learners at the center of their learning experiences, encouraging them to engage in exploration, interpret new information and experiences and thus form new understandings, and relate those understandings to other concepts by organizing new information.

The Kolb's (1984) cycle, a comprehensive and influential model of experiential learning, is inspired by the work of Kurt Lewin (1890–1947) about adult learning and group dynamics. According to Kolb's (1984) cycle, people go through a learning process which starts concrete and proceeds to become abstract, but then cycles around to concrete again. The cycle is formed by two axes (x-axis and y-axis). While y-axis indicates concrete experience-abstract conceptualization, x-axis indicates reflective observation-active experimentation. The two axes form four quadrants and each one is referred to as a stage or a style of learning for which Kolb (1984) uses the terms: (1) diverging, (2) assimilating, (3) converging, and (4) accommodating. Figure 1 (Kolb 1984)

Learning Cycles. **Fig. 1** Kolb's learning cycle (Kolb 1984)

shows Kolb's a four-stage cycle with four quadrants that refers to a style of learning.

Around the Kolb's cycle, people are in the process of observing and personally experiencing the surroundings, they frequently form certain concepts and test these concepts in real situations, thus, a concept becomes the learner's concrete experience, and later becomes a decision rule for similar matters (Tsai and Lee 2006).

Important Scientific Research and Open Questions

According to Marek et al. (2003), the learning cycle accommodates all methods of teaching (e.g., questioning strategies, group work, demonstrations, lectures) as well as all models of instruction (e.g., cooperative learning, direct instruction) to improve the quality of education. Marek et al. (2003) state that

► Through its fundamental nature, the learning cycle fosters scientific inquiry by allowing students to question and formulate solvable problems; to reflect on and construct knowledge from data; to collaborate and exchange information while seeking solutions; and to develop concepts and relationships from empirical experience. (p. 148)

In addition, Marek et al. (2003) emphasize that the learning cycle continues to be an integral component of many teaching practices and research studies which indicate the learning cycle as an effective teaching approach that enhances student outcomes.

Sowell (1993) applied the three-part learning cycle to an art history course for college students to help students realize that students' old methods of thinking

may not be adequate and to help students test new methods. Sowell (1993) summarizes the application of the learning cycle into an art history course:

► This technique [the three-part learning cycle] includes an exploration in which students, working in small groups, are asked to manipulate concrete objects... In order to complete the exploration, students are challenged to move to formal reasoning and develop new modes of thinking. Working in groups ensures that methods of reasoning will be tested as students functioning on different levels try to accomplish the task together...The second phase of the learning cycle is that of invention in which the new concepts are made explicit. This may begin in the groups and then is reinforced as the professor leads the class in a discussion of the results of group work. Finally, students use the ideas invented to solve new problems in an application phase, which may be accomplished in class work or in outside assignments. It is an important step when students realize that they can apply the new concepts not only to examples used in class but also to new situations. (p. 19)

According to Sowell (1993), the learning cycle can be applied to the teaching of many subjects and can offer a means for introducing active and group learning into traditional courses to present new concepts in a nonthreatening way and to encourage students to develop their own thinking and take responsibility for their own learning.

Considering other applications of the learning cycles, the most direct application of the Kolb's cycle is using it to ensure that teaching and tutoring activities give full value to each stage of the process. The instructor, tutor, or mentor should observe and follow that the learners round the cycle by asking questions which encourage Reflection, Conceptualization, and Active Experimentation (Kolb 1984).

According to social constructivism, learning is a social process and meaningful learning occurs in social activities. Social constructivist approaches emphasize the importance of group learning in which learners engage in how to organize new knowledge while creating new mental models as means of learning in group studies. Gogus presents a new learning cycle in regard to learning in group studies based on Kolb's (1984) theory of experiential learning (Gogus and Arikan 2009). Figure 2 shows this learning cycle

Learning Cycles. Fig. 2 Learning cycle for learning in group studies (Gogus and Arikan 2009)

which starts with a planning phase followed by sharing, interpreting, and developing phases. Evaluation phase forms the middle of the cycle since each phase receives feedback from the evaluation phase. This characteristic of the learning cycle makes it both a linear and a heuristic instructional system model (Gogus and Arikan 2009).

As an another application, Tsai and Lee (2006) use the learning cycle theory to discuss knowledge internalization. According to Tsai and Lee (2006), Kolb focuses on individual learning and goes on to describe the process of knowledge formation by dividing the learning cycle into four learning processes: concrete experience, observation, testing concepts in real situations, and formation of concepts. Tsai and Lee (2006) integrate the four phases of the Kolb' learning cycle into the distinguished four kinds of knowledge as follows:

● Self-motivated creativity (care-why) – concrete experiences
● Systems understanding (know-why) – reflection or observation
● Advanced skills (know-how) – active experimentation or testing concepts in real situations
● Cognitive knowledge (know-what) – abstract conceptualization or formation of concepts

Figure 3 shows knowledge internalization based on complete learning cycle (Tsai and Lee 2006).

As a new learning cycle model, Singer and Moscovici (2008) propose a frame for organizing the classroom interactions within a constructivist approach. This learning cycle, called IMSTRA, consists

Learning Cycles. Fig. 3 Knowledge internalization based on complete learning cycle (Tsai and Lee 2006)

of three general phases: IMmersion, STRucturing, Applying, each with two sub-phases that highlight specific roles for the teacher and the students. The IMSTRA model provides a powerful tool for curriculum development, being used in producing mathematics textbooks, as well as in developing teaching courses for long-distance teacher training program (Singer and Moscovici 2008). In addition, Singer and Moscovici (2008) analyze learning cycles in various areas and point out that learning cycles' models are very dynamic entities and tend to build on previous work as well as on the change in the context. Singer and Moscovici (2008) state that learning cycles get adjusted to fit the new learning environments since students, teachers, communities, as well as materials and equipment available all change over time.

Cross-References
► Active Learning
► Experiential Learning Theory
► Kolb's Learning Styles
► Learning Spiral
► Learning Styles

References

Gogus, A., & Arikan, H. (2009). Strategies of learning in groups. In *The First International Congress of Educational Technology, "Trends and Issues in Educational Research"*, organized in collaboration with EARA, INASED, IAQI, and Turkish Ministry of Education, May 1–3, 2009, Canakkale, Turkey.

Kolb, D. A. (1984). *Experiential learning experience as a source of learning and development*. Englewood Cliffs: Prentice Hall.

Marek, E. A., Laubach, T. A., & Pedersen, J. (2003). Preservice elementary school teachers' understanding of theory-based science education. *Journal of Science Teacher Education, 14*(3), 147–159.

Singer, F. M., & Moscovici, H. (2008). Teaching and learning cycles in a constructivist approach to instruction. *Teaching and Teacher Education, 24*, 1613–1634.

Sowell, J. E. (1993). A learning cycle approach to art history in the classroom. *Art Education, 46*(2), 19–24.

Tsai, M.-T., & Lee, K.-W. (2006). A study of knowledge internalization: from the perspective of learning cycle theory. *Journal of Knowledge Management, 10*(3), 57–71.

Learning Defense

Knud Illeris
Department of Learning, The Danish University
School of Education, Aarhus University, Copenhagen
NV, Denmark

Synonyms
Everyday consciousness; Non-learning

Definition

The term *Learning defense* refers to the Freudian concept of mental defense or defense mechanisms. These are hypothetical constructs of the psychoanalytical theory, referring to mental functions rooted in situations in which early traumatic experiences have been repressed into the unconscious, and from there develop a barrier which blocks or distorts the experience of everything that may be associated with the original situation. So this kind of defense is always an individual and personal matter with the nature of a psychological disorder. This will, of course, also influence an individual's learning in areas which relate to this disorder. However, in modern society a different kind of learning defense has developed, which is not due to individual and traumatic reasons but to general societal features, related to the amount and nature of influences and conditions to which all people are exposed.

Theoretical Background

The understanding of learning defense was first developed in the 1940s and 1950s by the French philosopher Henri Lefebvre (Lefebvre 1991) and later by the

German sociologist Thomas Leithäuser (Leithäuser 1976). However, it was the Danish learning theorist Knud Illeris who in several writings from the 1980s elaborated the concept further as part of his *comprehensive learning theory* (Illeris 2007).

The background of the concept is that the complexity of modern societies implies that people meet so many learning possibilities and influences that it far exceeds their learning capacity to take all this in – to try to do so would very soon lead to a mental breakdown. People therefore have to develop a mechanism to sort out what to learn and what not to learn, and as they cannot either manage to make all these choices consciously this mechanism has to be semiautomatic. For example, when people turn on the TV news they receive a lot of input information which could be transformed into learning, but only very few of them are actually taken in and learned, and generally people do not consciously direct this selection process. It happens automatically and operates on two levels.

First, there is a level of rejection. There are some topics that people habitually reject as a whole, it could be sport or financial affairs or whatever. There can also be a general rejection of features people find cruel or politically unacceptable or the like. Further, a lot of features are rejected just because people find them of no importance or interest. But all this usually happens without any conscious decisions.

Second, for topics people do take in, they can practice what the Swiss epistemologist Jean Piaget has termed a "distorted assimilation," that is, people twist the content or the message in a way so that it is in accordance with their pre-understanding or prejudice of the area in question and thereby prevent new learning.

Another significant feature is, that as the world and our existence during the second half of the twentieth century gradually have become much more complicated learning defense is not only caused by and directed toward the amount of influences and learning possibilities, but also toward certain kinds of content which an individual finds unbearable, disgusting, or the like. Further, during the latest decades learning defense against frequent changes of all sorts of life conditions have spread rapidly. A very important kind of learning defense today is what can be termed *identity defense*, that is, defense against the learning or accepting changes of identity which become necessary when people are faced with severe changes in their life conditions. In general, learning defense should today be regarded as the most common and widespread reason for adequate learning not taking place.

From a learning point of view it is important to emphasize that human beings are not born with any defense toward learning. On the contrary, it is something which has itself developed through learning. In early childhood, children are eager to learn as much as possible in order to capture the world in which they grow up. But it is not long before the first tendencies of learning defense can be seen, for example, against parents' admonitions or encroachments from older children. In school a defense against certain content, subjects, or teachers may occur, especially when teachers try to press or force pupils to learn something they cannot see the meaning of. But a regular defense system or everyday consciousness is usually not developed until during the teenage years, and only in adulthood will it normally take on the rather stable form that can be termed as a defense mechanism.

Important Scientific Research and Open Questions

Mainstream learning theory and research has not been dealing very much with *non-learning*, and it is significant that the concepts of everyday consciousness and learning defense have been developed in other theoretical areas or from the sideline. Both concepts relate to the Freudian theory of psychoanalysis and are accordingly developed and researched mainly by social, psychological, and philosophical studies. They are fundamentally hypothetical, and their scientific value depends on their ability to guide practice.

The concept of learning defense has so far been developed mainly in relation to adult education, and it is probably also in this area that learning defense is most widespread and important due to its ability to explain learning difficulties. In his studies of everyday consciousness, Thomas Leithäuser has pointed to *thematization* as a way to break through learning defense, that is, to develop a thematic dialogue with adult students about the topic in question, starting with how it is related to and relevant for their everyday life and experience, and how a deeper understanding may help them to improve their everyday situation.

Cross-References

▶ Freud, Anna
▶ Inhibition of Learning
▶ Learning Resistance

References

Freud, A. (1942 [1936]). *The ego and the mechanisms of defence.* London: Hogarth Press.

Illeris, K. (2007). *How we learn: Learning and non-learning in school and beyond.* London: Routledge.

Illeris, K. (2009). A comprehensive understanding of human learning. In K. Illeris (Ed.), *Contemporary theories of learning: Learning theorists . . . in their own words.* London: Routledge.

Lefebvre, H. (1991 [1947]). *Critique of everyday life.* London/New York: Verso.

Leithäuser, T. (1976). *Formen des Alltagsbewusstseins.* Frankfurt a.M: Campus (*The forms of everyday consciousness*).

Learning Diagnosis

▶ Remedial Learning

Learning Diary

▶ Self-Reflecting Methods of Learning Research

Learning Difficulties

▶ Vulnerability for Learning Disorders

Learning Disabilities

▶ Language-Based Learning Disabilities
▶ Socioemotional and Academic Adjustment Among Children with Learning Disorders

Learning Disability

▶ Learning and Fluid Intelligence Across the Life Span
▶ Vulnerability for Learning Disorders

Learning Disability (UK): Intellectual Disability Mental Retardation

▶ Anxiety Disorders in People with Learning Disabilities

Learning Disorders

▶ Vulnerability for Learning Disorders

Learning Dynamics in Social Dilemmas

MICHAEL WALTON MACY[1], ANDREAS FLACHE[2]
[1]Department of Sociology, Cornell University Social Dynamics Laboratory, Ithaca, NY, USA
[2]Department of Sociology, ICS, University of Groningen, TG Groningen, The Netherlands

Synonyms

Evolutionary dynamics, collective action

Definition

A *social dilemma* is defined as a collective action situation in which a tension exists between individual autonomy and collective interdependence. This tension can be formalized as an *n*-person positive sum game.

Theoretical Background

Evolution has played a cruel trick on our species. Physically, we are poorly equipped to prosper as self-reliant individuals in what enlightenment thinkers called the "state of nature," yet we also lack the cognitive hardwiring for cooperation observed among social insects. As a consequence, we often find ourselves confronted with a choice between doing what is best for the group and what is best for oneself. This tension between collective interdependence and individual autonomy has come to be known as a "social dilemma" (Van de Rijt and Macy 2009).

Social dilemmas can be formalized as *n*-person positive sum games. However, the Nash equilibrium, the main solution concept in analytical game theory, cannot make precise predictions about the outcome of repeated games. Nor can it tell us much about the dynamics by which a population of players moves from one equilibrium to another. An added concern is that analytical game theory imposes unrealistic assumptions about the knowledge and calculating abilities of the players that often bear little resemblance to actual decision making, even by business firms where forward-looking calculated rationality seems most plausible (Simon 1992).

These limitations have motivated efforts to explore backward-looking alternatives to the conventional assumption of forward-looking calculation, based on evolutionary adaptation (Binmore and Samuelson 1992) and learning (Fudenberg and Levine 1998). Evolution modifies the frequency distribution of strategies competing to survive and reproduce in a given population, while learning modifies the probability distribution of strategies competing for the attention of a single individual. In both evolution and learning, the probability that any randomly chosen individual uses a given strategy increases if the associated payoff is above some benchmark and decreases if below. In evolution, the benchmark is typically assumed to be the mean payoff for the population (Weibull 1998). In learning, the benchmark depends on the individual's aspirations.

Although evolutionary models based on competitive selection have contributed valuable insights into biological adaptation, concerns about their applicability to cultural and social evolution have led to growing interest in a learning-theoretic alternative. The principle of reinforcement learning dates to the cognitive psychology of William James. If a behavioral response has a favorable outcome, the neural pathways that triggered the behavior are strengthened, which "loads the dice . . . in favor of those of its performances which make for the most permanent interests of the brain's owner" (James 1981, p. 143). Thorndike (1898/1999) later refined the idea as the Law of Effect, based on the principle that "pleasure stamps in, pain stamps out." This early connectionist model of changes in the strength of neural pathways has changed very little during the 100 years since it was first presented and anticipates the error back-propagation used in contemporary neural networks (Rumelhart et al. 1986).

Analytical game theory assumes that players have sufficient knowledge and cognitive skill to make accurate predictions about the consequences of alternative choices. Learning theory lightens the cognitive load by allowing players to base these predictions on experiential induction rather than logical deduction. Learning theory also differs from game theory in positing two distinct cognitive mechanisms that guide decisions toward better outcomes, approach, and avoidance. Rewards induce approach behavior – a tendency to repeat the associated choices rather than search for alternatives that might have higher utility, a behavioral tendency March and Simon (1958) called "satisficing." In contrast, punishments induce avoidance, leading to a search for alternative outcomes, despite the risk that the alternatives might be even worse.

Approach and avoidance depend on whether or not an outcome is regarded as satisfactory relative to an aspiration level. If the payoff exceeds aspirations, the probability increases that the behavior will be repeated rather than searching for a superior alternative. If the payoff falls below aspirations, the probability decreases that the behavior will be repeated.

Applied to learning in games, approach and avoidance imply two dynamic alternatives to the traditional Nash equilibrium. Mutual rewards can generate a self-reinforcing pure-strategy equilibrium, even if an alternative strategy has higher utility. The number of these equilibria in a social dilemma depends on the number of outcomes in which all players are rewarded. A mix of rewards and punishments can generate a self-correcting mixed-strategy equilibrium in which outcomes that punish cooperation or reward non-cooperation (causing the probability of cooperation to decrease) balance outcomes that reward cooperation or punish non-cooperation (causing the probability of cooperation to increase). The expected change in the probability of cooperation is zero when the dynamics pushing the probability higher are balanced by the dynamics pushing in the other direction, like a tug-of-war between two equally strong teams.

Adaptive agents can also respond to an aversive stimulus by adapting their aspiration level, a process sometimes referred to as "habituation." Habituation can lead to desensitization to a recurrent stimulus, whether reward or punishment, and to increased sensitivity to change in the stimulus. Thus, habituation to reward increases sensitivity to punishment. Conversely,

habituation to punishment has a numbing effect that increases sensitivity to reward.

Important Scientific Research and Open Questions

Applications of learning theory to the problem of cooperation do not solve the social dilemma, they merely reframe it: Where the penalty for cooperation is larger than the reward, and the reward for non-cooperative behavior is larger than the penalty, how can penalty-aversive, reward-seeking agents elude the trap of mutual punishment? The earliest answer was given by Rapoport and Chammah (1965), who used learning theory to propose a Markov model with state transition probabilities given by the payoffs for each state. Macy (1991) elaborated Rapapport and Chammah's analysis using computer simulations of their Bush–Mosteller stochastic learning model. In general form, the Bush–Mosteller model consists of a stochastic decision rule and a learning algorithm in which the consequences of a decision create rewards and punishments that update the probability that the decision will be repeated. Applied to two-person social dilemmas, the model assumes binary choices (C or D) that intersect at one of four possible outcomes (mutual and unilateral cooperation and defection), each with an associated payoff that is evaluated as satisfactory or unsatisfactory relative to an aspiration level. Satisfactory payoffs present a positive stimulus (or reward) and unsatisfactory payoffs present a negative stimulus (or punishment). Rewards and punishments then modify the probability of repeating the associated action. Using this model, Macy showed how a random walk may lead adaptive agents out of a non-cooperative equilibrium and into a mutually rewarding equilibrium characterized by stable cooperation, a process he characterized as stochastic collusion, the backward-looking equivalent to the tacit collusion engineered by forward-looking players. Recently, Izquierdo et al. (2008) provided an analytical generalization of this mechanism, identifying how the medium and long term dynamics of the learning process decisively depend on the speed of learning of the players.

Roth and Erev (1995) have proposed an alternative to the earlier Bush–Mosteller formulation. Their payoff-matching model draws on the matching law which holds that adaptive agents will choose between alternatives in a ratio that matches the ratio of reward.

Applied to social dilemmas, both the Bush–Mosteller and Roth–Erev models identify a key difference with analytical game-theoretic solutions: the existence of a cooperative equilibrium that is not Nash equivalent, even in mixed-motive games where mutual cooperation is also a Nash equilibrium.

In a follow-up study, Macy and Flache (2002) showed that stochastic collusion is viable only within a narrow range of aspiration levels. If aspirations are too low, mutual cooperation can suffer from insufficient dissatisfaction with socially deficient outcomes. Mutual cooperation can then be preempted by attraction to an alternative self-reinforcing equilibrium that is socially deficient, such as mutual defection. If aspirations are too high, agents may not feel sufficiently rewarded by mutual cooperation to avoid the temptation to defect. Aspirations that adapt with experience (producing habituation to stimuli) do not gravitate into the window of viability; rather, they are the worst of both worlds.

In future research, cognitive game theory faces the challenge to show how more sophisticated strategy choices might emerge from simple learning principles. As a first step, Macy (1991) used artificial neural networks to see if adaptive agents could learn to cooperate based on conditionally cooperative supergame strategies, but found that the coordination complexity of stochastic collusion increased exponentially with the strategy space. Much more work is needed to see how adaptive agents might also learn to find nodal points or other solutions to the problem of coordination complexity. Previous work (Flache and Macy 1996; Macy 1991) also suggests that the coordination complexity of stochastic collusion increases with the number of players and with payoff asymmetry, and decreases with social influence. Much more work needs to be done to study the evolution of cooperation at the cognitive level, especially where dyadic games are embedded in dynamic social networks.

While theoretical elaborations are clearly needed, we should not lose sight of the elementary principles suggested by a simple learning model of the dynamics of cooperation. Social order may ultimately depend less on top-down global coordination or enforcement than on bottom-up emergence of self-enforcing norms for cooperation in everyday life. If so, then the emphasis in agent-based modeling of the evolution of cooperation may need to shift downward, from evolutionary

dynamics at the population level to cognitive dynamics at the level of the individual. The simple but elegant Bush–Mosteller learning model is a cautious first step in this direction.

Acknowledgments

Cross-References

► Cooperative Learning
► Evolution of Learning
► Habituation
► Social Construction of Learning
► Social Influence and the Emergence of Cultural Norms

References

Binmore, K. G., & Samuelson, L. (1992). Evolutionary stability in repeated games played by finite automata. *Journal of Economic Theory, 57*, 278–305.

Flache, A., & Macy, M. W. (1996). The weakness of strong ties: Collective action failure in a highly cohesive group. *Journal of Mathematical Sociology, 21*, 3–28.

Flache, A. & Macy, M. W. (2002). Stochastic collusion and the power law of learning. *Journal of Conflict Resolution, 46*, 629–653.

Fudenberg, D., & Levine, D. (1998). *The theory of learning in games.* Boston: MIT Press.

Izquierdo, S. S., Izquierdo, L. R. & Gotts, N. M. (2008). "Reinforcement learning dynamics in social dilemmas." *Journal of Artificial Societies and Social Simulation, 11*(2), 1. http://jasss.soc.surrey.ac.uk/11/2/1.html

James, W. (1890/1981). *Principles of psychology.* Cambridge: Harvard University Press.

Macy, M. W. (1991). Learning to cooperate: Stochastic and tacit collusion in social exchange. *The American Journal of Sociology, 97*, 808–843.

Macy, M. W. (1996). Natural selection and social learning in Prisoner's dilemma. Coadaption with genetic algorithms and artificial networks. *Sociological Methods & Research, 25*, 103–137.

Macy, M., & Flache, A. (2002). Learning dynamics in social dilemmas. *Proceedings of the National Academy of Sciences, 99*, 7229–7236.

March, J. G., & Simon, H. A. (1958). *Organizations.* New York: Wiley.

Rapoport, A., & Chammah, A. M. (1965). *Prisoner's dilemma: A study in conflict & cooperation.* Ann Arbor: Michigan University Press.

Roth, A. E., & Erev, I. (1995). Learning in extensive form games: experimental data and simple dynamic models in the intermediate term. *Games and Economics Behavior, 8*, 164–212.

Rumelhart, D. E., McClelland, J. L., & The PDP Research Group. (1986). *Parallel distributed processing: Explorations in the microstructure of cognition.* Cambridge, MA: MIT Press.

Simon, H. (1992). Decision making and problem solving. In M. Zey (Ed.), *Decision making: alternatives to rational choice models* (pp. 32–53). Newbury Park: Sage.

Sokolov, Y. N. (1963). *Perception & the conditioned reflex.* Oxford: Pergamon.

Thorndike, E. L. (1898). Animal intelligence: an experimental study of the associative processes in animals. *Psychological Review Monograph Supplement, 2*(4, Whole No. 8).

Van de Rijt, A., & Macy, M. (2009). The problem of order: egoism or autonomy? *Advances in Group Processes, 26*, 25–51.

Weibull, J. W. (1998). Evolution, rationality and equilibrium in games. *European Economic Review, 42*(3–5), 641–649.

Learning Edge Momentum

ANTHONY ROBINS
Department of Computer Science, University of Otago, Dunedin, New Zealand

Synonyms

LEM

Definition

Learning edge momentum (LEM) is a mechanism whereby the success or failure of learning becomes self-reinforcing over time. Given some target domain of new concepts, any successful learning makes it somewhat easier to acquire further related concepts from the domain, and unsuccessful learning makes it somewhat harder. Thus learning acquires momentum toward either a successful or an unsuccessful outcome for the domain as a whole. In certain circumstances, this effect can be particularly pronounced, such that early success or failure can become strongly predictive of the final learning outcome.

Theoretical Background

It is a well-known educational principle that we learn "at the edges of what we know." Almost by definition, understanding (on a short timescale) and learning (over a longer period) depends on fitting new material

into the context of existing knowledge. Cognitive psychologists have shown that new information is stored, retained, and retrieved most effectively when it is integrated into existing knowledge. The richer and more elaborate the links between new and old knowledge, the more effective learning appears to be. Thus effective learning depends on giving new information a "meaningful interpretation," processing it in a "deep and meaningful way," or elaborating/embellishing it with further meaningful details (Anderson 2005).

This fundamental observation finds its expression in the many specific mechanisms which highlight the active role of existing knowledge in assisting new learning. ▶ Analogical reasoning involves the transfer of structural information from a known "source" or "base" domain to the new "target" domain to be explained or understood. When learning is seen as ▶ transfer, the most important factor is the knowledge that the individual brings to and uses in the learning situation; it is "the very foundation of learning, thinking and problem solving" (Haskell 2001). Skill transfer focuses on practical and vocational issues relating to training, performance, and the factors involved in achieving good transfer from a training task to a real-world situation.

In the developmental literature, the concept of a sequence of stages of development is built on the assumption that cognition at some given level depends on, and cannot develop without, the capabilities of prior levels. Early psychologist Lev Vygotsky proposed that children learn most effectively when assisted in the zone that slightly extends their current level, the ▶ zone of proximal development. This theory has been highly influential in the educational field, leading to concepts such as "progressive problem solving" and "working at the edge of one's competence" (Bereiter and Scardamalia 1993). ▶ Scaffolding emphasizes the role of the teacher in learning, and the dynamic process of providing support for learning where it is needed and withdrawing it as learning is secured. ▶ Bootstrapping is the mechanism whereby learners are able to use their existing knowledge to facilitate new learning, sometimes described as "a series of *local repairs* of a knowledge structure," where "local repairs require simple mechanisms such as adding links, deleting links, reattaching links, and so forth." Crucially this requires that the learner "recognizes that the repairs are needed, by reflecting on the differences between his or her existing knowledge and new knowledge" (Chi and Ohlsson 2005).

All of the above is recognition in various forms that we learn at the edges of what we already know. The consequences of this principle in terms of the pacing, structuring, and presentation of material are well known to educational theorists and teachers. Less well explored and understood is the way in which this property of learning interacts with the particular nature of the material being learned, and how its consequences express themselves over time. Learning edge momentum (LEM) is a hypothesized mechanism which relates to both of these factors (Robins 2010).

The core of the LEM hypothesis is the common sense claim that given some target domain of new concepts, any successful learning makes it somewhat easier to acquire further related concepts from the domain, and unsuccessful learning makes it somewhat harder. Successful learning adds new "edges" to existing knowledge, which in turn facilitates the *local repair* process of adding further new concepts. Unsuccessful learning means that no new edges are added, making further learning/*local repair* more difficult. When learning related concepts sequentially from a domain, this simple effect means that the success or failure of learning becomes self-reinforcing over time, and learning acquires momentum toward either a successful or an unsuccessful outcome for the domain as a whole. A further claim of the LEM hypothesis is that not all learning edges are created equal. For some domains the significance of the LEM effect is particularly strong, such that early success or failure can become strongly predictive of the final learning outcome.

LEM varies in strength depending on the properties of the target domain. In particular, momentum varies in proportion to the extent to which the concepts in the domain are either independent or dependent (interrelated/integrated). When the domain consists of *tightly integrated* concepts, the significance of the edges is increased because they afford multiple constraints on and connections to related concepts. In such cases the momentum effect (positive or negative) will be strong.

By analogy, we can think of learning as adding pieces to an existing structure of some kind. For a *tightly integrated* domain, this process is like adding pieces to a growing jigsaw puzzle. The edges of the puzzle pieces are sharply defined; there is only one correct place that each new piece can fit. Higher order

structure in the puzzle's "picture" provides further useful constraints. As the puzzle grows, the emerging edges and structures provide so many constraints that adding each new piece becomes easier. If on the other hand we have not successfully begun to build the puzzle then new pieces have nowhere to fit, and if they are lost or placed at random the task quickly becomes impossible. Where the target domain is not tightly integrated, the task is more akin to building a tower out of blocks. There is probably considerable flexibility in the range of exact forms that an acceptable finished tower might take, and there is no single correct place for any given block. Placing blocks does not necessarily get any easier, so that placing the last block may not be any easier or any harder than placing the first.

To summarize, LEM arises out of an interaction between the learner and the learned. For some knowledge domains, *tightly integrated* and highly constrained like a jigsaw puzzle, the momentum effect is strong. Each concept successfully acquired creates rich new edges that constrain and assist the *local repair* episodes of further learning (and conversely the failure to acquire a concept is damaging). The success or failure of learning becomes self-reinforcing over time, and learning acquires momentum toward either a successful or an unsuccessful outcome for the domain as a whole, such that early success or failure can become strongly predictive of the final learning outcome.

Important Scientific Research and Open Questions

The LEM hypothesis arose from the consideration of outcomes in a particular subject domain, the learning of a first programming language (Robins 2010). In Computer Science Education (CSEd) literature spanning more than 40 years it has often been noted that learning a first programming language appears to be very difficult, and that many students fail. Paradoxically, however, many students also do very well. Typical (large, open entry) introductory programming courses usually have a bimodal distribution of results, with more fail grades, more high grades, and fewer midrange grades than other courses.

The bimodal grade distribution is a big robust effect. It is persistent across several countries, several decades, many programming languages, and very many individual teachers and students. A big robust effect should have a big robust cause. The working hypothesis

in the CSEd literature has been that there are simply two kinds of people in the world, those who can program and those who cannot (the former group sometimes flippantly described as having the "programmer gene"). But a review of over 40 years worth of CSEd literature (Robins 2010) finds little or no evidence to support this hypothesis. None of the cognitive, attitudinal, behavioral, or demographic factors explored has been found to be either a good predictor of success (certainly no better than IQ) or bimodally distributed in the population.

LEM was proposed in this context as an alternative account of the observed bimodal outcomes. By way of a crude analogy, a common demonstration of the normal distribution is the Galton box (Fig. 1a), where a quantity of balls falling through layers of pegs (falling left or right in each layer with equal probability) will end up normally distributed (Fig. 1a, b). If the balls have momentum, however, such that falling in one direction makes it slightly more likely to fall in the same direction in the next layer (and therefore less likely to fall in the opposite direction), compounding with each layer, then the resulting distribution changes. A small momentum constant flattens the normal distribution slightly (Fig. 1c) and a moderate momentum converts it into a bimodal ("antinormal") distribution (Fig. 1d).

Like a ball falling through a Galton box, a student encounters a sequence of concepts to be learned. If the concepts are independent, then the success or failure of learning one concept has no influence on the success or failure of learning the next (the standard Galton box with no momentum). Over a population of students, this results in a normal distribution of acquired concepts/final grades. If the concepts are *tightly integrated* then the success or failure of learning one concept influences the success or failure of learning the next, creating momentum, and therefore a bimodal distribution of acquired concepts/final grades.

Thus the LEM hypothesis suggests that momentum arises as a consequence of the interaction of two factors: the widely accepted principle that we learn at the edges of what we know; and the new claim that different domains of knowledge have "edges" which vary in their structural significance and thus their impact on the course of learning. An interaction between the way that people learn and the nature of the subject material can create an inherent structural bias which drives learners toward extreme outcomes.

Learning Edge Momentum. Fig. 1 (**a**) A Galton box with superimposed normal distribution, (**b**) standard no momentum, (**c**) 5% momentum at each layer, and (**d**) 15% momentum at each layer

LEM is a new hypothesis and there are many open questions to be explored:

1. How widespread are bimodal learning outcomes? Learning to program is just one end of a spectrum, there are other subjects where bimodal outcomes are sometimes reported (Robins 2010).
2. How can we test the hypothesis that bimodal outcomes are related to the degree to which the subject material is integrated/interdependent?
3. How can we quantify the degree to which the concepts of a domain are integrated/interdependent? Initial possible methods include statistical analysis of text books or other relevant linguistic corpora, or measures (such as "mind maps") derived from subject experts.
4. What are the factors which influence the significance of the LEM effect across different individuals?
5. Are there other significant effects arising from the interaction between the mechanisms of learning and the specific subject material of the target domain?

If the LEM hypothesis is correct, there are two main pedagogical implications for *tightly integrated* domains/subjects areas:

1. The very early stages of learning are critical to the outcome of the process. Ideally, positive momentum should be established right from the start.
2. There is little point in progressing if concepts have not been acquired. If the curriculum progresses at a fixed pace, then some students will be left behind.

Ideally a self-paced curriculum or a mastery model of learning and course structure should be employed.

Cross-References

▶ Analogy-Based Learning
▶ Bootstrapping: How not to Learn
▶ Complex Learning
▶ Concept Learning
▶ Knowledge Integration
▶ Scaffolding for Learning
▶ Transfer of Learning
▶ Zone of Proximal Development

References

Anderson, J. A. (2005). *Cognitive psychology and its implications* (6th ed.). New York: Worth.

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: an inquiry into the nature and implications of expertise.* Chicago: Open Court.

Chi, M. T. H., & Ohlsson, S. (2005). Complex declarative learning. In K. J. Holyoak & R. G. Morrison (Eds.), *Cambridge handbook of thinking and reasoning* (pp. 371–399). New York: Cambridge University Press.

Haskell, R. E. (2001). *Transfer of learning: Cognition instruction and reasoning.* California: Academic.

Robins, A. (2010). Learning edge momentum: A new account of outcomes in CS1. *Computer Science Education, 20*, 37–71.

Learning En-Passant

▶ Incidental Learning

Learning Environment

Norbert M. Seel
Department of Education, University of Freiburg,
Freiburg, Germany

Synonyms
Learning setting

Definition
Learning environment is a term widely used in educational and instructional psychology to capture the idea that learning always occurs in a social and physical context. Generally speaking, a learning environment can be considered as a particular place where individuals can learn by using a variety of information resources and tools that are designed and allocated in the pursuit of learning objectives.

Theoretical Background
According to Collins et al. (1994), the term learning environment replaced the term teaching method due to a subtle change in the basic understanding of teaching and learning that can be traced back to Jean Piaget, who maintained that learning can only be supported but not externally forced. In order to support learning and problem-solving thinking effectively, it is especially important to design environments which provide optimal conditions for fostering self-initiative of the learners and reducing external interference. This idea originated with Wertheimer's (1959) suggestion of designing environments in which information is provided in such a way that learners are enabled to deal effectively with new problems. More generally, Lewin (1942) proposed that human behavior is the function of both the person and the environment where behavior takes place. This idea resulted in the famous equation B = f (P, E) with B = behavior, P = person, E = environment.

In accordance with Piaget's view on education and inspired by Bruner's theory of instruction, Farnham-Diggory (1972) introduced the concept of *free learning environments*, whereas Stolurow (1973) advanced the approach of transactional instruction, which aims at the design of learning environments to provide learners with opportunities for reflection and channel their attention into effective directions. According to these educational conceptions, learning environments should organize external conditions which enable a maximum of cognitive and motivational development with a minimum of intervention in order to provide students ample room for learning and productive thinking. The nature of human learning and thinking serve as a basis for designing learning environments and accordingly it defines teaching as a well-planned sequence of actions designed to enable learners to process available information. At lower levels of cognitive processing, the learning environment prompts learners to acquire knowledge structures or cognitive skills and store them in memory in order to retrieve and use them in subsequent task situations. At higher levels of cognitive processing, the learning environment should support learners in developing and applying mental models and causal explanations that create subjective plausibility with regard to complex phenomena in the world of objects and events. Finally, the highest level of cognitive processing at which learning environments aim is associated with problem solving, the construction of learning strategies, and metacognition (Clements and Nastasi 1999).

Learning in the classroom is further characterized by participation in a discourse (the goal of which is to construct social meaning), by specific learning activities and actions, and by work evaluated by a teacher. Collins et al. (1994, p. 3298) differentiated between three main groups of learning environments:

- *Communication environments*, in which learners participate in the discourse either through the active proposal of objectives, problems, values, and attitudes or through simple information processing
- *Problem-solving environments*, in which learners work on problems and projects, or training environments, in which learners complete exercises in order to improve particular skills
- *Test situations*, in which learners have to complete specific tasks (such as making a presentation or taking an exam)

Communication and problem-solving environments are grounded on the argumentation that learning is a constructive process in which the learner manages and organizes all available information resources in a strategic manner in order to create new

knowledge structures and/or mental models which can be used to accomplish a task. Since a couple of years, the conception of ▶ synthetic learning environments plays an increasing role as communication and problem-solving environments which contain regularly a computer simulation as a central component and thus serve as simulation-based training (Cannon-Bowers and Bowers 2008).

As studies by Dreistadt (1969), Ploetzner et al. (1999), and others demonstrate, the environment can be a centrally significant information source: It may contain specific solution-relevant problem representations, or other persons may be used as an information source during cooperative problem solving. People who are engaged with a problem continually extract solution-relevant information from the immediate environment and connect it with existing information in order to create mental models of the problem space.

Important Scientific Research and Open Questions

Clearly, many learning opportunities exist in everyday life and constitute effective conditions for learning. Learning occurs not only in the classroom, but also in a variety of informal environments such as museums, zoos, gardens, and activity centers. It also occurs on many levels (individuals, groups of various size and composition, in diverse cultures). However, when educational psychologists use the concept of learning environment they do so regularly under the assumption that learning environments are not given a priori; rather, they must be developed and designed. This technology, however, which rests on theoretical assumptions concerning the psychological dispositions of learners, learning activities, attainable learning outcomes, and the potential effects of learning materials, is still in a state of continuous development. There have been some attempts in the past to derive general guidelines for the design of problem-oriented learning environments (e.g., Farnham-Diggory 1972; Stolurow 1973); today this is a major task of instructional design, a discipline in which specific prescriptions for the development of learning environments have been identified and discussed. For example, Savery and Duffy (1995) argue that problem-oriented learning environments should aim at

- Anchoring of learning activities in a larger context or a global task
- Assistance for the learners in identifying with the task
- The use of authentic learning tasks
- A complexity which corresponds to the complexity of the environment in which the learners will operate after completion of the learning
- Communication of a feeling of responsibility and a consciousness of having developed solution processes independently
- Support for and encouragement of independent thought processes in the learners
- Encouragement to test alternative viewpoints and contexts
- Opportunities for reflection on content and learning processes

Generally speaking, the components of a learning environment should provide as many information resources as possible in order to extend the scope of topics and content progressively (instead of limiting their scope in a misguided attempt to promote expertise). The important decisions made in the course of instruction should be made by the learners themselves (e.g., decisions as to whether they wish to solve a problem independently or in cooperation with others). The learners are thus seen as masters of their own decisions as to what should be learned, when, and how. Not only do they choose the learning activities and sequence them; first and foremost they must identify, create, cultivate, follow, and satisfy their subjective learning needs. This means that they must also be in possession of the metacognitive skills necessary for deciding what assistance and guidance they need.

The implications for the design of learning environments are obvious: Learning environments must first of all provide a suitable context or an organizing topic for learning activities. They must then ensure the availability of assistance and support, and in addition they must provide other resources which the learners can choose from in order to enrich their understanding. In other words, effective learning environments offer a lavish amount of resources in order to enable the learners to retrieve knowledge or procedures when they need them. They allow learners to navigate proactively through a lesson

when they find that they need help. Furthermore, learning environments should also provide learners the opportunity to request advice on a particular topic or problem or demand thematic elaborations of key concepts. And finally, effective learning environments should also offer tools for "manipulating" provided information. In a definition which is fully aligned with these demands, Hannafin (1992) describes learning environments as "comprehensive, integrative systems that promote engagement through student centered activities, including guided presentations, manipulations, and explorations among interrelated learning themes" (p. 51).

Several developmental laboratories and research groups have developed design principles for implementing these features of effective learning environments in the classroom: The "Cognition and Technology Group at Vanderbilt (CTGV)" (1997), for instance, has developed various (video based) learning environments which present macro-contexts of real-life situations as cases in order to enable analogical problem solving. Spiro et al. (1991), to name another example, focused on knowledge acquisition in complex, poorly structured domains and worked with information-rich hypertext environments which allow advanced students to follow their own learning goals in a cognitively flexible manner. The learning environments propagated by Spiro and colleagues are something of an unstructured odyssey in a relatively structured micro-world, and learning is conceived of as a self-regulated process in which the learners discover the principles of this world.

Proponents of "structured" approaches, on the other hand, view completely learner-controlled situations as problematic, especially for weaker students who do not possess the knowledge and metacognitive abilities necessary for completely self-guided learning and problem solving (Leutner 1992). In order to provide students with goal-directed support, assistance, and guidance in problem-solving situations, a group led by Schank developed the concept of "goal-based scenarios" (e.g., Schank et al. 1993/1994), which is influenced by the idea of case-based problem solving. However, maybe the most comprehensive and complete approach for identifying relevant features of effective learning environments is

the cognitive apprenticeship approach of Collins and Brown (e.g., Collins et al. 1989; see the entry on this topic).

Conclusion

The aforementioned teaching theories call for learning environments which possess the following general characteristics:

1. Learning environments should engage the learners in authentic learning tasks.
2. They should make it easier for the learners to identify, define, and solve problems.
3. Not the reproduction but the construction of knowledge should be the main focus.
4. In order to apply knowledge flexibly and according to demand, learning environments should always offer several perspectives of one and the same phenomenon.
5. Moreover, they should offer the possibility of alternative procedures for reflecting on individual points of view and ideas.
6. Finally, they should have an experiential basis in which the phenomena to be learned are embedded in everyday life contexts.

Clearly, these conceptions are oriented around the theoretical concepts of case-based learning and problem solving, and therefore they correspond to the origins of the concept of learning environments.

Cross-References

▶ Adaptive Blended Learning Environments
▶ Advanced Learning Technologies
▶ Climate of Learning
▶ Cognitive Apprenticeship Learning
▶ Computer-Based Learning Environments
▶ Design of Learning Environments
▶ Experiential Learning Spaces
▶ Microculture of Learning Environments
▶ Narrative Learning and Narrative Environments
▶ Open Learning Environments
▶ Perceptions of the Learning Context and Learning Outcomes
▶ Playful Learning Environments
▶ Situation Prompts in Authentic Learning Environments
▶ Virtual Reality Learning Environments

References

Cannon-Bowers, J. A., & Bowers, C. A. (2008). Synthetic learning environments. In J. M. Spector, M. D. Merrill, J. van Merrienboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 317–327). Mahwah: Lawrence Erlbaum.

Clements, D. H., & Nastasi, B. K. (1999). Metacognition, learning, and educational computer environments. *Information Technology in Childhood Education Annual, 1*, 5–38.

Cognition and Technology Group at Vanderbilt. (1997). *The Jasper project. Lessons in curriculum, instruction, assessment, and professional development*. Hillsdale: Lawrence Erlbaum.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction* (pp. 453–494). Hillsdale: Lawrence Erlbaum.

Collins, A., Greeno, J. G., & Resnick, L. B. (1994). Learning environments. In T. Husén & T. N. Postlethwaite (Eds.), *The international encyclopedia of education* (2nd ed., Vol. 6, pp. 3297–3302). Oxford: Pergamon.

Dreistadt, R. (1969). The use of analogies and incubation in obtaining insights in creative problem solving. *The Journal of Psychology, 71*, 159–175.

Farnham-Diggory, S. (1972). *Cognitive processes in education: A psychological preparation for teaching and curriculum development*. New York: Harper & Row.

Hannafin, M. J. (1992). Emerging technologies, ISD, and learning environments: critical perspectives. *Educational Technology Research and Development, 40*(1), 49–63.

Leutner, D. (1992). *Adaptive Lehrsysteme. Instruktionspsychologische Grundlagen und experimentelle Analysen*. Weinheim: Beltz/Psychologie VerlagsUnion.

Lewin, K. (1942/1964). Field theory and learning. In D. Cartwright (Ed.), *Field theory and social science. Selected theoretical papers by Kurt Lewin* (pp. 60–86). New York: Harper & Row.

Ploetzner, R., Fehse, E., Kneser, C., & Spada, H. (1999). Learning to relate qualitative and quantitative problem representations in a model-based settings for collaborative problem solving. *The Journal of the Learning Sciences, 8*(2), 177–214.

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: an instructional model and its constructivist framework. *Educational Technology, 35*(5), 31–38.

Schank, R. C., Fano, A., Bell, B., & Jona, M. (1993/94). The design of goal-based scenarios. *The Journal of the Learning Sciences, 3*(4), 305–345.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1991). Cognitive flexibility, constructivism, and hypertext: random access instruction for advanced knowledge acquisition in ill-structured domains. *Educational Technology, 31*(5), 24–33.

Stolurow, L. M. (1973). Lernumwelten oder Gelegenheiten zum Nachdenken. In W. Edelstein & D. Hopf (Eds.), *Bedingungen des Bildungsprozesses. Psychologische und pädagogische Forschungen zum Lehren und Lernen in der Schule* (pp. 351–398). Stuttgart: Klett.

Wertheimer, M. (1959). *Productive thinking* (Enlargedth ed.). New York: Harper & Row.

Learning for Health

Laura Thorogood
EHLE Project, Padova, Italy

Synonyms

Health learning

Definitions

Learning for health. Learning for health can take place at the individual, group, or community level, or through mass media. Learning for health is often facilitated through health education informing people what to do in order to be healthier. A wider view of health education and health learning is called health promotion, which looks at the wider context of each individual to maximize the effectiveness of health education and therefore learning for health. This entry will discuss the issues around learning for health in context of older people.

Health learning for older people involves the selection of material and content, the choice of techniques and methods to ensure absorption and ▶ retention of information. The ultimate aim of learning for health in this context is to change behavior to include more choices for better health.

Theoretical Background

Learning for health grows from the concept of health promotion as education about consequences of health choices. These health choices might be about (for example) diet, exercise, medicines, alcohol, and tobacco use. The idea is that, given better information, people will make choices that lead to better health, or in other words, "if you know it harms you, you can avoid it." In recent years this idea of health promotion has undergone two major developments: (1) the realization that knowledge of the consequences of "poor" health choices does not necessarily lead to alteration of those choices and (2) that ensuring adherence to better health choices is extremely difficult and complex.

The first development was a serious shift in perceptions of health promotion and education. People make choices not just on the basis of available information but several other factors, many of which are difficult to isolate and measure. These may include: the choices made by peers and members of wider social networks,

socioeconomic status, emotional connections with certain activities or choices, other pressures which reduce the energy to make and maintain new choices, and resistance to change. Understanding the presence of these factors has radically changed the methods used to promote healthier choices through learning for health.

The second development follows on from the first. Simply explaining the benefits of different health choices, even to a group, does not counter the difficulties that people often have in maintaining their intended "better" health choices. There have been various attempts to improve adherence to better health choices, including follow-up meetings or phone calls, rewards for reaching certain objectives and milestones, outlining the physical benefits and opportunities of improved health, and promoting specific health changes in response to a reported need, for example, a smoker who complains about not being able to play football with his children. More recently, work has been done to promote healthy choices among groups, for example, groups of friends or colleagues, or to encourage individuals to follow diets or exercise regimes with a friend or with family members. Making and maintaining new health choices seems to be more successful when undertaken in pairs or groups with social ties, increasing the likelihood of permanent or long-term behavior change.

Encouraging health learning for older people is in many ways both more difficult and more important. In the West, the current generation of older people is living longer with an increasing burden of chronic conditions often associated with loss of autonomy. This epidemiologic transition is triggering an increase in health-related expenses mainly used to improve the quality of life of older persons in their later years. This is particularly true in Europe and Japan, where lower birth rates and longer life expectancy means more people will be living longer, with fewer working people to look after them. This current generation will therefore need to try to age healthily (extending their active life expectancy rather than simply extending their total life expectancy), take more responsibility for their daily needs, and be better equipped to do so effectively. In terms of health promotion, this means that addressing the deficit in health learning for older people is both important and urgent.

Improving health learning for older people is only now gaining significant academic and practical attention, and is not a simple or easy target to achieve:

- Older people tend to have more complex health issues, tend to have less autonomy over their health choices, and, older women in particular, are more likely to be poor (and therefore have less to spend on food, medicines, healthcare, and associated costs). They may also have difficulty absorbing or adhering to health advice because of bias or prejudice.
- Older people's health status is usually more complex. For example, older people are more likely to suffer from chronic and debilitating health conditions, to be prescribed multiple medicines by more than one practitioner, and to suffer more side effects from those medicines they do take.
- Older people's health choices are usually less under their control: they are more likely to have limited autonomy or flexibility in their diet and/or levels of physical activity.
- Finally, older people may not be aware of the impact their health choices make, and they may have difficulty understanding or adhering to medical advice (related to memory function, education levels, and the relatively low level of educational material/initiatives directed at this demographic).

To be effective, health learning for older people needs to take into account the complexities and context-specific factors outlined above. This means that both method and content need to be tailored to the specific needs and capacities of older people, which can be surprisingly heterogeneous (distinct) both from other age groups and internally. The term "older people" encompasses a wide age group from 65 to 90+. Since this also covers a period of significant physical, social, and mental change, the group is generally divided into the "young old" and the "older old." To a greater or lesser extent, the topics covered here apply to both these age groups. Older people generally need far fewer calories, and tend to have different sleep patterns. Postretirement they tend to sharply reduce their mental stimulation, often without realizing the effect this has on their mind and memory. They tend to leave the house less, meaning they get less vitamin D (from sunlight) and often suffer from loneliness, while decreased physical activity weakens the muscles and slows the digestion. These differences mean that recommendations for "healthy lifestyles" should be significantly different for older people, and thus implies the

need for explicit training/information for general medical professionals, including doctors, nurses, pharmacists, and social care workers.

Various techniques can be tried to ensure the efficacy and easy adherence to health lessons, including both practical steps and changes in medical relationships. Some are valid for all age groups. For example:

- A timetable for pill taking
- Writing ▶ instructions for medication on the pill box
- Facilitating the use of daily activity to keep in better health (gardening, cleaning, and walking to the shops)
- Promoting a closer relationship with the local pharmacist and other health professionals (who may have more time to discuss side effects and other issues around medication)
- Simplifying and distilling messages from general medical practitioners, for example, using pictorial aids like a food pyramid, or suggesting "more tinned tuna" rather than "more Omega 3"

Both for older people and other age groups, ▶ empowerment as part of learning for health is crucial, as a means and as an end. Loss of autonomy is a major factor in reduced ▶ quality of life, so empowering older people both improves their emotional health and well-being and enables them to make their own choices and remain more independent for longer. Extending healthy lives is as important for their physical health as it is for happiness and well-being.

Important Scientific Research and Open Questions

In recent years the impact of learning for health has been of increasing interest, both in terms of the benefit of improved knowledge and the benefit of the activity of learning itself (Feinstein and Hammond 2004). Self-regulated learning (where the student is in control of what and how they learn) has been increasingly popular as a way to engage people in the treatment and prevention of ill health (Clark et al. 2009). Research shows that patients who are active in the development of their care plans are more likely to adhere to the treatment agreed and are more likely to feel positive about their situation (Wagner et al. 1996). However, it has also become clear that there is a minority of patients who do not show the expected positive response to the effects of engaging with care plans and treatment decisions; the reasons behind this resistance are not yet clear but may include a wider sense of disempowerment, poor implementation of the engagement process, or cultural differences in the expectations of patient/health professional engagement patterns. Research also suggests that there may be an optimum set of conditions for health learning to be most effective, but as yet these are not confirmed or widely tested (Glasgow et al. 2002).

Cross-References

▶ Altruism and Health
▶ Empowering Health Learning for the Elderly (EHLE)

References

Clark, N. M., Janz, N. K., Dodge, J. A., et al. (2009). Heart disease management by women: does intervention format matter? *Health Education & Behavior, 36*(2), 394–409.

Feinstein, L., & Hammond, C. (2004). *The contribution of adult learning to health and social capital.* Wider Benefits of Learning, Research Report No. 8. London: Centre for Research on the Wider Benefits of Learning.

Glasgow, R. E., Funnell, M. M., Bonomi, A. E., Davis, C., Beckham, V., & Wagner, E. H. (2002). Self-management aspects of the improving chronic illness care breakthrough series: Implementation with diabetes and heart failure teams. *Annals of Behavioral Medicine, 24*(2), 80–87.

Wagner, E. H., Austin, B. T., & von Korff, M. (1996). Organizing care for patients with chronic illness. *The Milbank Quarterly, 74*(4), 511–544.

Learning for Mastery

▶ Mastery Learning

Learning from Animals

Monique A. R. Udell, Clive D. L. Wynne
Department of Psychology, University of Florida, Gainesville, FL, USA

Synonyms

Animal behavior and human learning; Observation of animals and human learning

Definition

Any occasion on which a person's behavior is modified by observation of the behavior of a member of another species may be labeled "Learning from animals."

Theoretical Background

Humans have used animals to guide their behavior for centuries by learning the connection between an animal's behavior and environmental circumstances or consequences. Though as humans we flatter ourselves through the scientific name we chose – *Homo sapiens*, "wise man" – that we are the most thoughtful and learned of species, nonetheless there are innumerable instances in which people have learned from members of other species. Often – though not exclusively – this occurs in situations in which a nonhuman species has senses that exceed in sensitivity or range of responsiveness those of the human. Other cases include those where a nonhuman can move more readily through an environment than humans can, such as dolphins aiding fishermen in Brazil. A particularly interesting case is where people learn from animals something that they could just as easily learn from conspecifics but are inhibited by cultural taboos – as when people learn how to copulate by observing farm animals.

Important Scientific Research and Open Questions

One of the simplest situations in which people may learn from animals is, because of its taboo nature, difficult to document. Ulrich (1912) in an article evasively titled "An Immediate Problem of Education," described with approval how observations of animals can teach children "relations of sex" (p. 235). The author argued: "The child who has been taught as I have suggested can never surround the relations of sex with any atmosphere of morbid mystery. Such a child has nothing to learn from its comrades" (p. 235). Though undocumented, such learning may have been common in earlier eras when more people lived in close proximity to farm animals and taboos on sexual education were strong.

People have been taking honey from bees for thousands of years. In Africa, a species of bird aptly known as the honey guide (*Indicator indicator*) helps natives learn the location of active bees' nests by giving a specific call when a nest has been found. The birds also perform a characteristic display behavior and thereby guide people to the nest. This benefits both the humans, who obtain the honey by breaking into the tree concealing the nest, and the birds, which feed on the developing brood inside the nest. Without the aid of the humans the nest would be inaccessible to the birds; without the birds the humans might not find the hidden source of honey (McGregor 2005).

Pliny the Elder (A.D. 23–79) recorded that dolphins help people in their fishing (Pliny 1940), but this seemed fanciful until confirmed in modern times. Pryor et al. (1990) reported that in Laguna, Brazil, dolphins help fishermen by herding fish toward the men's nets. The water in the lagoons is too turbid for the fishermen to be able to see the fish, but the dolphins with their echolocation abilities can clearly identify the fishes' location. As the fishermen wait in shallow water, the dolphins herd the fish by first submerging and then reappearing and coming to an abrupt halt. The dolphin's sudden stop produces a surging wave that pushes the fish toward the waiting fishermen. The dolphins also benefit because in the confusion arising from the rolling surf they have produced, plenty of fish swim back into the mouths of the dolphins. For the fishermen this method of fishing is highly productive: Pryor et al. reported that each fisherman typically caught 20 kg of mullet in a half-hour period. And the dolphins appear to be in control of the procedure, with the fishermen moving up or down the beach to wherever the dolphins are active. The local fishermen even have a name for those dolphins that fail to help them. They are called "ruim," "bad dolphins."

One of few aspects of learning from animals that remains an area of active contemporary research is the learning about the location or presence of dangerous substances, explosives, or environmental factors undetectable by human senses. People have been relying on animals for this purpose for centuries. Coal miners used the song of canaries as assurance that the levels of dangerous gases were sufficiently low to keep working. A buildup of dangerous gas, such as carbon monoxide, would result in the canary's death and indicate the need for evacuation from the mine. In recent times, rodents and dogs have been used to locate landmines, and dolphins have been trained to locate mines underwater. As technology advances, animals are being used as models for more automated systems of mine detection. Dogs commonly assist people to detect aspects of the environment that are not directly

perceivable by humans, such as guard dogs that alert to sounds that are beneath the threshold of human hearing. Dogs also work in other capacities, for example as guide dogs, which not only serve as a mobility aid but in some cases allow for increased independence and confidence as well as an improvement in social skills. Research shows, however, that these outcomes are strongly influenced by individual preference and perception (Whitmarsh 2005).

In some cases, the human ability to learn from animals is being extended to robots; for example, robots can be programmed to "learn from the animal to navigate cluttered environments" (Nanayakkara et al. 2009 p. 298). In the future, such robots may accompany animals into mine fields allowing humans to remain a safe distance away. However, the ability of animals to detect the presence of specific chemical agents makes it likely that they will remain an integral part of mine detection, providing humans with the information needed to regain usable territory, for years to come (Nanayakkara et al. 2009). In addition to detecting land mines, domestic dogs have also been commonly used to detect illegal or dangerous substances in airports and at borders, locate human survivors and cadavers in rescue efforts, and have even been trained to help humans detect the presence of pests such as termites or the presence of illness, such as cancer (Helton 2009).

These examples of people learning from animals are probably part of a declining trend. Of the cases summarized here, only sniffer detection dogs are increasing in number. Instead, many people learn about the abilities of animals only through deeply anthropomorphized representations proffered by the entertainment industry. These pseudo-presentations fail to capture the true wonder and diversity of animal behavior, and may stunt future generations' interest in learning from animals.

Cross-References

► Adaptation and Learning
► Anthropology of Learning and Cognition
► Imitative Learning in Humans and Animals
► Joint Attention in Humans and Animals

References

Helton, W. S. (2009). *Canine ergonomics: The science of working dogs.* Boca Raton: CRC Press.

McGregor, P. K. (2005). Communication. In J. J. Bolhuis & L.-A. Giraldeau (Eds.), *The behavior of animals.* Malden: Blackwell.

Nanayakkara, T., Jamshidi, M., & Sahin, F. (2009). *Intelligent control systems with an introduction to system of systems engineering.* Boca Raton: CRC Press.

Pliny the Elder. (1940). *Natural history* (Vol. 3). Cambridge, MA: Loeb Classical Library, Harvard University Press.

Pryor, K., Lindbergh, J., Londbergh, S., & Milano, R. (1990). A dolphin-human fishing cooperative in Brazil. *Marine Mammal Science, 6*, 77–82.

Ulrich, M. (1912). An immediate problem of education. *Minnesota Farmers Institute Annual, 25*, 231–236.

Whitmarsh, L. (2005). The benefits of guide dog ownership. *Visual Impairment Research, 7*, 27–42.

Learning from Counseling

Paul C. Burnett
Queensland University of Technology, Brisbane, QLD, Australia
Division of Research and Commercialisation, Queensland University of Technology, Kelvin Grove, QLD, Australia

Synonyms

Behavior change; Counseling outcomes; Lifelong learning

Definition

Counselors generally agree about the critical importance of client's learning from counseling. Two important outcomes of counseling involve clients learning to deal with situations differently and more productively in the shorter term, and then transferring what they have learned to subsequent problems experienced in the longer term. A major goal of counseling is the development of skills within a lifelong learning framework. Counselors assist clients to learn how to cope with the problematic situations that are encountered throughout the passage of their lives. A critical question for counselors is how to define and measure the learning outcomes which result from a counseling experience.

Theoretical Background

Counseling outcome research has not typically been conceptualized within a learning framework. It has tended to focus on the self-report assessment of

behavior change or symptom relief in the shorter term. However, quantitatively assessing counseling outcomes using measures of short term behavior change can be complemented by considering the learning outcomes of counseling that impact on a client's longer term well-being and on those changes that are unique to individual clients.

The psycho-educational learning literature has the potential to provide a robust theoretical framework for assessing the structure of the learning outcomes resulting from counseling. An investigation of the structure used by learners to document their learning was undertaken by Biggs and Collis (1989) and resulted in the development of a taxonomy known as the Structure of Observed Learning Outcomes (SOLO). This hierarchical taxonomy describes the structural organization of knowledge and what has been learned and has been used to measure secondary and tertiary students' learning. Burnett (1999) investigated the application of the SOLO taxonomy to assess the structure that was used by clients when they were asked to describe and record what they had learned from counseling. The SOLO taxonomy was found to have utility for determining various hierarchical levels of client learning emerging from the counseling experience. Burnett (1999, p. 578) noted that "the findings of this exploratory study are tentative but suggest that an expanded SOLO offers a promising and exciting way to view the outcomes of counseling within a learning framework." The modified SOLO taxonomy as reported by Burnett (1999) is described below:

1. Prestructural: Nothing learned and no benefits gained from counseling.
2. Unistructural: Only one relevant learning described.
3. Multistructural (Weak): More than one learning described but limited in number and scope.
4. Multistructural (Sound): Several independent learnings are outlined.
5. Multistructural (Strong): Several independent learnings are developed through elaboration and examples which results in a "chunking" structure.
6. Relational (Weak): Learnings are mostly integrated around a relating concept or theme but some points are discussed which digress from the structure.
7. Relational (Strong): Learnings are integrated into a relating concept/theme with a strong robust integrated structure.

8. Extended Abstract: Learnings are transferred into more abstract situations. A personal theory for living in a society or community may be explained.

The role of learning in counseling has been recognized and considered a factor that is common across all types of helping therapies, but it has tended to be associated with positive outcomes rather than being considered as a desired outcome in itself. The notion of enhancing learning as a significant goal of counseling suggests that learning should be investigated as a valid outcome measure in its own right. Additionally, a learning outcomes approach, which assesses what clients have learned as a result of counseling, has implications for counseling practice, such as assisting clients to learn from counseling and modifying counseling to ensure maximum client learning.

Burnett's (1999) study focused on assessing *the structure* used by clients to report and document what they had learned from counseling. However, the SOLO taxonomy does not evaluate *the content* of what clients report they have learned. Burnett and Van Dorssen (2000) addressed this issue when they analyzed the transcripts of documented client learnings using a content analysis approach. Thirty-five clients wrote a Letter To a Friend (LTF) describing in a much detail as possible what they had learned from counseling. The analysis of these transcripts yielded three major areas of learnings, namely *Learnings about Self* (SL), *Learnings about Relations with Others* (RL), and *Learnings about the Process of Change* (PL). The statements were then classified using the theoretical framework developed by Marton et al. (1993) to form hierarchical taxonomies for the learnings in each of the three areas. The higher the level attained the deeper and better was the learning outcome because it represented a higher level of cognitive understanding.

The hierarchies from lowest level of learning to highest level of learning for each of the three areas were as follows:

Learnings about self:
    SL1 – Survival and Basic Coping
    SL2 – Self-awareness and Self-acceptance
    SL3 – Personal Change and Improvement
    SL4 – Personal Growth and Development
    SL5 – Personal World View
Learnings about relations with others:
    RL1 – Awareness and Acceptance of Others

RL2 – Insights into Relationships

RL3 – Self as Responsive but not Responsible for Others

RL4 – Change and Growth in Relations

Learnings about the process of change:

PL1 – Insight into the Nature of Change

PL2 – Knowledge and Skills that Facilitate Change

PL3 – The Self as Change Agent

PL4 – Generalization of the Change Process

The Burnett and Van Dorssen (2000) study reported 55 learning statements which were derived from the clients' interview transcripts as exemplars for each of the hypothesized levels of the three taxonomies. For example, I learned that I will survive (SL1); I learned that I have to work to maintain relationships (RL2); and I learned that the answers to my problems come from within (PL3). These statements were then published by Burnett (2005) as a scale titled "*What did I Learn from Counseling Scale.*"

In summary, the findings of the studies cited above provide three promising mechanisms for assessing the learning outcomes of counseling. First, the structure used by clients to report learnings from counseling can be assessed using a modified version of the SOLO taxonomy. Second, the hierarchical level of the content of the learning can be determined using the three hierarchical taxonomies. Third, some of the learning statements form a scale that quantitatively assesses the content of what has been learned from counseling. These three assessment methods address the methodological gap associated with measuring the learning outcomes of counseling.

What Can Counselors Do to Facilitate Client Learning?

Burnett and Meacham (2002) extended the link between learning and counseling further by exploring the use of learning journals as a counseling strategy to complement a counselor's therapeutic strategies. Burnett and Meacham (2002) noted that the writing of learning journals has been used in education to promote reflection and argued a prima facie case for their use in counseling. They noted that "of most relevance to counselors is the type of journal that provides a means to systematically document learning and promotes self-analysis, reflection and positive action on the part of the client" (pp. 411–412). Burnett and

Meacham (2002) highlighted the critical importance of preparing clients to write a learning journal. They described ten instructional dimensions and provided exemplars as to how the counselor could address each dimension. The ten dimensions are Introduction, Usage, Competence, Perspective, Structure, Genre, Routine, Power Relations, Feedback, and Privacy. Burnett and Meacham (2002, p. 414) do not suggest that "journal-based learning strategies that focus on reflection should be the prime counseling strategy but rather that learning enhancement should be considered for all suitable clients and takes its place as a counseling strategy based on constructivist learning principles." They note that future research is needed to determine the impact of using learning journals on client's learning in the short and longer term.

Important Scientific Research and Open Questions

There is a need to investigate and develop new methods to assess the impact of counseling on clients' lives, both in the short term and longer term. The focus of new methods should be on data generated directly from clients as they seek help and reflect on the helping process and its outcome on their lives. Future research is needed to investigate the impact of the use of reflective learning journals on what clients' learn from counseling and the changes made in the short and longer term. The results will determine the impact of counseling on client self-awareness, their understanding of relationships, and their capacity to deal with future problems in their lives and with the process of change. Furthermore, the statements published by Burnett (2005) as scale ("*What did I Learn from Counseling Scale*") need to be administered to clients who have had a counseling experience and then psychometrically evaluated to determine their reliability and validity. There is a need to develop innovative methods that are consistent with contemporary narrative and qualitative understandings of counseling and which reliably assess outcomes over time. The outcomes of this research will enhance our understanding of counseling practice, advance the profession, and provide vital information to governments, mental health funding bodies, and the professional service providers about the contribution that counseling makes to clients' lives. As the counseling profession moves forward from establishing the general efficacy of counseling,

novel approaches to outcome research need to be developed. Assessing the learning outcomes of counseling is one such approach.

Cross-References

▶ Assessment in Learning
▶ Field Research on Learning
▶ Life-Long Learning
▶ Outcomes of Learning

References

Biggs, J. B., & Collis, K. F. (1989). Towards a model of school-based curriculum development and assessment: Using the SOLO taxonomy. *Australian Journal of Education, 33*, 149–161.

Burnett, P. C. (1999). Assessing the structure of learning outcomes from counselling using the SOLO taxonomy: An exploratory study. *British Journal of Guidance and Counselling, 27*, 567–580.

Burnett, P. C. (2005). What do adolescents learn from counselling: Measuring learning outcomes. *Australian Journal of Guidance and Counselling, 15*, 35–42.

Burnett, P. C., & Meacham, D. (2002). Learning journals as a counselling strategy. *Journal of Counseling and Development, 80*, 410–416.

Burnett, P. C., & Van Dorssen, L. (2000). What do clients learn from counselling. *International Journal for the Advancement of Counselling, 22*, 241–254.

Marton, F., Dall'Alba, G., & Beaty, E. (1993). Conceptions of learning. *International Journal of Educational Research, 19*, 277–300.

Learning from Demonstration

▶ Apprenticeship Learning in Machines
▶ Model-Based Imitation Learning

Learning from Errors

▶ Learning from Failure

Learning from Examples

▶ Worked Example Effect

Learning from Experience

▶ Experiential Learning Theory

Learning from Failure

MARK D. CANNON[1], AMY C. EDMONDSON[2]
[1]Department of Leadership, Policy, and Organizations, Vanderbilt University, Nashville, TN, USA
[2]Harvard University, Boston, MA, USA

Synonyms

Learning from errors; Organizational learning from error; Organizational learning from failure

Definition

Failure is defined as an outcome that deviates from expected and desired results. Learning from failure describes processes and behaviors through which individuals, groups and organizations gain accurate and useful insights from failures and modify future behaviors, processes, or systems accordingly.

Theoretical Background

The ability to learn from experience is crucial to the performance and well-being of individuals, groups, and organizations. However, research has shown that organizational learning from failure is thwarted by defensive interpersonal cognitions and routines (Argyris 1982), as well as by organizational systems and processes that favor continuity and routine over learning (March and Simon 1958). In short, learning from failure is widely acknowledged as a good idea but is not consistently practiced in most organizations (Baumard and Starbuck 2005).

There are at least two distinct streams of research on this topic. One examines large data sets in which documented failures have occurred and their frequency can be related to dimensions of organizational performance. A recent exemplar of this kind of research analyzed failures in the orbital vehicle launch industry and found that organizations learn more from failures than from successes (Madsen and Desai 2010). A second stream focuses on error management culture (e.g., Van Dyck et al. 2005) and interpersonal behaviors

related to organizational learning from error and failure (e.g., Argyris 1982; Cannon and Edmondson 2005; Carmeli and Gittell 2009; Edmondson 1996; Ellis et al. 2006). The emphasis in this short article is on research in this stream, to which we have contributed, and we seek also to identify areas of potential confusion or discrepancy between these different approaches to the study of organizational learning from failure.

Behavioral and Cultural Challenges to Organizational Learning from Failure

Organizational learning from failure involves at least three activities (Cannon and Edmondson 2005). First, failures must be detected, rather than missed, ignored, or hidden. Although large and consequential failures that occur in organizations, such as the 2009 British Petroleum explosion and oil spill in the Gulf of Mexico, are obvious and cannot be hidden, small process failures are often hidden from those in a position to implement change as a result of learning from them (Edmondson 1996). Early identification of failures is particularly important in preventing larger and sometimes catastrophic failures (Cannon and Edmondson 2005). Second, organizations must analyze failures carefully to obtain the right lessons from them. Failure analysis is crucial because the appropriate conclusions and lessons to draw from failure are often not apparent from a cursory examination. Third, organizations must promote experimentation, which necessarily produces failures as an integral part of producing new knowledge. Deliberate experimentation, including through the use of "trial and error," enables learning from failure in a controlled manner and involves keeping experiments modest in size and appropriately directed.

Social and technical barriers in most organizations make all three of the above activities difficult to practice consistently. Social barriers involve both interpersonal and psychological attributes, including how people treat each other, how people expect to be treated by others, and how people anticipate they will feel as a result of such treatment. Technical barriers have to do with knowledge, skill, structural characteristics, and information systems.

Technical Barriers to Learning from Failure

Particular technical barriers affect each of the practices of learning from failure. With respect to identifying failure, a lack of metrics, data, feedback, or information systems to capture such data may lead the small failures that could have generated learning to go unnoticed. Identifying failure can be particularly challenging in complex systems, where detecting signals amidst chaotic or simply non-repetitive events requires judgment and expertise.

The practice of analyzing failure can be complicated by a lack of technical knowledge about how to rigorously examine a failure, understand the root cause, and draw relevant implications. Consequently, organizations such as the military have established formal, detailed processes such as the After Action Review (AAR) and provide significant training to help soldiers and leaders learn from failure. And training in methods such as Statistical Process Control (SPC) is one means for ensuring systematic analysis of deviations from expected and desired processes.

Deliberate experimentation is difficult when employees are unfamiliar with scientific reasoning and methods to design experiments that produce the desired learning. To overcome this challenge, some organizations provide training in experimental design or employ experts with the necessary knowledge and skill to design informative experiments.

Social Barriers to Learning from Failure

Learning from failure starts with identifying it. However, identifying failure in an organization is often inhibited by the fear of how others will react to an admission of error or failure or even to bad news (Argyris 1982; Edmondson 1996). Confronting one's own failure directly threatens self-esteem and the additional anticipation that others may "shoot the messenger" or may lose respect for those associated with failure may lead people to cover up or ignore small failures rather than identify and explore them. Organizations can work through this by building psychological safety and through practices such as blameless reporting systems (Carmeli and Gittell 2009).

Analyzing failure is hindered by ineffective group process. The different perspectives that employees bring to the group may be essential for making a thoughtful analysis of the failure. However, differences of perspective can also lead to escalating and unproductive conflict. Competition and political dynamics may lead team members not to engage in

the open dialogue that is essential for effective failure analysis. Finally, process failures in organizations are often not analyzed, but instead subject to workarounds and quick fixes, due to workers' sense of time pressure as well as to their reluctance to bother managers or others who could help analyze and correct recurring problems (Tucker and Edmondson 2003). Organizations can address these issues through training and by making facilitators or other experts available to support dialogue, analysis, and team learning (Cannon and Edmondson 2005).

Effective experimentation may also be inhibited by social factors. If employees perceive that they will be penalized for experiments that might fail, even though they are thoughtfully designed, they may be unwilling to experiment. Similarly, even organizations whose survival depends on continual innovation can experience "innovation trauma" that inhibits future innovation, when prior innovation failures are not handled constructively (Valikangas et al. 2009).

Organizations can make sure that reward systems do not impede this goal, and they can emphasize the importance of learning through experimentation by publicizing the results of experiments and accepting as valuable both positive and negative results. When trying to innovate, some organizations have even established a target failure rate under the assumption that lack of failure in experiments may mean that the experimenters are not exploring sufficiently novel ideas (see Cannon and Edmondson 2005, for a review).

Important Scientific Research and Open Questions

Descriptive Versus Normative Research Orientation

An important difference separating the two streams of research noted above is the study of what individuals, groups, and organizations actually do versus what they should do to best learn from failure. For example, in research on organizational performance in the aftermath of catastrophic failures such as airplane crashes, train wrecks and crashes (Baum and Dahlin 2007), or failures in orbital vehicles, scholars have argued that learning occurs from "large failures, rather than from successes or small failures" (Madsen and Desai 2010: 472). Yet, large-scale data sets on organizational failures such as in these studies lack information on small

failures, which are difficult to detect without intensive qualitative research. This means that such studies are not designed to investigate learning from small failures, because they cannot determine whether small failures received attention.

In contrast, those studying individual and interpersonal behavior focus on the potential for learning from small, everyday failures. As noted earlier, these studies find evidence that failure detection is not consistent in organizations, and argue that organizational inability to discuss small failures helps explain why little is learned from them, and further that relying on large failures for learning is wasteful and ineffective. In short, it is not easy to assess how much organizations can actually learn from small failures, when such events are not recognized or systematically analyzed (Argyris 1982; Edmondson 1996). Normative research in this area thus suggests that the way organizations tend to behave with respect to failures is not a good indicator of how they should behave. Notably, large failures that cause significant harm command attention, but learning from small failures may be an effective strategy for preventing large, harmful failures (Cannon and Edmondson 2005). Additional research is needed to clarify how organizations can take a proactive, preventative approach to identifying and learning from small failures, so as to benefit the organizations and the broader society.

Content of Shared Cognition

A number of studies have shown that the nature of perceptions or beliefs and the extent to which they are shared in a particular social context affect the ability of participants to engage in learning behavior (e.g., Van Dyck et al 2005). Edmondson (1999) identified shared beliefs about psychological safety – the extent to which team members share the belief that it is safe to take interpersonal risks – as contributing to learning behaviors.

At the group level, shared beliefs about appropriate responses to failure varied across teams in the same organization and affected learning-oriented behavior and performance (Cannon and Edmondson 2001). At the organizational level, Carmeli and Gittell (2009) found that the relational aspects of relational coordination (shared goals, shared knowledge, and mutual respect) led to psychological safety and thereby contributed to learning from failure. Additional focus on

the types of shared cognitions that contribute to learning from failure and the best ways to facilitate the development of those shared cognitions would also add to practical and theoretical knowledge in this area.

Leadership

Research suggests that leadership attitudes and behaviors at the group level (Edmondson 1996) and at the organizational level (Carmeli and Gittell 2009) are influential in the development of the types of shared cognitions that contribute to learning from failure. Research on specific leadership behaviors that promote learning from failure and help people manage the interpersonal threat associated with failure should be valuable.

Framing or Mindset

Researchers have demonstrated that engaging in the practices of identifying failure, analyzing failure, and deliberate experimentation is facilitated by a learning-oriented frame or mindset that is distinctly different from the typical frame with which people have been socialized to approach work. Research on how best to develop a learning orientation is needed to further theory and practice in this important area.

Levels of Analysis

Learning from failure has been studied at the individual, group, and organizational levels (e.g., Ellis). What factors drive learning across all three levels, and what factors differ, remains a question for further research, as does the complex interplay among these levels.

Learning from Success Versus Learning from Failure

Though learning from experience includes both learning from failure and learning from success, some scholars have argued that these are different phenomena. Future research is needed to expand understanding of how the learning processes differ and to develop implications for organizational learning.

Conclusion

In conclusion, although learning from failure is essential for performance, research suggests that it happens irregularly in organizations. Both technical and social barriers inhibit key processes through which learning from failure occurs – failure identification, failure analysis, and experimentation. These barriers appear to be particularly detrimental to learning from the kinds of small failures that ought to be studied before they contribute to larger, even catastrophic failures. Further research should examine learning from failure at multiple levels of analysis and discover how leaders can behave and structure organizations so that constructive frames or mindsets develop, are shared, and consistently promote effective learning from failure throughout the organization.

Cross-References

▶ Group Cognition and Collaborative Learning
▶ Group Learning
▶ Individual Learning
▶ Learning from Imperfect Data
▶ Learning to Learn
▶ Organizational Change and Learning
▶ Organizational Learning
▶ Self-esteem and Learning
▶ Self-organized Learning
▶ The Learning Organization

References

Argyris, C. (1982). *Reasoning, learning, and action.* San Francisco: Jossey-Bass.

Baum, J. A., & Dahlin, K. B. (2007). Aspiration performance and railroads' patterns of learning from train wrecks and crashes. *Organization Science, 18*, 368–385.

Baumard, P., & Starbuck, W. H. (2005). Learning from failures: Why it may not happen. *Long Range Planning, 38*, 281–298.

Cannon, M. D., & Edmondson, A. C. (2001). Confronting failure: Antecedents and consequences of shared beliefs about failure in organizational work groups. *Journal of Organizational Behavior, 22*, 161–177.

Cannon, M. D., & Edmondson, A. C. (2005). Failing to learn and learning to fail (intelligently): How great organizations put failure to work to improve and innovate. *Long Range Planning, 38*(3), 299–319.

Carmeli, A., & Gittell, J. H. (2009). High-quality relationships, psychological safety, and learning from failures in work organizations. *Journal of Organizational Behavior, 30*(6), 709–729.

Edmondson, A. (1996). Learning from mistakes is easier said than done: Group and organizational influences on the detection and correction of human error. *The Journal of Applied Behavioral Science, 32*, 5–32.

Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*, 350–383.

Ellis, S., Mendel, R., & Nir, M. (2006). Learning from successful and failed experience: The moderating role of kind of after-event review. *The Journal of Applied Psychology, 91*, 669–680.

Madsen, P. M., & Desai, V. (2010). Failing to learn? The effects of failure and success on organizational learning in the global orbital launch vehicle industry. *Academy of Management Journal, 53*, 451–476.

March, J. G., & Simon, H. A. (1958). *Organizations*. New York: John Wiley.

Tucker, A. L., & Edmondson, A. C. (2003). Why hospitals don't learn from failures: Organizational and psychological dynamics that inhibit system change. *California Management Review, 45*(2), 55–72.

Valikangas, L., Hoegl, M., & Gibbert, M. (2009). Why learning from failure isn't easy (and what to do about it): Innovation trauma at Sun Microsystems. *European Management Journal, 27*, 225–233.

Van Dyck, C., Frese, M., Baer, M., & Sonnentag, S. (2005). Organizational error management culture and its impact on performance: A two-study replication. *The Journal of Applied Psychology, 90*(6), 1228–1240.

Learning from Imperfect Data

PITOYO HARTONO
Department of Mechanics and Information Technology, Chukyo University, Toyota, Aichi, Japan

Synonyms

Fault tolerant learning; Learning from noisy data

Definition

It is widely known that many learning mechanisms such as Multilayered Perceptron (MLP), Radial Basis Function (RBF) network, Support Vector Machine, and so on (Rumelhart and McClelland 1984; Vapnik 1995) are equipped with intrinsic abilities to tolerate the existence of errors in the learning data or some inconsistencies of the training supervisors. It is also well known that the supervised training mechanism of MLP often benefits from the intentional random perturbation in the training data for improving its generalization ability (Holmstrom and Koistinen 1992). However, it is often theoretically and empirically obvious that after some degree, the existence of corrupted training data causes significant deterioration in the quality of the classifier. To guaranty the quality of the trained classifier, it is imperative to guaranty the quality of the training data or the consistency of the training supervisor. For small-scale training data, it is possible to handpick the data while keeping their consistency. However, for large-scale data or real-time learning, this task becomes unmanageable. Hence, a learning mechanism which can tolerate a relatively high percentage of corrupted samples in the training data is of interest to many real-world applications. This entry explains about a neural network ensemble model (Hartono and Hashimoto 2007) that can be trained using an imperfect supervisor that produces erroneous training samples with a certain probability.

Theoretical Background

Many supervised learning mechanisms assumed the existence of a perfect training data, which in real-world problems are not always available. The imperfect training data here are generated by the imperfect supervisor illustrated in Fig. 1. Given a training input **x** this supervisor mostly generates correct teacher signals, but occasionally produces incorrect ones. Although most of the learning algorithms can to some extent tolerate the existence of this kind of corrupted teacher signals, high probability of incorrect teacher signal generation causes the degradation in the quality of the supervised

Learning from Imperfect Data. Fig. 1 Imperfect supervisor

learning systems. The generation of corrupted teacher signals occurs, for example, in real-time learning where the learning systems have to automatically obtain the training data from the learning target. In this case, the corrupted signal may occur due to the various factors like observation error, signal transmission error, or the inherent error in the training target itself.

Here, behavior of the imperfect supervisor can be formulated as follows:

$$
\begin{aligned}
P(T^{w}(\mathbf{x})|\mathbf{x}) &= \epsilon \\
P(T^{c}(\mathbf{x})|\mathbf{x}) &= 1 - P(T^{w}(\mathbf{x})|\mathbf{x})
\end{aligned}
\tag{1}
$$

$P(T(\mathbf{x})|\mathbf{x})$ is the conditional probability for the supervisor to generate a teacher signal, $T(\mathbf{x})$ given an input $\mathbf{x}$. $T^{c}(\mathbf{x})$ and $T^{w}(\mathbf{x})$ are the correct and the incorrect teacher signal for a given input $\mathbf{x}$, respectively. Here, because the teacher signals are in majority correct,

$$
0 < \epsilon < 0.5 \tag{2}
$$

The learning objective of the neural network is to produce an output $O(\mathbf{x})$ such that

$$
O(\mathbf{x}) \approx T^{c}(\mathbf{x}). \tag{3}
$$

It is obvious that training MLP with Backpropagation method will result in output as follows:

$$
O(\mathbf{x}) \approx \epsilon T^{w}(\mathbf{x}) + (1 - \epsilon)T^{c}(\mathbf{x}) \tag{4}
$$

Equation 4 shows that the fidelity of the neural networks deteriorates along with the increase of probability of the supervisor to produce incorrect teacher signals (Hartono and Hashimoto 2000).

The behavior of the imperfect supervisor can be treated as switching dynamics problem as explained in Müller et al. (1995). Switching dynamics problem deals with a learning target which occasionally switches its input–output relationship, thus generating different outputs from a same input, as illustrated in the upper half of Fig. 2. The imperfect supervisor can be considered as a supervisor that switches between two input–output functions, the correct function and the corrupted one. Some models of neural networks ensemble (Hartono and Hashimoto 2000; Müller et al. 1995) were proposed to solve these problems. These models execute competitive learning mechanisms that allow them to automatically assign one of the input–output functions to a member of the

ensemble and activate that member whenever the input–output relation is observed.

Important Scientific Research and Open Questions

In this entry, the ensemble model proposed in Hartono and Hashimoto (2007) is explained. As illustrated in the lower half of Fig. 2, this ensemble consists of several MLPs (members), each with different number of hidden neurons to ensure diversity between them. Facing the imperfect supervisor, it is expected that one of the members is able to learn only from the correct training data letting other members to absorb the corrupted data.

The behavior of each member in this ensemble is explained as follows. Given an input $\mathbf{x}$ that is shared by all the members, the output of kth hidden neuron of the ith member is calculated as follows:

$$
\begin{aligned}
I_{k}^{i,\mathrm{hid}}(t) &= \sum_{j=1}^{N_{\mathrm{hid}}} w_{jk}^{i,\mathrm{in}}(t) x_{j}(t) \\
O_{k}^{i,\mathrm{mid}}(t) &= f\left(I_{k}^{i,\mathrm{mid}}(t)\right)
\end{aligned}
\tag{5}
$$

In Eq. 5 $I_{k}^{i,\mathrm{hid}}$ and $O_{k}^{i,\mathrm{hid}}$ are the potential and output of the kth hidden neuron of the ith MLP in the ensemble, respectively, while x_{j} is the jth component of the input vector, $w_{jk}^{i,\mathrm{in}}$ is the connection weight between the jth input neuron and the kth hidden neuron in the ith member, and f is sigmoid function. For simplicity, in this entry, a member with only one output neuron is considered, in which its output is as follows:

$$
\begin{aligned}
I^{i,\mathrm{out}}(t) &= \sum_{j=1}^{N_{\mathrm{in}}} w_{k}^{i,\mathrm{hid}}(t) O_{k}^{i,\mathrm{hid}}(t) \\
O^{i,\mathrm{out}}(t) &= g_{i}(I^{i,\mathrm{out}}(t))
\end{aligned}
\tag{6}
$$

In Eq. 6 $I_{k}^{i,\mathrm{out}}$ and $O_{k}^{i,\mathrm{out}}$ are the potential and output of the kth hidden neuron of the ith MLP in the ensemble, respectively, while $w_{k}^{i,\mathrm{hid}}$ indicates the weight connecting the kth hidden neuron with the output neuron. g is a scaled sigmoid function as follows:

$$
g_{i}(x) = \frac{1}{1 + \exp\left(-\frac{x}{T_{i}(t)}\right)}, \tag{7}
$$

where $T_{i}(t)$ is the temperature of the ith member.

The temperature of each member affects the member's output, in that a member with a very high

Learning from Imperfect Data. Fig. 2 Outline of nonstationary training supervisor

temperature always produces a constant output regardless of the input. This kind of member is considered to be a passive member which is not contributing in classifying the input. Defining the error of the ith member in Eq. 8 and applying the standard Backpropagation training method, the temperature of the member has

a significant influence on the learning process, because the modifications of connection weights are directly scaled by the temperature as follows:

$$E^i(t) = \frac{1}{2}\left(T(\mathrm{x}(t)) - O^i(\mathrm{x}(t))^2\right) \qquad (8)$$

$$\frac{\partial E^i(t)}{\partial w_k^{i,\text{hid}}(t)} = \frac{1}{T_i(t)} O_k^{i,\text{mid}}(t)\delta^{\text{out}}(t)$$

$$\delta^{\text{out}}(t) = \left(T(x(t)) - O^i(\text{x(t)})\right)\frac{\partial f(I^{\text{out}}(t))}{\partial I^{\text{out}}(t)} \tag{9}$$

Similarly,

$$\frac{\partial E^i(t)}{\partial w_{jk}^{i,\text{in}}(t)} = \frac{1}{T_i(t)} x_j(t)\delta_k^{\text{hid}}(t)$$

$$\delta_k^{\text{hid}}(t) = \frac{\partial f(I_{(}^{\text{hid}}t))}{\partial I_k^{\text{hid}}(t)} w_k^{i,\text{hid}}(t)\delta^{\text{out}}(t) \tag{10}$$

Equations 10 and 11 clearly indicate that a member with a large temperature, T, will not be significantly affected by the learning process as the connection weight modifications are trivial. From this learning characteristic, a mechanism to train one of the members with only the correct training data can be built, provided that the majority of the teacher signals generated by the supervisor are correct most of the time. This learning mechanism can be realized by controlling the temperatures of the members. The core idea behind this learning mechanism is to protect a member that already to some extent is able to approximate the correct input–output relation by increasing its temperature whenever a corrupted training pattern is presented. The temperature control of the ith member is executed as follows:

$$T^i(t+1) = T^i(t) + \Delta T^i(t) \tag{11}$$

$$\Delta T^i(t) = -p_{\text{self}}\left(1 - N\tau^i(t)\right) + p_{\text{cross}}\sum_{j\neq i}\left(1 - N\tau^j(t)\right) \tag{12}$$

$$\tau^i(t) = \frac{\left(D(x(t)) - O^{i,\text{out}}(t)\right)^2}{\sum_j(D((x(t)) - O^{j,\text{out}}(t))^2} \tag{13}$$

In Eq. 12, p_{self} and p_{cross} are the self and cross penalty coefficients, where $p_{\text{self}} > p_{\text{cross}}$. It is also clear that for ensuring the coherency of this competitive learning mechanism the value of the temperatures should be limited to $0 < T^i < T_{\text{max}}$, where T_{max} is empirically set constant. From Eq. 12 it is obvious that if the ith member produces smaller relative error τ^i than other members, its temperature decreases, consequently allowing it to further improve its performance with regard to the same training sample.

Oppositely, a member with a large relative error will be penalized with a large increase in its temperature which prevents it to learn from the given training sample. Here, it is obvious that a member which performs well with regard to the correct training signals will perform poorly with regard to the incorrect training signals implying that it is possible to produce a member which consistently learns only from the correct training patterns. Because the supervisor in majority produces correct training signals, the member which learns from only the correct training pattern should be a member that benefits most from the training process. Such a member can be singled out in the end of the training process, by choosing a member with the lowest average temperature over the whole training process.

Several computational experiments in (Hartono and Hashimoto 2007) show that this temperature-based ensemble model can consistently produce better classifiers given imperfect training supervisors.

Cross-References

References

Hartono, P., & Hashimoto, S. (2007). Learning from imperfect data. *Applied Soft Computing Journal, 7*(1), 353–363.

Hartono, P., & Hashimoto, S. (2000). Temperature switching in neural network ensemble. *Journal of Signal Processing, 4*(5), 395–402.

Holmstrom, L., & Koistinen, P. (1992). Using additive noise in back-propagation training. *IEEE Transactions on Neural Networks, 3*(1), 24–38.

Müller, K.-R., Kohlmorgen, J., & Pawelzik, K. (1995). Analysis on switching dynamics with competing neural networks. *IEICE Transactions on Fundamentals of Electronics, Communications, and Computer Sciences, E78-A*(10), 1306–1315.

Rumelhart, D. E., & McClelland, J. (1984). Learning internal representation by error propagation. *Parallel Distributed Processing, 1*, 318–362, MIT Press.

Vapnik, V. (1995). *The nature of statistical learning theory*. New York: Springer.

Learning from Interventions

▶ Human Causal Learning

Learning from Labeled Data

► Supervised Learning

Learning from Life

► Informal Learning

Learning from Media

► Media and Learning

Learning from Model Answers

► Worked Example Effect

Learning from Noisy Data

► Learning from Imperfect Data

Learning from Observation

► Conceptual Clustering

Learning from Questions

AIMEE A. CALLENDER
Department of Psychology, Auburn University,
Auburn, AL, USA

Synonyms

Adjunct questions; Embedded questions

L

Definition

Questions can be used in the science of learning in a number of different ways. A question is a statement of inquiry that requires some type of reply. The statement of inquiry can be provided to the learner or generated by the learner, and then the reply is generated by the learner. Learning can be defined as acquiring new skills or knowledge through written, auditory, or visual presentation of information.

Theoretical Background

Questions have been used to enhance learning since the time of the ancient Greek philosophers. In fact, one method of learning by questions, the Socratic method, is named after the philosopher who first used the method. Although the original intent of the Socratic method was to address esoteric question such as "What is beauty?" and to disprove hypotheses, it can also be applied to other situations in which the task is to learn basic facts, mathematical equations, and other similar types of information. Currently, questions are commonly used to promote fact-based learning or to prompt critical thinking during reading.

Questions used to promote learning during reading (also called adjunct questions) can take many different forms, and, depending on the goals of the instructor or learner, the questions can target different types of information or thinking skills. For example, questions can be fact based (answers are taken directly from the text), conceptual (may require some integration of information in the text), application (requires applying information in the text to a new situation), or why questions (termed ► elaborative interrogation). Questions can be presented to the learner at three different times during the learning process: before learning (pre-questions), during learning (*embedded questions*), or after learning (post-questions). Pre-questions can be answered at the time that the questions are presented (immediate) or can be answered after the new information is presented to the learner (delayed). The purpose of pre-questions is to prompt the reader to begin thinking about the topic of the text. This prompting aids comprehension and memory in two ways. First, it encourages the reader to activate prior knowledge, which is necessary for constructing a complete mental representation of the text. These benefits are conferred even when the reader is unable to answer the question correctly. Activating prior knowledge allows the reader to make

connections between the new information being learned and prior knowledge, resulting in a more complete mental representation of the text even if the learner is unable to successfully answer the question. The second way in which pre-questions improve comprehension is by orienting the reader to important information in the text. This is particularly helpful for lower ability readers who have difficulty identifying main ideas in the text.

Embedded questions are study questions that are presented within the text and prompt the reader to monitor their own comprehension during reading. Post-questions often function in the same way that embedded questions do; however, the questions are placed at the end of the text. Embedded questions and post-questions allow the reader to focus on main ideas or important information within the text, activate prior knowledge during reading, and integrate the current text with prior knowledge. Readers can either look back at the text to answer the questions or the question may require the reader to respond without referencing the text. Embedded questions can be fact based or application questions. The fact-based questions can be taken directly from the text (verbatim) or paraphrased. Paraphrased questions produce better understanding of the text than verbatim questions whereas application questions, originally thought to produce more complete processing, have not been shown to produce better performance on test questions than fact-based questions (Andre et al. 1980).

A specific form of questioning that is presented during or after learning that can be used to activate prior knowledge is elaborative interrogation. Elaborative interrogation is a question that begins with "why" as opposed to questions that begin with "what" or "who." Why questions are questions about the information currently being learned, but instead of only using the text (or other given materials) to answer the question, the learner is prompted to retrieve prior knowledge to create a more complete answer (Pressley et al. 1987). Why questions have been shown to be successful with children and adults when learning basic facts or reading short prose. However, it has not been as successful with longer texts. Elaborative interrogation, similar to other questioning methods, encourages the reader to activate prior knowledge during reading. The act of activating prior knowledge and using that knowledge to clarify relationships

between newly learned information improves both memory and comprehension for short text. Elaborative interrogation has not been as effective with longer texts, likely because the text provides the necessary elaboration, reducing the knowledge activation that is required to complete the task.

The standard questioning techniques can improve learning by orienting the learner to important information, activating prior knowledge, and improving metacognitive awareness. Many students have poor ▶ metacognition and cannot gauge what they have and have not learned. Questions, then, can act as prompts for the learner to monitor the learning process, assessing what they do and do not know, thus improving metacognition.

Important Scientific Research and Open Questions

Adjunct questions are thought to be generally beneficial, and such questions are often used in textbook for learners of all ages (elementary school through college). However, research indicates that such questions may not be equally beneficial for all learners, as the benefits of such questions may depend on individual differences in reading and learning (e.g., reading comprehension; Callender and McDaniel 2007) and the type of text being read. Although the general conclusion is that questions aid learning, there are indications that the learner's abilities may determine whether the questions are effective. For example, some studies have indicated that pre-questions facilitate learning for low ability readers whereas post-questions improve the learning of high ability readers. Embedded questions are particularly beneficial for low ability readers because low ability readers have difficulty focusing on the important points of the text. These types of question may impair the naturally occurring processing of high ability readers, and may actually decrease memory and comprehension of the text. Thus, it is important to consider the learner's abilities when determining what types of questions to use.

Further, according to the theory of ▶ Material Appropriate Processing (Einstein et al. 1990), the questions that are asked should complement the materials (or text), and not simply ask the learner to engage in processing that is normally done when reading the text. For example, when reading an expository text,

particularly technical texts, readers naturally process individual items or facts. In this situation, questions should encourage relational processing. For a narrative text, in which the relational aspects of the text are easily processed, the questions should target individual facts. Thus, according to Material Appropriate Processing, the questions should promote the type of processing (relational or item-specific) that is not naturally processed when reading that type of text.

Due to advances in technology, learning from questions is transforming from a static, predetermined set of questions (for example, questions preprinted in a textbook) to a more dynamic learning experience. Although not widely available, intelligent tutoring systems have been created to aid learning through questions. Intelligent tutoring systems (e.g., AutoTutor [Graesser et al. 2005]) initially present a question to a learner and as the learner attempts to answer the questions, the system can analyze the quality, accuracy, and completeness of the answer. Through additional questions, the system can assist the learner in creating a more complete answer. Intelligent tutoring systems have been shown to greatly improve student learning, with effect sizes ranging from 0.5 to 1.0 standard deviations.

Recently, questions have also been used as the critical task in ► test-enhanced learning, or the testing effect. Test-enhanced learning is the concept that by repeatedly retrieving a set of information, long-term retention is enhanced compared to repeatedly studying the information. Learners initially study the information and then are asked a series of questions on the just studied information. On an immediate test, if the learner had repeatedly studied the information, performance is higher than if the learner was tested on it. However, after a delay (48 h to 1 week), testing produces much higher performance on the final test than repeated studying (Roediger and Karpicke 2006). Test-enhanced learning is different from other questioning techniques in that instead of focusing on improving encoding, learning and memory is improved by strengthening retrieval processes. Test-enhanced learning is an effective method to increase memory for the information repeatedly tested as well as for other information was not tested, known as transfer. It can also protect against proactive interference, which is often a source of forgetting for newly learned information.

Cross-References

► Adjunct Questions – Effects on Learning
► Computer-Enhanced Learning and Learning Environments
► Discourse Processes and Learning
► Effects of Testing on Learning
► Test-Enhanced Learning

References

Andre, T., Mueller, C., Womack, S., Smid, K., & Tuttle, M. (1980). Adjunct application questions facilitate later application, or do they? *Journal of Educational Psychology, 72*(4), 533–543.

Callender, A., & McDaniel, M. (2007). The benefits of embedded question adjuncts for low and high structure builders. *Journal of Educational Psychology, 99*(2), 339–348.

Einstein, G., McDaniel, M., Owen, P., & Coté, N. (1990). Encoding and recall of texts: The importance of material appropriate processing. *Journal of Memory and Language, 29*(5), 566–581.

Graesser, A. C., Chipman, P., Haynes, B. C., & Olney, A. (2005). AutoTutor: An intelligent tutoring system with mixed-initiative dialogue. *IEEE Transactions on Education, 48*, 612–618.

Pressley, M., McDaniel, M., Turnure, J., Wood, E., & Ahmad, M. (1987). Generation and precision of elaboration: Effects on intentional and incidental learning. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 13*(2), 291–300.

Roediger, H., & Karpicke, J. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science, 1*(3), 181–210.

Learning from Screen Media

► Learning from Television During Early Childhood

Learning from Television During Early Childhood

Rachel Barr, Natalie Brito
Department of Psychology, Georgetown University, Washington, DC, USA

Synonyms

Learning from screen media

Definition

Learning from television during early childhood is cognitively demanding. The *video deficit effect* refers to the finding that prior to age 3, children have difficulty transferring what they view on screen to real life, and consistently learn less from television than from a live demonstration (Anderson and Pempek 2005). Furthermore, exposure to *background television*, content that is designed for an older audience, is detrimental to later cognitive outcomes. The fact that infants learn less from television than from live demonstrations, as well as the effects of background exposure on play, may limit what infants can gain from television exposure. Since the 1990s, however, there has been a large increase in the production of programming for infants and young children. At present, the long-term effects of early media exposure on social and cognitive development are largely unknown. Researchers are examining how specific kinds of exposure to commercial programming influence early development and what kinds of experiences help young children understand and decode the symbolic nature of screen media.

Theoretical Background

Early Media Exposure

American children are born into and develop in a world in which media pervade their daily experiences. A recent nationwide survey of 1,000 homes with children aged 0–6 years conducted by the Kaiser Family Foundation found that that 99% of homes contain a television set, 95% a DVD player or VCR, 50% have three or more televisions, 73% have a computer, and one-third of the children have televisions in their bedrooms. Media content for infants and young children is also changing. During the 1970s children were first exposed to television on a regular basis at approximately 2.5 years of age. During the 1990s television programs and videos/DVDs started to be produced specifically for infants. This has shifted the age of regular exposure downward, such that many infants begin consistently viewing videos/DVDs at 6- to 9-months of age; 74% are exposed to television before the age of 2, and of those exposed, they spend approximately 2 hours per day with screen media. Furthermore, 58% of parents believed that early exposure to educational television programming was "very important."

Patterns of television use differ across ethnicity and socioeconomic status with low-income minority children being exposed to more television than children from higher income households.

Partly in response to this change in the media landscape, the American Academy of Pediatrics (1999) recommended that parents should not expose children under 2 years of age to any type of screen media and limit screen time to a maximum of 2 hours per day for all screen media, including computers, for children who were over 2 years of age. This recommendation was based on two major concerns. First, numerous studies had shown negative effects of media aggression on preschooler's behavior and such effects were also predicted when exposure occurred at a younger age. Second, time spent with screen media may be displacing other activities that are more important for children's development, such as face-to-face time with parents and caregivers. At the time of the recommendation, very little was known about the impact of exposure to screen media during early childhood.

Attention and Learning

Observational studies show that children's visual attention to television increases between 1 and 2.5 years of age. There are a number of salient formal features that consistently increase toddlers' and preschoolers' attention to television. Attention to televised content increases and remains high in the presence of female adults, character action, children, puppets, animation, active movement (including dancing and repetition), singing and lively music, peculiar voices, and sound effects. It decreases as the length of a segment increases, during low action, and during periods of adult narration or abstract adult dialogue. Increased attention in the presence of a salient effect has also been associated with increased comprehension of the media content by young children (Anderson and Pempek 2005). Other forms of attention such as online verbal and nonverbal imitative behavior, pointing, and verbalizations have also been associated with increased comprehension. Studies show that attention increases for highly familiar content and when parents are interacting with their child during media viewing (Barr 2010).

The *video deficit effect* has been demonstrated using multiple paradigms including imitation tasks, object search tasks, emotion processing tasks, and verbal

comprehension tasks. For example, using a speech discrimination paradigm, very young infants can distinguish between different speech sounds early in life, but gradually lose their sensitivity to sounds they do not hear regularly (sounds not found in their native language). In order to see if continued experience with nonnative sounds would prevent this loss in sensitivity, 9- and 12-month-old American infants were repeatedly exposed to a set of nonnative (Mandarin) speech sounds. The sounds were presented to the infants either by a live person or via video. Only the infants who were exposed to the Mandarin sounds by a live person were able to prolong their sensitivity to those speech sounds, and the infants who learned via video did not. Social contingency within the interaction, which was absent on video, was necessary for language learning (Linebarger and Vaala 2010). Similarly, 8- to 16-month-olds exposed to higher levels of infant-directed programming show slower vocabulary gains, during a time when social interaction is pivotal (Christakis 2009).

Most of the research on learning from television has been conducted using the imitation paradigm because it is a direct and ecologically valid measure of knowledge transfer (Barr 2010). Successful imitation from a videotaped model requires the participant to form a memory of the event from the 2D objects on television and be able to transfer that memory to 3D objects in the real world. In Bandura's classic studies, 3- to 5-year-old children watched as an adult modeled a number of novel, aggressive acts using an inflatable Bobo doll. Children who were exposed to the televised adult model exhibited high levels of aggressive behavior toward the doll when they were allowed to play with it immediately after the demonstration. Furthermore, children were as likely to imitate aggressive acts modeled on television as when they were modeled live.

More recently, the ability of preverbal and early-verbal infants to learn from televised presentations has also been examined using imitation paradigms. For example after observing a live demonstration in which a model engaged in a sequence of target actions, 12-, 15-, and 18-month-olds successfully imitated what they had seen the model do, even after a 24 h delay. Only 18-month-olds imitated after observing a televised model, however, they imitated fewer target actions than the infants who saw the live demonstration, exhibiting the typical *video deficit effect*. When the

number of repetitions of the target actions was doubled, 6- to 18-month-olds were able to imitate from television. Furthermore, other imitation studies have shown that judicious use of formal features (e.g., sound effects), reduction of memory load, and addition of social contingency or language cues can ameliorate this deficit (Barr 2010).

Possible Risks

Background television. As predicted by the AAP, exposure to screen media does interfere with play and parenting behavior. This finding applied primarily to exposure to background television, which is not designed for young children and does not include age-appropriate educational content. Very young children do not overtly attend to background television, because its content is usually incomprehensible to them. Furthermore, because incidental sound effects attract infant attention to the television for short bursts and away from ongoing play, it diminishes both the length of play episodes and the degree of focused attention during play. Early exposure to background television is due to other family members using media in the infants' presence; it has been estimated that interactions between parents and children decrease by up to 22%. Therefore background television may interfere with learning on two fronts, by disrupting play and also by decreasing parent–child interactions (Anderson and Pempek 2005).

Attention Problems. The relationship between early television exposure and later attention problems is complex and research findings have been mixed (Christakis 2009; Courage and Setliff 2009). Some studies have shown associations between high television exposure during early childhood and later parental reports of attention difficulties. Although early television viewing may cause later attention disorders, it is not possible to identify the directionality of this association. For example, it is possible that parents with attention deficit use more television and therefore expose their children to higher levels of television, or that parents who are finding it difficult to cope with high levels of hyperactivity or poor attention encourage their children to watch more television. Other factors may also contribute to this relationship, such as maternal education and socioeconomic status which are also associated with higher television exposure (over

7 hours per day) and higher prevalence of reported attention difficulties. Researchers examining poverty have suggested that high television use may be a risk factor for children living in poverty, because it contributes to overall noise and disruption within the household.

Ways to Ameliorate Risk

Use of Repetition to Enhance Learning from Television. Young children often see material from media sources repeatedly, due to accessibility of videos and television programming schedules, and parents often report that preschoolers frequently ask to repeatedly view the same program. Furthermore, with repeated presentations of the same television program preschoolers' attention is maintained while comprehension increases until it finally reaches a ceiling. When televised demonstrations are repeated, even 6-month-olds can imitate simple actions from television (Barr 2010). Furthermore, vocabulary gains from television viewing can be seen in a longitudinal study when infants repeatedly viewed Sesame Street® videos or DVDs but not when they viewed television programs (Linebarger and Vaala 2010). These findings have important applied implications for television programmers and have been applied to programs such as Blues Clues which air the same episodes multiple times per week.

Use of Educational Content to Enhance Language Development and Academic Success. There are beneficial effects of screen media for children as young as age 2. When television content was examined, children who watched educational television actually had higher school readiness and language skills (Linebarger and Vaala 2010). For example, children exposed to high-quality children's educational programs such as *Sesame Street®* and *Mister Rogers' Neighborhood®* during the preschool years have enhanced cognitive development, language development, prosocial skills, and such exposure has a long-lasting positive impact on school readiness and academic performance (Anderson et al. 2001). For very young children, findings are emerging to suggest that parental scaffolding may be essential to reaping these benefits from educational content.

Important Scientific Research and Open Questions

Children start watching television at a very young age and the amount of child-directed programming is increasing in television and now in other platforms including computers and touch screens. The research on early media exposure for children is still a small but growing field and there are many open questions including how developing perceptual, linguistic, and cognitive skills and symbolic understanding contribute to transfer of learning. Longitudinal studies and intervention experiments are also needed to address the potential negative and beneficial impacts of television for young children. Our understanding of the effects of television viewing is still developing, but the finding that parents believe that television has the potential for educational benefits can be used to reinforce the message that co-viewing is particularly important for very young children who find learning from television cognitively demanding. Reducing exposure to background television, increasing the availability of high-quality educational programming, and emphasizing the importance of co-viewing for younger audiences may facilitate learning from television during early childhood.

Cross-References

▶ Attention Deficit and Hyperactivity Disorder
▶ Audiovisual Learning
▶ Imitation and Learning
▶ Play, Exploration, and Learning

References

American Academy of Pediatrics, Committee on Public Education. (1999). Media education. *Pediatrics, 104*, 341–342.

Anderson, D., & Pempek, T. (2005). Television and very young children. *The American Behavioral Scientist, 48*, 505–522.

Anderson, D. R., Huston, A. C., Schmitt, K. L., Linebarger, D. L., & Wright, J. C. (2001). Early childhood television viewing and adolescent behavior: the recontact study. *Monographs of the Society for Research in Child Development, 68*, 1–143.

Barr, R. (2010). Transfer of learning between 2-D and 3-D sources during infancy: Informing theory and practice. *Developmental Review, 30*, 128–154.

Christakis, D. A. (2009). The effects of infant media usage: what do we know and what should we learn? *Acta Paediatrica, 98*, 8–16.

Courage, M., & Setliff, A. (2009). Debating the impact of television and video material on very young children: attention, learning, and the developing brain. *Child Development Perspectives, 3*, 72–78.

Linebarger, D., & Vaala, S. (2010). Screen media and language development in infants and toddlers: an ecological perspective. *Developmental Review, 30*, 176–202.

Learning from Text

Noorizah Mohd. Noor, Tg. Nor Rizan Tg. Mohd. Maasum
Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

Synonyms

Text learning; Textual schema

Definition

Learning from text involves a multidimensional perspective that includes students' knowledge, reader goals, interests, reader strategies, and levels of understanding. The basic idea of a text identifies it as a medium or tool used to impart knowledge and communicate ideas. Text-based learning is not restricted to classroom learning but also encompasses societal context. This process is inevitably a synthesis of skills which requires readers to strategically engage in the construction and interpretation of meaning. The background of the reader, style of the text, and origin of the content contribute to cognitive interests when the text captures the readers' minds and thoughts.

Theoretical Background

Learning from text can be interpreted as a developmental process in three levels from novice, competent, to proficxient readers. Novice readers have little or limited experience and knowledge about the topic or field of study. If the text does not have enough explanations or elaborations, these readers will face difficulty in determining if the information found in the text is relevant. When they have enough subject matter knowledge and strategy to read in a particular area of study, these readers are said to achieve competence. As competent learners, they have a richer and more cohesive framework of knowledge to guide their reading. This knowledge includes the ability to employ more sophisticated strategy. Proficient readers have a wealth of knowledge, deep interest in the subject matter, and use strategic effort to gain a deep understanding of the reading (Alexander et al. 1994). However, very few readers achieve this stage. Thus, in terms of pedagogy, there is a need to provide considerable amount of scaffolding that helps them in building a meaningful base of content knowledge and the seed of personal interest. As the reader progresses through competence, the need for scaffolding will be reduced in helping the student to construct knowledge using their own strategies; competent readers can construct their own knowledge. The tasks and text should become more challenging. Once the students progress to proficient readers, opportunities for pursuing topics in an in-depth manner should be provided (see for an overview McNamara 2007).

There are a number of factors associated with learning from text. Background knowledge is regarded as the most influential on what readers understand and remember. Comprehension of the text will take place when there is a match between the readers' background knowledge and the information found in the text. Background knowledge is dynamic and constantly altering (McNamara and Kintsch 1996). They are not permanent structures which are stored and retrieved from memory. Hence with all the components of knowledge, readers will be provided with various perspectives on text content. Simultaneously, to activate and sustain interest, readers will select information to form interpretations of the text.

Background knowledge can be categorized into three areas: linguistic, formal (school-based), and informal (experience-based) learning context, and subject matter (content). Linguistic knowledge refers to structures and forms of written language such as vocabulary and text genres. To construct meaning of a given text, the readers need to utilize the two sources of knowledge: spontaneous (informal) and school-based (formal). However, to construct meaning and maximize learning experience, readers should combine both types of knowledge. In reference to linguistic knowledge, textual or formal schema refers to the organizational forms and rhetorical structures of the written text. This is the knowledge that one brings to a text about structure, syntax, grammar, and vocabulary. Thus, textual or formal schema relates to cohesion, organization, domains/genres of text. Subject matter knowledge or content represents the notion of topic knowledge that a reader has on a certain domain-related concept.

In their attempt to interpret what they read, various factors interact with one another (Huang 2009). Apart from knowledge of the language, which includes orthographic, lexical, syntactic, and semantic, knowledge on reading strategy also contributes toward readers'

reading competence. Singhal (2001:1) identifies reading strategies as "how readers conceive of a task, how they make sense of what they read and what they do when they don't understand." For example, when reading becomes difficult, the reader would first need to identify and select the most appropriate strategy to facilitate a better understanding of the text. Hence these reading strategies reveal how learners use a range of strategies to cope with acquisition, storage, and retrieval of information.

The process of reading also includes the ability to assign or create meaning from linear and nonlinear materials. Kintsch (1998) classifies the comprehension process into three levels: a micro-level of sentences, a macro-level of discourse and a third level addressing the text-reader relationship. First, at the micro-level of sentences (verbatim or semantic representation of the text), meaning is analyzed as a series of short, abstract statements called proposition. Propositions comprise word concepts that may appear in a real sentence as a word or a phrase. There are two functions of the word concepts: (1) as a predictor/relational term (often verbs) or (2) as arguments. According to Kintsch (1998), several conventions are used in the writing of propositions. First, the word concepts are written in capital letters. Second, the predicator is always written first and separated from other word concepts by commas. Finally, each proposition is enclosed in parenthesis and numbered. The example below is adapted from Horning (1987):

| Andrew plays a guitar | (PLAY, ANDREW, GUITAR) |

In this instance, PLAY is the predicator and ANDREW and GUITAR are the arguments of the proposition. The abstract nature of this proposition is highlighted by the fact that it might be the proposition underlying any of the following terms:

Andrew plays a guitar.
Andrew is playing a guitar.
A guitar is being played by Andrew.
The playing of a guitar by Andrew.
Andrew's playing of a guitar.

A number of possibilities in terms of the propositional content can also be found in a sentence or group of sentences. This form of analysis can be used to deal with larger units of discourse apart from simple sentences such as a complex sentence, paragraph, or whole essay.

Second, the macro-level or discourse-level analysis (propositional representation) consists of an ordered list of proposition that is derived from the text known as a text base. In the text base, two features of the proposition are evident. The first feature describes the capacity for embedding whereby one proposition may be embedded in another by serving as an argument. The other feature distinguishes between two broad types of proposition: subordinate or superordinate. The system of classification leads to the formation of a hierarchical arrangement of proposition in the text base and produces a measure of text coherence.

In the third level, readers construct the meaning as a result of their interaction in the form of a text base and other factors. One of the crucial factors is knowing one's audience which is considered the broadest level of analysis of meaning using the concept of schema. A schema helps to present a context in which inferences can be made to complete the meaning of a text. Thus, it provides a structure for organizing a text base into its macro-structure proposition. Here, both the macro structure and the individual propositions can be placed in comprehension. From these propositions, factors such as individual's prior knowledge, abilities, preferences, and strategies will be moderated as the mental representations/schema. An example of the schema for a children's visit to the zoo implies animals and rides.

A paradigm shift in literacy education has provided students with environments which are filled with visual, electronic, and digital texts which are referred to as multimodal (Kress and van Leeuwen 2001). Multimodal texts are referred to as texts which have more than one mode. Thus, meaning from this text can be communicated through a synchronization of modes. These texts may incorporate spoken or written language, still or moving images or produced on paper or electronics screen, and may incorporate sounds. Nowadays, learners encounter different types of multimodal texts in their educational environment in the print form such as picture books, information books, newspapers, and magazines. In nonprint forms, multimodal texts are films, videos, and texts through the electronic screens such as e-mails, the Internet, and the digital media such as CD-ROMs and DVD.

When a learner reads from multimodal instructional materials, he or she needs to simultaneously

process the message in words, pictures, images, and graphics. In addition with the growing dominance of multimodal texts and digital technology, these materials are displayed on electronic or digital screens where learners will be able to approach meaning with added combination of movement and sound (Kress and van Leeuwen 2001)..

Important Scientific Research and Open Questions

Latent semantic analysis (LSA) is a powerful statistical technique to generate a new theory of knowledge induction and representation by providing a method to determine the similarity of meanings of words and passages in a large corpus of text (Landauer et al. 1998). Its function is to forecast the extent in which readers will learn from text based on the estimated conceptual match of similarity between their topic knowledge and text information. LSA is used to stimulate a variety of human cognitive phenomenon that ranges from developmental acquisition of recognized vocabulary to word-categorization, sentence-word semantic priming, discourse comprehension, and judgment of essay quality. In other words, it is capable of correctly inferring deeper relations and regarded as better predictors of human-based judgments and performance. In practical terms, LSA produces measures of word-word, word-passage, and passage-passage relations that are well correlated with several human cognitive phenomena involving association or semantic similarities. Based on the correlations, there is a close resemblance between the LSA extracts and the way people construct meaning based on what they have read or heard (Magliano and Millis 2003). Consequently, we can relate human judgments of meaning similarity between words and predict word-based similarity between passages.

Online reading is another reading context that is gaining popularity. One of the challenges of managing electronic or online texts is the need to have stronger literacy abilities due to the fact that the information presented online is in nonlinear form. The reading process is not merely a simple transfer of strategies from print to online (Kasper 2003) but rather assessing information using a semantic network and to make connections with the multiple related sections of the text. By following certain support tools or links, then only the reader can actively engage with that text. With

online texts, readers can enhance comprehension by utilizing background knowledge to create and expand their cognitive capacity that guides the construction of meaning. Following this, readers will be provided with numerous opportunities to acquire, examine, and transform knowledge through reconstruction of text, intertextual analysis, and exposure to multiple subject matter content.

Learning from texts has a broader perspective now in lieu of the expansion of the aspects of texts which is referred to as multimodal. There is a need to look at the new theories of literacy and pedagogies to meet the challenges of this continuously evolving learning environment. With the integration of visual, electronic, and digital features in multimodal texts, further research is needed to understand how these complex modes are processed and how meaning is constructed (Kress, and van Leeuwen 2001).

Cross-References

► Discourse
► General Literacy in a Digital Work
► Literacy and Learning
► Reading and Learning
► Schema(s)
► Text Relevance for Learning

References

Alexander, P. A., Kulikowich, J. M., & Jetton, T. L. (1994). The role of subject-matter knowledge and interest in the processing of linear and nonlinear texts. *Review of Educational Research, 64*, 201–252.

Horning, A. S. (1987). Propositional analysis and the teaching of reading with writing. *Journal of Advanced Composition, 7*. Retrieved December 12, 2010, from http://jac.gsu.edu/jac/6/Articles/4.htm

Huang, Q. (2009). Background knowledge and reading teaching. *Asian Social Science, 5*(5), 138–142.

Kasper, L. (2003). Interactive hypertext and the development of ESL students' reading skills. *The Reading Matrix, 3*(3). Retrieved June 22, 2009, from http://www.readingmatrix.com/articles/kasper/index2.html

Kintsch, W. (1998). *Comprehension – Paradigm of cognition*. Cambridge: Cambridge University Press.

Kress, G., & van Leeuwen, T. (2001). *Multimodal discourse: The modes and media of contemporary communication*. London: Arnold.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analysis. *Discourse Processes, 25*, 259–284.

Magliano, J. P., & Millis, K. K. (2003). Assessing reading skill with a think-aloud procedure and latent semantic analysis. *Cognition and Instruction, 21*(3), 251–283.

McNamara, D. S. (Ed.). (2007). *Reading comprehension strategies: Theories, interventions, and technologies.* Mahwah: Lawrence Erlbaum.

McNamara, D. S., & Kintsch, W. (1996). Learning from texts: Effects of prior knowledge and text coherence. *Discourse Processes, 22,* 247–288.

Singhal, M. (2001). Reading proficiency, reading strategy, metacognitive awareness and L2 readers. *The Reading Matrix, 1.* Retrieved March 9, 2004, from http://www.readingmatrix.com/articles/singhal

Learning from Varied Experiences

▶ Variability of Practice

Learning from Video

Katherine S. Cennamo
Department of Learning Sciences and Technologies, School of Education, Virginia Tech, Blacksburg, VA, USA

Synonyms

Video-Based Learning

Definition

"Learning from video" refers to a change in knowledge, skills, attitudes, or behaviors as the result of viewing information presented via video. For the purposes of this review, video is defined as the simultaneous presentation of a continuous stream of visual and auditory information. Auditory input may involve a combination of spoken words, music, and sound effects. The visual information may include a combination of real images, animations, graphics, and text. Video content can be delivered through a wide variety of distribution modes including broadcast or cable television, videotapes, DVDs, CD-ROMs, and the Internet. Video can be prerecorded, as with videotapes or DVDs, for example, or delivered as it happens, as with streaming video delivered via webcams or live television broadcasts. Although video can be made "interactive" through two-way broadcasts or computer-based branching techniques, for the purposes of this review, video will be considered a one-way medium where interactions, when they are even possible, are limited to stopping, starting, and replaying a linear presentation.

Despite the wide variety of distribution modes, the process of learning is similar for them all: all require the learner to simultaneously attend to, and cognitively integrate, a continuous stream of visual and auditory information. Consequently, learning from video requires the ability to decode the meaning of the various ▶ symbol systems presented and integrate them into a coherent whole.

Because of its ability to present synchronized images and sounds, video is particularly effective in modeling behaviors, demonstrating procedures, adding realism to a lesson, telling stories, creating an emotional response, and influencing attitude formation. Learning can be intentional, as when viewing an instructional program, or incidental (▶ Incidental Learning), as when learning occurs as the result of viewing a program designed for entertainment.

Theoretical Background

Most current research in learning from video is grounded in cognitive theories of learning (▶ Cognitive Learning) (Seels et al. 2004). According to cognitive theories, learning from video begins with receiving information though our senses. As information is received through the ▶ sensory register, certain information is selected for further processing. The selected information is placed in short-term memory (▶ Short-Term Memory and Learning) and, there, learners organize and elaborate on the content in order to encode the information for storage in long-term memory.

The process of encoding involves connecting new information with related information, often stored as prior knowledge. Prior to encoding, the learners may need to search their long-term memories for related concepts in order to generate the relationships between ideas that are necessary for the efficient storage of the new information. When new information is mentally connected to related information, more cues are available for retrieval, thus facilitating the effective storage and retrieval of new information. When presented with new information, we would like for our learners to

"think about" the content. We would like for them to connect the new information with related information. We would like for their minds to wander in a meaningful way.

However, due to the transient nature of the symbol systems present in video-based instruction and the linear, fixed pace of the presentation, learners may be forced to choose between perceptual processing of the new content as it is being received, searching long-term memory for ideas related to the content previously attended to, or actively elaborating on the content of the program. In addition, the constant pace of information-presentation inherent in video-based materials may present additional challenges. Under most conditions, learners are not able to spend additional time studying difficult information presented through video-based materials; instead learners who wish to organize and elaborate on difficult content presented through this medium are required to concentrate harder and expend more ▶ mental effort per unit of time. Given the assumption of cognitive theories of a limited capacity ▶ working memory, the challenge for teachers, trainers, and instructional designers is to maximize the effort that learners expend in organizing and elaborating on the content of a video-based lesson (referred to by proponents of ▶ cognitive load theory as germane load), while minimizing the effort devoted to processing sensory input, searching long-term memory for related information, and similar activities necessary to "make sense" of the information (or extraneous load in cognitive load theory).

Important Scientific Research and Open Questions

Research on learning from a constant stream of synchronized visual and audio information began in the early 1900s with research on instructional films (Seels et al. 2004). Most of what is known about the cognitive processing of video comes from research using prerecorded videocassettes as part of the "television" research of the 1980s and early 1990s.

Researchers have investigated the cognitive processing of video materials using a variety of ▶ opinion measures, secondary tasks techniques, and ▶ physiological measures to determine when and how learners invested their limited cognitive resources in processing the materials. They found that, under

certain conditions, increased cognitive effort may increase achievement, yet, under other conditions, increased effort may not result in achievement gains.

When increased cognitive effort is expended on processing sensory input, additional effort does not always result in increased achievement. For example, Reeves, Thorson, and Schleuder (1985) presented learners with a videotaped program through audio-only, visual-only, or audio-visual conditions and measured the amount of effort they expended in processing the information using a secondary task technique. Learners were asked to watch the videotape and also to press a key each time they heard a tone. The researchers found that learners who attended to the audio-visual presentation had the longest reaction times to the secondary task, and thus, assumed that processing audio and visual information simultaneously required more effort than processing the audio or visual information alone. However, there were no significant differences in learners' performance among the three groups. It is likely that the additional effort expended by learners who received the audio-visual presentation was allocated to processing and integrating the information presented through both the auditory and visual channels; as a result, this increased effort had no significant effects on achievement scores.

In other studies, increases in mental effort that did not result in increased achievement scores may have been accounted for by the effort required to search long-term memory for prior knowledge related to the new information. For example, Lang et al. (1993) found that learners exerted more effort in processing video segments that included cuts which represented changes in content (unrelated cuts) than they did in processing segments that included cuts related to the information preceding them through visual elements or narration (related cuts). However, the learners recalled more of the information surrounding related cuts than surrounding unrelated cuts. When learners were presented with an unrelated cut, they may have needed to devote additional mental effort to searching long-term memory for information related to the new information and, thus, missed the content critical to performing well on a test of information surrounding the unrelated cuts.

When the materials are structured in such a way that learners' can easily organize and elaborate on the

information presented, increased effort may result in increased achievement. In one study (Grimes 1990), the researcher presented learners with three versions of a videotaped program and found that learners expended more effort in the condition where the visual and auditory channels presented corresponding information (high correspondence), and least effort in the condition where there was only a thematic match between the visual and the audio portion of the program (medium correspondence). Scores on a visual recognition test followed the same pattern; learners who viewed the program with high correspondence scored highest and those who viewed the program with medium correspondence scored lowest. The presence of auditory and visual information with a high degree of correspondence may have minimized the need for learners to expend effort in "making sense" of competing ideas presented through the audio and visual channels and provided the best conditions under which to expend effort in organizing and elaborating on the content.

The positive relationship found between invested mental effort and achievement in some studies and the apparent lack of such a relationship in others may be due to differences in the cognitive activities that occur during increases in effort. When additional effort is devoted to the process of elaboration and creating meaning from the content, parallel increases in achievement scores may result. However, effort devoted to perceptual processing or to searching memory for related knowledge may result in a breakdown in comprehension, and thus achievement gains may not parallel expenditures of effort.

Although it seems intuitive that learner control of a video presentation would result in more strategic cognitive processing and increased achievement scores, Krendl and Watkins (1983) found that there was no significant difference in the achievement scores of learners who were presented with a fixed paced video lesson and those who were provided with the opportunity to stop and start the program at will. In fact, recent research using DVDs of lectures suggests that comprehension may actually be disrupted when learners stop and restart the program to take notes (Caspi et al. 2005).

Cennamo (1993), however, has identified several promising techniques that may enhance learners'

opportunities to elaborate on the content of a video-based lesson through a review of the literature on the cognitive processing of video-based lessons. The research suggests that the complexity of the video-based message should be reduced through the use of simple syntax, common words, and simple visual effects. Programs should be designed so there is a high degree of correspondence between the video and audio messages. Programs that provide pauses following complex elements, such as unrelated scene changes and difficult sentences, may provide time for perceptual processing and for viewers to make sense of the message relative to their existing schemata before additional critical information is presented. Music, explanatory examples, and other mentally undemanding content may be used to allow the learners time to prepare to elaborate on new content information.

In addition, research suggests that videotaped materials should be designed so that the intended message is embedded in a context that emphasizes its importance. Learners seem to allocate their effort strategically, expending more effort in processing content that is central to the story line than to other less central information. Embedded questions can focus the learners' attention on the most relevant information and help them fit the new information into a meaningful context. Although viewers may not be able to actively respond to questions that are embedded in video, increased effort can be encouraged simply by including questions to which the viewers are expected to respond covertly. In addition, research suggests that questions which require a high level of cognitive processing may stimulate learning at a more comprehensive level than questions which require rote learning. Techniques as simple as informing the users that the materials are designed to be educational and they are to learn as much as possible from the lesson were also found to increase the effort invested in learning from a video-based lesson.

Current trends in video delivery may provide distinct advantages for cognitive processing over older delivery modes. For example, more and more frequently video content consists of short segments delivered via the Internet. Findings of older research on learning-from-video suggest that learners need time to mentally elaborate on the content when learning

from video. They need time for their minds to wander in meaningful ways. Through presenting the video in short segments, as is common on the Web, learners are provided with, and can take, the time they need for cognitive processing before viewing another segment.

Although there are many possible techniques that may enhance learners' opportunities to elaborate on the content of video-based lessons, there is a paucity of research using current video-based delivery modes and strategies. Since the early 1990s research investigating the simultaneous processing of audio and visual information has increasingly focused on computer-delivered multimedia (▶ Multimedia Learning) and animations (▶ Animation and Learning and ▶ Learning with Instructional Animations) often from a cognitive load perspective. The extent to which the results of cognitive load research, as well as research that has investigated the cognitive processing of text, audio, and video materials, may provide practical guidelines for increasing the effectiveness of video-based lessons is worthy of further research.

Cross-References

▶ Audiovisual Learning
▶ Children's Learning from TV
▶ Cognitive Learning Strategies for Digital Media
▶ Interactivity in Multimedia Learning
▶ Media Effects on Learning
▶ Streaming Media

References

Caspi, A., Gorsky, P., & Privman, M. (2005). Viewing comprehension: Students' learning preferences and strategies when studying from video. *Instructional Science, 33*, 31–47.

Cennamo, K. S. (1993). Learning from video: Factors influencing learners' preconceptions and invested mental effort. *Educational Technology Research and Development Journal, 41*(3), 33–45.

Grimes, T. (1990). Audio-video correspondence and its role in attention and memory. *Educational Technology Research and Development, 38*, 15–25.

Krendl, K. A., & Watkins, B. (1983). Understanding television: An exploratory inquiry into the reconstruction of a narrative content. *Educational Communications and Technology Journal, 31*, 201–212.

Lang, A., Geiger, S., Strickwerda, M., & Sumner, J. (1993). The effects of related and unrelated cuts on television viewers' attention, processing capacity and memory. *Communication Research, 20*(1), 4–29.

Reeves, B., Thorson, E., & Schleuder, J. (1985). Message complexity and attention to television. *Communication Research, 12*, 427–454.

Seels, B., Fullerton, K., Berry, L., & Horn, L. (2004). Research on learning from television. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (2nd ed.). Mahwah: Lawrence Erlbaum.

Learning from Worked Examples

▶ Example-Based Learning

Learning from Worked-Out Examples

▶ Example-Based Learning

Learning Goal Pursuit

▶ Volition for Learning

Learning Goals

▶ Goal Theory/Goal Setting

Learning Group

▶ Group Dynamics and Learning

Learning Hierarchical Features

▶ Learning Hierarchies of Sparse Features

Learning Hierarchies of Sparse Features

Marc'Aurelio Ranzato[1,2], Y-Lan Boureau[1,3],
Koray Kavukcuoglu[1], Karol Gregor[1], Yann LeCun[1]
[1]Courant Institute of the Mathematical Sciences,
New York University, New York, USA
[2]Computer Science, University of Toronto, Toronto,
ON, Canada
[3]INRIA - Willow project-team (INRIA/ENS/CNRS
UMR 8548), Paris, France

Synonyms

Deep learning; Learning hierarchical features; Sparse feature learning

Definition

In the context of learning, a *feature* is a representation of part of a percept, for example the presence of a particular motif in a particular location in the visual field. Low-level features, for example signaling the presence of a contour, may be combined into higher-level features, for example signaling the presence of a corner or a cross formed by two intersecting lines. This aggregation process can be repeated to form a multistage *hierarchy* in which representations of visual percepts are increasingly abstract, global, and invariant to irrelevant variations of the input. Such hierarchies have been proposed in many computational models of perception. In general, a *computational model* of perception is a computer program that receives an input, for example in the form of an image, and produces some prediction, for example as indicating the categories and locations of the objects present in the image. *Machine Learning* is a discipline at the intersection of computer science, statistics, and engineering, concerned with devising algorithms by which computers can *learn* some desired behavior from examples of inputs and corresponding output. The recently emerged subfield of *Deep Learning* concerns learning algorithms to train all the stages in a multistage hierarchical model, in such a way that the model develops appropriate representations of the perceptual world as a result of the training process. *Deep Belief Networks* are a particular instance in this class of models that aim at capturing uncertainty in the formation process of the sensory inputs. Deep

Learning is usually conducted by endowing features at higher levels with some desirable properties, such as sparsity, compactness, statistical independence, and selective activation for certain classes of sensory events. A popular criterion to construct representations is to promote *sparsity* – namely, that only few features should be allowed to be active for any given input.

Theoretical Background

Trainable models of perception can be seen as input–output functions parameterized by a large number of parameters (typically in the millions). During the training phase of *supervised learning* the learning algorithm adjusts the parameters so that the output of the model matches the desired output as well as possible for every sample in the training set. At test time, the model is used to produce outputs for previously unseen input data. Learning models can also be trained with unsupervised learning. In this case, no desired output is provided, and the model merely attempts to capture the dependencies between input variables, and to produce a good representation of the inputs in the process. Unsupervised learning has the double objective of ensuring that the representation contains all the significant information about the data (e.g., by making sure that the data can be reconstructed from the representation), while making the representation more suitable for further processing, such as classification. In particular, theoretical and empirical evidence suggest that high-dimensional and sparse representations tend to make categories more easily discriminable by simple classifiers.

Neuroscience is often a source of inspiration for practitioners of machine learning and computer vision, providing clues as to what successful architectures may look like. For example, hierarchical organization and sparsity are properties that can be found both in the visual cortex of animals, and are often exploited in computational models. The initial motivation for incorporating these properties into architectures has often been provided by neuroscience. But characteristics imported from biology can also be motivated by a purely statistical or practical point of view.

Many biological systems exhibit hierarchical organizations, for instance the sensory areas of the mammalian cortex. The visual cortex has been particularly well studied. Seminal experiments by Hubel and Wiesel (1962) have shown that visual cortex area V1 comprises orientation selective cells (simple cells, and complex

cells which respond to larger ranges of phases and locations), arranged in a very structured organization according to orientation and location in the visual field. Downstream from V1, neurons in area V2 respond to more complex patterns such as corners or T-junctions.

An important characteristic of V1 cells is the sparseness of their activation: individual simple or complex cells do not respond to stimuli which do not match their preferred orientation. More generally, sparsity is a fundamental characteristic of neuronal spiking, which is the basic signaling device in animals. An advantage of sparsity is that it cuts down metabolic cost (how much energy is needed to process the sensory event). Sparsity has garnered a lot of interest following the pioneering work of Olshausen and Field (1997), who showed that enforcing sparsity in a simple computational model of photographic natural images was enough to learn oriented edge detectors very similar to typical simple cells in V1.

In a sparse coding model, features are sparse, that is, there are only few nonzero features used to represent any given input. The set of features that are turned on depends on the input stimulus being described. This leads to the grouping of isolated elementary events that often occur simultaneously (e.g., illumination of points along a line, seen as separate events), into more comprehensive and meaningful events (e.g., wholesale illumination of a line, seen as a single event, thus yielding a more concise description better suited to interpretation), thus avoiding the spreading of semantic content across too many features. From a computational point of view, learning a sparse representation has potentially many advantages: it is more efficient because the program can skip the zero entries in the subsequent computation; it leads to more interpretable features that are often very useful in discrimination tasks. The key idea of an unsupervised sparse coding algorithm is to learn representations that are sparse, but informative enough that a good approximation of the input can be recovered.

Sparse representations have proven very useful for many tasks in computer vision (e.g., image denoising, compression, classification) and audio processing (e.g., source separation).

When animals are tested on simple visual tasks (e.g., deciding whether the image contains the representation of a familiar object), they are able to make very accurate decisions within a few hundred milliseconds (Kirchner and Thorpe 2006) – a time too short to allow for any recurrent processing, showing that purely feed-forward information processing should be enough to perform well on those tasks. In contrast, the main shortcoming of sparse coding algorithms is their computational cost at test time, when inferring a sparse representation for a given input. It is very difficult to find out which combination of nonzero features can explain the input at the best. An open research question is how to design algorithms that can perform such operation very efficiently. One

Learning Hierarchies of Sparse Features. Fig. 1 Features learned on photographic image patches using the algorithm by Kavukcuoglu et al. (2008). Any image patch (small part of an image) can be represented as a linear combination of these features. Each tile represents an image primitive, detecting edges at a particular orientation, position, and scale. These are the features at the lowest layer of a hierarchical system

solution Kavukcuoglu et al. (2008); Ranzato et al. (2007) is to add an extra component to the model to learn a direct mapping between input and sparse representation so that, after training, computing (an approximation to) the sparse code can be done very quickly. Features learned by such model are shown in Fig. 1.

Important Scientific Research and Open Questions

Deep Learning is a field of Machine Learning that aims to design computational models which use hierarchical models to make effective predictions. The prediction is produced by passing the input through a series of adaptive nonlinear transformations that capture complex dependencies among the sensory inputs. This has the major computational advantage that intermediate features in the hierarchy can be shared across different classes (e.g., both cars and trucks have wheels), and

combined to produce more abstract patterns (e.g., two wheels with car doors and windows form the higher-level feature of a car side).

The task of learning hierarchical models has proven very difficult, because primitive features at the lowest layer barely affect the outputs of the model which are used for prediction. Moreover, in some models it is difficult to determine which high-level features are responsible for representing the observed sensory input. Deep Belief Networks Hinton et al. (2006) were the first probabilistic model that could learn hierarchical systems with many layers of nonlinear features. They use a single-layer unsupervised algorithm, called Restricted Boltzmann Machine, in a recursive way. First, the algorithm is applied to the input data in order to optimally represent each input data case through some configuration of features. After training this layer, configurations of features corresponding to training data cases are fed into the very same

Learning Hierarchies of Sparse Features. Fig. 2 Features learned by a sparse coding model that learns features from small portions of photographic images and arranges them in a topographic map. Features that are nearby in the map (like those inside the *black rectangle*) capture similar patterns in the input image

Learning Hierarchies of Sparse Features. Fig. 3 Features learned by a sparse coding model that learns from high-resolution photographic images (as opposed to small portions of images). Besides edge detectors, there are also corner, cross, and other more complex shape detectors

unsupervised algorithm to learn another layer of features. This procedure is repeated for as many layers as desired, yielding a hierarchical model. Hinton et al. (2006) showed that under some conditions, this procedure is guaranteed to improve the fitting of the model to the data as more layers are added.

Later advancements in the field showed that many unsupervised algorithms can be used in the same way to learn feature hierarchies. Thus, the unsupervised algorithms based on sparse coding presented above can be successfully used to learn feature hierarchies in a recursive way. Typically, the features on the topmost layer are used to describe the input and are fed into a classifier for discrimination (e.g., to predict which object is present in the input image). The whole system (combining the hierarchical model and the classifier) can be jointly optimized on the discrimination task, by using gradient-based optimization methods. This procedure usually yields the best performance in practical applications.

The basic sparse coding algorithm can be extended in several ways. One extension is to group the features into pools of correlated features and enforce sparsity only across groups. When such algorithm is trained on photographic natural images, it yields topographic maps (see Fig. 2) with pinwheels patterns that mimic those found in area V1 of the visual cortex of mammals. Another useful extension is to train sparse features using chunks of images that are larger than the actual size of each individual feature, in a way that takes into account the overlap between areas represented by

neighboring features. This leads to richer sets of feature detectors as shown in Fig. 3.

One open research question is how to learn these models in a more computationally efficient way, and how to learn better higher-level features. It has proven difficult to represent very different kinds of features (e.g., an ensemble of features capturing at the same time shape, texture, color), and features that are invariant to irrelevant transformations of the input (e.g., pose of objects in images for features used in subsequent discrimination of object category). Another important avenue of investigation is how to intelligently scale up these algorithms to very large inputs and to very large datasets (e.g., collection of high-quality images stored in public Web sites like Flickr) and how to parallelize the computation during training and test time to make it faster. Finally, current research has lately focused on the issue of using these algorithms on multimodal inputs (e.g., video sequences accompanied by sound and text) as well as on the issue of using higher-level representations to predict multiple related tasks (e.g., predicting the identity of a subject from a face image and, at simultaneously, using the representation to retrieve similar subjects from a database).

Cross-References
▶ Anticipatory Schema(s)
▶ Associative Learning in Early Vision
▶ Bottom-up and Top-down Learning
▶ Connectionist Theories of Learning

References

Hinton, G., Osindero, S., & Teh, Y.-W. (2006). A fast learning algorithm for deep belief nets. *Neural Computation, 18*, 1527–1554.

Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *Journal de Physiologie, 160*, 106–154.

Kavukcuoglu, K., Ranzato, M., and LeCun, Y. (2008). *Fast inference in sparse coding algorithms with applications to object recognition*. Technical report, Computational and Biological Learning Lab, Courant Institute, NYU. (Tech Report arXiv:1010.3467).

Kirchner, H., & Thorpe, S. J. (2006). Ultra-rapid object detection with saccadic eye movements: Visual processing speed revisited. *Vision Research, 46*(11), 1762–1776.

Olshausen, B. A., & Field, D. J. (1997). Sparse coding with an overcomplete basis set: A strategy employed by v1? *Vision Research, 37*, 3311–3325.

Ranzato, M., Boureau, Y., & LeCun, Y. (2007). Sparse feature learning for deep belief networks. In J. Platt, D. Koller, Y. Singer, & S. Roweis (Eds.), *Advances in neural information processing systems 20*. Cambridge, MA: MIT Press.

Learning Hierarchy Technique

Maizam Alias
Faculty of Technical Education, Universiti Tun Hussein Onn Malaysia, Johor Darul Takzim, Malaysia

Synonyms

Hierarchical analysis technique; Prerequisite analysis technique

Definition

The learning hierarchy technique is a top-down analysis technique that can be used by an instructional designer (or a teacher) to identify the prerequisites for an expected learning outcome (learning objective) in the intellectual learning domain. The ► top-down analysis of the top-most expected learning outcome would result in a set of subordinate intellectual skills that are related to each other in a hierarchical manner.

The top-most expected learning outcome is known as the terminal objective while the subordinate objectives are known as the enabling objectives. A representation that shows the hierarchical relationship between all objectives (terminal and enabling objectives) is known as the learning hierarchy for the particular terminal objective. A learning hierarchy can be illustrated using a bottom-up flow diagram to show the mapping of the hierarchical relationships between all objectives with the terminal objective located at the top-most position. The learning hierarchy represents the most direct path to achieving the terminal objective given only instruction.

Theoretical Background

The learning hierarchy technique is a derivative of the cumulative learning theory (Gagné 1968). According to the cumulative learning theory, learning of a complex intellectual skill becomes a reality only if a learner has already acquired a set of intellectual skills that are subordinates of the new intellectual skill. This means, for a learner to acquire a specific higher-order intellectual skill, he or she must first master a set of lower level intellectual skills that are prerequisites to the higher-order skill. In other words, the subordinate skills serve as the foundation to the new higher-order intellectual skills, without which, the new skill cannot be acquired.

Different levels of a learning hierarchy are associated with different types of learned capabilities with the more intellectually demanding skill being presented at the top and the lesser demanding skill in the lower positions. Gagné classifies intellectual skills into four categories: problem solving, rule application, concepts, and discrimination. An example of a learning hierarchy is shown in Fig. 1, which is a learning hierarchy for ascertaining the median for a set of data. The learning hierarchy shown is not yet validated but suffices for the purpose of explaining the concept and procedure of the learning hierarchy technique. The terminal objective in this case is "able to determine the new median for a set of data when x points is added to the lowest datum in the data set" and the enabling objectives are those below the terminal objective. The hierarchical relationships between the learning objectives are indicated by the arrows that are always pointing upward.

Based on the learning hierarchy shown in Fig. 1, it can be deduced that to learn the top-most intellectual skill, which involves the applications of a set of rules in

Learning Hierarchy Technique. Fig. 1 The learning hierarchy for ascertaining a new median for a set of data when x points is added to the smallest datum

the correct order, a learner must first master the intellectual skills of rule application, concepts, and discriminations. Specifically, in order for a learner to be able to apply the rules in the right order, the learner must first know how to apply the individual rule:

- Add x to the lowest datum.
- Arrange the new data set in ascending order.
- Locate the middle position using formula $(n + 1)/2$.
- If n is even, median is computed by finding the average of the two data that are immediately above and below the midpoint, and if n is even, median value is the datum located at the midpoint of the data set.

Before a learner can learn how to apply the above rules, he or she must know several concepts such as the concepts of "ascending order" and "addition," and

before ascending order can be understood the learner must be able to discriminate between a smaller and a larger value.

Deriving a learning hierarchy is just one of the two key tasks in the learning hierarchy technique, the second task being the validating task. The derivation task involves a three-stage iterative process that would ultimately result in a learning hierarchy that has yet to be validated. In the first stage, the terminal objective is explicitly stated in the form of a behavioral objective. Using the example in Fig. 1, the terminal objective would be stated as "able to determine the new median for a set of data when x points is added to the lowest datum in the data set."

In the second stage, the enabling objectives for the terminal objective are identified. To identify the enabling objectives, the question "what must the

learner be able to do in order to learn the new element, given only instructions?" is posed (Gagné 1985). The answers to this question are then stated in the form of new behavioral objectives that would serve as the enabling objectives to the terminal objective. Referring to the example above, the immediate enabling objectives are shown in Fig. 2.

The same question is posed to the newly identified enabling objectives to identify their subordinates and other new enabling objectives would be formulated. The learning hierarchy development process is considered complete when the latest enabling objectives identified are at the most basic level or at the same level as the existing skills of the target learners. At this stage, the learning hierarchy is ready for validation. Upon validation, the learning hierarchy can be used in the selection and formulation of learning objectives, design of instructional materials and strategies, and in the design and development of assessment tools for diagnostic, formative, and summative assessment.

Important Scientific Research and Open Questions

Initial research on learning hierarchies was mainly in mathematics education (White 1973). Since then, research has been conducted in other areas of the sciences, engineering education, computer education, and language education among others. Although its application has been mainly in the establishment of prerequisites for specific tasks, successful applications of this technique in the design of a curriculum has also been undertaken. Irrespective of the breadth of application, the hierarchical relationships between the various intellectual skill levels that are depicted by a learning hierarchy provide the basis for sequencing of instructions for achieving the target learning outcome.

Intuitively, deploying the learning hierarchy technique would result in a learning hierarchy that provides an efficient route to achieving the terminal objective. However, the degree of efficiency is highly dependent on the validity of the learning hierarchy itself. Thus, the focus of many learning hierarchy studies in the past has been on establishing a way to validate the proposed learning hierarchy that can be achieved through various means which involve consulting subject matter experts and experimentations. A study by Kurshan and Sherman (1978) provides a good example of how a combination of validation methods can be successfully used to validate a learning hierarchy. Kurshan and Sherman (1978) use the Guttmann Scaling Procedure, the Gagné procedure on proportion of positive transfer, and the Walbesser transfer measure to validate a curriculum for computer literacy.

Due to the logical step-by-step identifications of prerequisites, the learning hierarchy technique provides a good means of identifying all the necessary prerequisites to a complex learning task which will ensure learning of the terminal objective. However, mastering a learning hierarchy by itself is insufficient for problem solving transfer, i.e., solving problems that are non-routine (Myer 1998). Therefore, when using

Learning Hierarchy Technique. Fig. 2 Immediate enabling objectives for the terminal objective

the learning hierarchy technique for learning transfer purposes, other factors need to be considered in ensuring learning success.

Cross-References

References

Gagné, R. M. (1968). Contributions of learning to human development. *Psychological Review, 75*, 177–191.

Gagné, R. M. (1985). *The conditions of learning and theory of instruction* (4th ed.). New York: Holt, Rinehart and Winston.

Kurshan, B. L., & Sherman, M. T. (1978). *Evaluating a computer literacy curriculum: A comparative study of evaluation procedures for validating a computer literacy curriculum* (ACM SIGCUE outlook – Topics in instructional computing volume special, pp. 55–68). doi:10.1145/1318457.1318462. Online http://delivery.acm.org/10.1145/1320000/1318462/p55-kurshan.pdf?key1=1318462&key2=1189011921&coll=DL&dl=ACM&CFID=113192129&CFTOKEN=59559329

Myer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science, 26*, 49–63.

White, R. T. (1973). Research into learning hierarchies. *Review of Educational Research, 43*(3), 361–375.

Learning How to Learn

Learning Human Emotion from Body Gesture

Caifeng Shan
Philips Research, Eindhoven, The Netherlands

Synonyms

Emotional body gesture learning

Definition

Learning human emotion from body gesture is to estimate the emotional state of a person based on his or her body gesture. Although the perception of human emotion is commonly linked with facial expression and voice, human beings can express and interpret others' emotional states from body gesture (or bodily expression) such as body movement, posture, and gesture. Human affective states are actually conveyed by a set of nonverbal cues including facial expression, body movement and posture, gesture, tone of voice, speaking style, touching behaviors, and so on; the combination of these cues yields an overall emotional display, in which body gesture plays a vital role. Psychological studies suggest that the perception of facial expression is strongly influenced by the concurrently presented body language. Automatic recognition of affective body gesture is an emerging topic in affective computing.

Theoretical Background

The ability to recognize emotional states of a person is indispensable and important for social interaction. Affective arousal modulates all nonverbal communication cues such as facial expression, body movement and posture, gesture, tone of voice, and speaking style. Charles Darwin was the first to describe in detail the specific facial expressions associated with emotions in animals and humans; he argued that all mammals show emotions reliably in their faces. Paul Ekman's influential studies on facial expression determined that expressions of anger, disgust, fear, joy, sadness, and surprise are universal. Beyond facial expression, human bodily expression (including configuration and movement) also reveals and enhances emotions. For example, an angry face is more menacing when accompanied by a fist. Some examples of emotional body gesture are shown in Fig. 1.

Psychological studies (Ambady and Rosenthal 1992; Meeren et al. 2005) suggest the visual channels of facial expressions and body gestures are the most important and informative for judging human behaviors, and their integration is a mandatory process occurring early in the human processing stream. Furthermore, the perception of facial expression is strongly influenced by the concurrently presented body language, and the effect is a function of the ambiguity of facial expression. According to the experiments on attributing six universal emotions by human observers to static body postures (Coulson 2004), the human recognition of emotion from body posture is comparable to recognition from the voice, and some postures

Learning Human Emotion from Body Gesture. Fig. 1 Examples of emotional body gesture (Gunes and Piccardi 2006). From *top* to *bottom*: fear, joy, uncertainty, and surprise

are recognized as well as facial expressions. Similarly, in another study on affective motion features of virtual ballet dancers, human observers were highly accurate in assigning an emotional label to each dance exercise.

It is desired that the machine could sense and interpret the emotional states of human beings, and adapt its behavior to them, giving an appropriate response. This has been studied as an interdisciplinary field called *Affective Computing* (Picard 1995), which focuses on the study and development of systems and devices that can recognize, interpret, process, and simulate human affects. Computer recognition of human emotion has many important applications, for instance, automatic assessment of boredom, inattention, and stress in situations where firm attention is essential (e.g., driver monitoring). Another application is for e-learning, where the presentation style is adjusted when a learner is detected to be bored, frustrated, or interested.

Over the past two decades, various methodologies have been explored to automate the process of sensing and interpretation of human emotions. A great deal of attention has been focused on how emotions are communicated through facial expression, and a similar although smaller literature exists on the perception of emotion from voice. However, there has been few studies on the analysis and modeling of affective body gesture; emotion recognition via body gesture has only recently started attracting attention. This is probably due to the high variability of the emotional body gesture that can be displayed; with the combinations of various body parts, there is an unlimited vocabulary of body gesture, which is much more varied than face gesture.

Important Scientific Research and Open Questions

Although human cognitive process appears to detect and interpret human emotion with little or no effort, designing and developing an automated system that accomplishes this task is rather difficult. In the last two decades, computer recognition of human affect from facial expression or voice has been widely studied, and much progress has been made. However, it is still far from the stage of realizing real-life applications in

natural environments. Compared to facial expression or audio affect learning, affective body gesture learning is still an unexplored and unsolved area in psychology; many issues about emotional body gesture remain unknown or still under discussion for psychologists. Further investigation is needed in order to better understand how body gesture contributes to the perception and recognition of emotional states.

For automatic recognition of affective body gesture, many problems remain open, some of which are considered here. Firstly, how to combine body gesture with other modalities (e.g., facial expression)? Human affective states are naturally conveyed via multiple modalities. The single sensory observations are often ambiguous, uncertain, and limited. Integrating multiple modalities or cues could potentially accomplish better performance. Following the psychological findings, researchers advocate that a reliable affect recognition system should combine facial expression and body gesture; recently some attempts have been made to fuse facial expression and body gesture in video sequences for human affect analysis (Gunes and Piccardi 2009). Furthermore, certain modalities or cues seem to be more reliable than others, depending on the context and the problem at hand; studies need to be conducted to confirm which modality or cue is more reliable for which cases.

Secondly, how to model and analyze spontaneous affective body gesture in real life? Realistic emotion recognition is much more difficult than recognizing the posed face or body gesture. Spontaneous affective body gesture induced in natural environments sometimes is more subtle. The existing few efforts are mostly on the analysis of posed bodily expression data.

Thirdly, how to make use of the temporal dynamics information? Psychological studies indicate temporal dynamics is crucial for successful interpretation of emotional display, which is especially true for spontaneous emotions. Directed or posed face or body gestures differ both in appearance and timing from spontaneously occurring ones. The complex spatial properties and dynamics of body gesture pose a great challenge to affect recognition. More studies should be conducted on the data obtained in the realistic settings.

Cross-References

▶ Emotion-Based Machine Learning
▶ Facial Expression Learning

References

Ambady, N., Rosenthal, R. (1992). Thin slices of expressive behavior as predictors of interpersonal consequences: A meta-analysis. *Psychological Bulletin, 111*(2), 256–274.

Coulson, M. (2004). Attributing emotion to static body postures: Recognition accuracy, confusions, and viewpoint dependence. *Journal of Nonverbal Behavior, 28*(2), 117–139.

Gunes, H., Piccardi, M. (2006). A bimodal face and body gesture database for automatic analysis of human nonverbal affective behavior. *Proceedings of International Conference on Pattern Recognition, 1*, 1148–1153.

Gunes, H., Piccardi, M. (2009). Automatic temporal segment detection and affect recognition from face and body display. *IEEE Transactions on Systems, Man, and Cybernetics. Part B, Cybernetics, 39*(1), 64–84.

Meeren, H., Heijnsbergen, C., Gelder, B. (2005). Rapid perceptual integration of facial expression and emotional body language. *Proceedings of the National Academy of Sciences, 102*(45), 16518–16523.

Picard, R. W. (1995). *Affective computing*. MIT technical report, #321.

Learning Identity

ALICE Y. KOLB, DAVID A. KOLB
Organization Behavior Department, Weatherhead School of Management, Case Western Reserve University, Cleveland Heights, OH, USA

Synonyms

Learning attitude; Learning self-image

Definition

Learning identity is a key aspect of metacognitive knowledge about how one learns, particularly their views about their ability to learn. People with a learning identity see themselves as learners, seek and engage life experiences with a learning attitude and believe in their ability to learn. At the extreme, if a person does not believe that they can learn, they will not.

Theoretical Background

People with a learning identity see themselves as learners, seek and engage life experiences with a learning attitude and believe in their ability to learn. Having a learning identity is not an either-or proposition. A learning identity develops over time from

tentatively adopting a learning stance toward life experience, to a more confident learning orientation, to a learning self that is specific to certain contexts, and ultimately to a learning self-identity that permeates deeply into all aspects of the way one lives their life. This progression is sustained and nurtured through growth producing relationships in one's life.

In ELT, the concept of learning identity is based on the works of Carl Rogers and Paulo Freire. For both of these foundational scholars of experiential learning, people who see themselves as learners are those who trust their direct personal experiences and their ability to learn from them. Their primary focus is not on immediate performance or goal achievement but on the ongoing process of learning from these experiences. Instead of desiring some fixed goal, they prefer the excitement of being in the process of potentialities being born.

In his classic paper on how values are learned, Carl Rogers emphasizes the central role of experiencing in the learning process of the mature person: "He uses his experiencing as a direct referent to which he can turn in forming accurate conceptualizations and as a guide to his behavior." The process of learning values is, "fluid and flexible... highly differentiated... the locus of evaluation is within the person... There is also involved in this valuing process a letting oneself down into the immediacy of what one is experiencing, endeavoring to sense and to clarify all its complex meanings" (1964, pp. 163–164). Echoing William James' radical empiricism he emphasizes that experiencing includes not only direct sensations and emotions but prior concepts: "For there is involved in the present moment of experiencing the memory traces of all the relevant learnings from the past. This moment has not only its immediate sensory impact, but it has meaning growing out of similar experiences in the past" (p. 164).

He contrasts this approach of a mature learning person with fixed values formed through introjections acquired in youth in order to please loved ones: "These conceived preferences are either not related at all, or not clearly related, to his own process of experiencing. Often there is a wide discrepancy between the evidence supplied by his own experience and these conceived values. Because these conceptions are not open to testing in experience, he must hold them in a rigid and unchanging fashion" (p. 162).

In a very different context, Paulo Freire also has emphasized the critical role that learning centered on one's own personal experience plays in forming a learning identity. In *Pedagogy of the Oppressed*, he describes his literacy work with Brazilian peasant farmers helping to liberate them from a self-identity formed through internalized oppression, the incorporation and acceptance by individuals within an oppressed group of the prejudices against them – "So often do (the oppressed) hear that they are good for nothing, know nothing and are incapable of learning anything – that they are sick, lazy and unproductive – that in the end they become convinced of their own unfitness" (1993, p. 49). His method for achieving the personal and social transformations necessary to escape this negative, fixed self-identity was to facilitate the creation of critical consciousness in these farmers through his version of the experiential learning cycle which he called *praxis*, "reflection and action on the world in order to transform it." In a definition echoing metacognition, Leistyna (1999) defines critical consciousness as presence of mind in the process of learning and knowing – the ability to analyze, pose problems, and change the political and cultural realities that affect our lives.

Freire argues that traditional education also promotes a form of internalized oppression and a non-learning identity. It is based on a "banking concept" where all-knowing teachers deposit ideas in students' minds to be received uncritically, mechanically memorized and repeated. He offers the alternative of "problem-posing education" that empowers a learning self-identity. It is based on a democratic relationship between student and teacher that begins with the here-and-now experience of students' lives and encourages the praxis of critical reflection and action to improve their lives.

If there is a starting point for learning from experience, it must be in the belief that I *can* learn and develop from my life experiences. In our many years of sharing results from the Kolb Learning Style Inventory (2005) (Kolb and Kolb 2005) with thousands of people, we have discovered to our surprise that not only do most people not understand their unique way of learning; many have not thought about what learning is and themselves as learners. More people than we imagined do not think of themselves as learners at all and have what psychologist Carol Dweck calls a "fixed" view of

themselves, in varying degrees believing that they are incapable of learning. At the extreme, if a person does not believe that they can learn, they will not. Learning requires conscious attention, effort, and "time on task." These activities are a waste of time to someone who does not believe that they have the ability to learn.

A story from our recent work with an experiential learning focused high school provides an example. A colleague at the school teaches remedial mathematics to freshmen and sophomore students. He was lamenting the fact that students were failing repeatedly to grasp the most elementary of mathematics concepts, and was frustrated that most never did any homework. He had just given a quiz that was an exact copy of the homework he had given the week before with the "heads-up" that the homework questions would be on the upcoming quiz. Still the majority of students failed. In desperation, he asked the students what was going on. Why did they think that some students got better grades than others? Did they not understand if they just did the homework they would get better grades? To his surprise, he found that students did not believe that they could learn by studying and that the reason that some students got good grades was because they were "smart."

Like other aspects of self-identity, learning identity is strongly influenced by one's important relationships. Learning identity is determined not by past learning successes and failures alone but by the self-attributions about these successes and failures that a person makes. These attributions are strongly influenced by important relationships. We have already seen Roger's description of the lasting power that introjected evaluations from loved ones can have. Evaluations from others can also influence learning identity, sometimes in unexpected and subtle ways. Dweck (2000) has shown that teachers who reward students for successful learning by praising them for being "smart" actually promote a fixed identity and less expenditure of study effort ("I don't need to study because I am smart"). Peers also play a role in shaping learning identity. Another intriguing finding is that learning identity may be contagious in the sense that those who have a learning identity tend to create relationships that stimulate it in others and those with fixed identities also act in ways that pass on fixed views of others.

Important Scientific Research and Open Questions

Carol Dweck (2000) has studied the "lay theories" that people have about themselves and others. In particular, she and her colleagues have examined the differences between those who see their abilities and attributes as fixed and static and those who believe that they can incrementally learn and change themselves. Those individuals who believe that they can learn and develop have a learning self-identity. The learner faces a difficult challenge with a "mastery response" while the person with a fixed identity is more likely to withdraw or quit. Learners embrace challenge, persist in the face of obstacles, learn from criticism, and are inspired by and learn from the success of others. The fixed identity person avoids challenge, gives up easily, avoids criticism, and feels threatened by the success of others. Not surprisingly students with a learning identity, regardless of their tested intelligence, are more successful in school than those with a fixed identity. Learning self-identity also affects how students relate to others. Those with a fixed versus incremental view show greater stereotype endorsement, perceive greater out-group homogeneity, are more susceptible to the fundamental attribution error, show greater intergroup bias, and more biased behavior toward out-group members.

It is possible to develop a learning self-identity. Research studies have shown that educational interventions can influence the development of a learning identity. Blackwell, Trzesniewski, and Dweck found that eight 25 min classes for seventh graders focused on the message that "learning changes the brain by forming new connections and that students are in charge of this process" (2007, p. 254) led to increased classroom motivation and reversed a decline in grades experienced by the control group. Similarly, Good et al. (2003) found that an incremental learning intervention led to significant improvements in adolescents' achievement test scores and Aronson et al. (2002) found that such teaching led to higher grades among college students.

Another example in higher education has focused on the difficult problem of mathematics anxiety and the sense of inferiority many students feel when required to take remedial mathematics education. Hutt (2007) implemented an experiential "learning to learn" course focused on transforming students' math learning self-identity from one of anxious inferiority

("I don't do math") to one of confident self-efficacy ("I can totally do math") as well as improving students' math learning performance in developmental mathematics courses. Results from this research showed that the experiential course content and the teachers' conscious attention to unconscious processes in the learning space, combined with the students' depth level reflections on their learning experiences and self talk, had positive impacts on learning. Students' mathematics anxiety was reduced, with students in the course feeling safer, more confident, and efficacious about themselves as learners. Students in the "learning to learn" course performed a letter grade better than controls in their developmental math course. Students' learning style preferences played an interesting role in the findings. Typically in mathematics courses, students with an abstract "thinking" learning style preference, which tends to match that of their instructor's teaching style, perform better than students with other learning styles. This learning style difference was erased for students in the experiential course where students

of all learning style preferences earned better grades than controls. Hutt maintains that change from a fixed to learning self-identity requires a safe learning space characterized by unconditional positive regard (Rogers 1951) from the teacher. This space reduces defensive behavior and allows persons to experience themselves as learners in a new way.

Becoming a learner, someone who can say with confidence, "I am a learner" is not accomplished overnight. One's self-identity is deeply held and defended against experiences that contradict it. For the vast majority of us our self-identity is a mix of fixed and learning beliefs. We may feel that we are good at learning some things like sports and not good at others like mathematics. Dweck and her colleagues argue that lay theories are domain specific, e.g., one can believe that intelligence is fixed and morality is learned (Levy et al. 2001). Every success or failure can trigger a reassessment of one's learning ability.

Figure 1 depicts self-identity as balancing characteristics that reinforce a fixed self – negative self-talk,

Learning Identity. Fig. 1 Moving from a fixed to learning identity

avoidance of risk and failure, and being threatened by the successes of others – and those that build a learning self – trusting one's ability to learn from experience, seeking new experiences and challenges, persistence, learning from mistakes and using other's success as a source of learning. It is hypothesized that learning identity can be developed by reducing fixed self-characteristics and improving learning identity characteristics, thus tipping the balance toward becoming a learner.

Cross-References

► Experiential Learning Cycle
► Experiential Learning Spaces
► Experiential Learning Spiral
► Experiential Learning Theory
► Kolb's Learning Styles
► Metacognitive Experiential Learning

References

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing stereotype threat and boosting academic achievement of African-American students: The role of conceptions of intelligence. *Journal of Experimental Social Psychology, 38*, 113–125.

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality and development*. Hove: Psychology/Taylor & Francis.

Freire, P. (1993). *The pedagogy of the oppressed*. New York: Continuum.

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology, 24*, 645–662.

Hutt, G. K. (2007). Experiential learning spaces: Hermetic transformational leadership for psychological safety, consciousness development and math anxiety related inferiority complex depotentiation. Ph.D. dissertation, Department of Organizational Behavior, Case Western Reserve University, Cleveland.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs: Prentice-Hall.

Kolb, A. Y., & Kolb, D. A. (2005). *The Kolb learning style inventory – Version 3.1: 2005 technical specifications*. Boston: Hay Transforming Learning. www.haygroup.com/tl.

Kolb, A. Y., & Kolb, D. A. (2009). The learning way: Meta-cognitive aspects of experiential learning. *Simulation and Gaming: An Interdisciplinary Journal, 40*(3), 297–327.

Leistyna, P. (1999). *Presence of mind: Education and the politics of deception*. Boulder: Westview.

Levy, S. R., Plaks, J. E., Hong, Y., Chiu, C., & Dweck, C. S. (2001). Static versus dynamic theories and the perception of groups: Different routes to different destinations. *Personality and Social Psychology Review, 5*(2), 156–168.

Rogers, C. R. (1951). *Client-centered therapy: Its current practice, implications and theory*. London: Constable. ISBN 1-84119-840-4.

Rogers, C. R. (1964). Toward a modern approach to values: The valuing process in the mature person. *Journal of Abnormal and Social Psychology, 63*(2), 160–167.

Learning II

► Deutero-learning

Learning in Apprenticeship

► Apprenticeship-Based Learning in Production Schools

Learning in Artificial Neural Networks

RONAN G. REILLY
Department of Computer Science, NUI (National University of Ireland) Maynooth, Maynooth, Co., Kildare, Ireland

Synonyms

Connectionist networks; Neural networks

Definition

An artificial neural network is a computational artifact used for data classification and prediction and as a tool for cognitive modeling. Networks comprise a collection of simple, interconnected computational units each of which can be considered a highly simplified model of a biological neuron. The biological features of the real neuron typically modeled by the abstraction include adaptivity, parallel distributed computation, nonlinearity of the input-to-output function, and the locality of each neuron's computation. The model neuron typically sums its inputs, weighted by the incoming connection strengths, and produces a single output value. The output function can be any of a variety of linear, or semi-linear, or nonlinear functions.

L

Theoretical Background

Much of the motivation for early developments in the area of artificial neural networks was the desire to understand how collections of neurons could give rise to intelligent behavior. Among the earliest pioneers in this field were McCulloch and Pitts (1943) who designed a model neuron that implemented simple logical operators (e.g., AND, OR, NOT), which could be used as network components to implement more complex logical expressions. The networks of McCulloch and Pitts neurons were limited in the type of computation they could perform, being restricted to making simple binary decisions based on some small set of inputs. Their most significant limitation, however, was their lack of adaptability. Consequently, in order for these networks to perform any useful computation, their weights had to be set manually. One of the important outcomes of the work of McCulloch and Pitts was that it demonstrated the feasibility of building networks from simple components that could generate relatively complex overall behavior.

Frank Rosenblatt (1958) built on the work of McCulloch and Pitts and of psychologist Donald Hebb (1949). Most significantly, he developed an algorithm that could be used to train a feed-forward network of artificial neurons, similar to those of McCulloch and Pitts, to perform classifications of their inputs. Rosenblatt designated his networks Perceptrons and they embodied the first instance of a supervised learning algorithm. Training this type of network involves first initializing the connections to some small random values. Input is propagated across the connections, and the actual output of the network is compared to a desired output, which forms the basis for an error computed from some function of the difference. This error is then used to adjust the weights of the input-to-output connections.

The classification capabilities of Perceptrons were, however, limited to problems that were linearly separable (see Fig. 1 for an illustration of this issue). This and other related limitations were highlighted by Minsky and Papert (1988) in a comprehensive critique of the computational properties of Perceptrons.

While the need to deal with linear separability was clear to many at the time, as indeed were the outlines of a solution, it took several more years before a workable algorithm to implement a solution was discovered. Indeed, a number of similar solutions were discovered around the same time (e.g., Bryson and Ho 1969), but none reached as wide an audience as the backpropagation algorithm, proposed by Rumelhart et al. (1986a).

Learning in Artificial Neural Networks. Fig. 1 This is a schematic representation of a simple Perceptron and its limitation in solving the exclusive OR (XOR) problem. Part (**a**) of the figure gives the table of input values (a1 and a2) and the expected output values for the XOR function. Beneath this table is a diagram of the simple Perceptron, with just two modifiable weights (w1 and w2). The accompanying equation then defines an inequality the goal of which is to divide the input data into the two categories represented by the output value R. Part (**b**) of the Figure shows the futility of this task, since there is no position on the two-dimensional weight space at which we can place the *dashed line* representing the inequality so that the inputs (0,0) and (1,1) are on one side of the line and (1,0) and (0,1) are on the other

Another important strand of research in the area of artificial neural networks was initiated by an influential paper by the physicist John Hopfield (1982). He introduced a symmetrically connected, randomly weighted neural network model that could be used as an associative memory to store patterns coded as a sets of binary values and retrieve them on the basis of only partial input. The Hopfield model was attractive because of its mathematical tractability and its similarity to the way human memory was thought to work.

Hopfield's work was adapted by Teuvo Kohonen who extended the basic model to account for, among others things, the developing structural organization of the sensory parts of the brain. Versions of his model have subsequently found a large range of applications in such disparate areas as language processing and the classification and visualization of DNA sequences (Kohonen 1982; Ritter and Kohonen 1989; Mahony et al. 2006). Kohonen's work formed the basis for a distinct learning paradigm referred to as unsupervised learning. In this case, the algorithms adaptivity is driven by similarities among input data items. This feature allows the network to be particularly suitable for uncovering inherent patterns in the data, similar to techniques such as cluster analysis and principal components analysis.

Ackley et al. (1985) were also influenced by the Hopfield network and extended it to incorporate a more general and powerful learning algorithm called the Boltzmann learning algorithm. This algorithm generalized the learning rule used in the Hopfield network to a stochastic form and employed a variant of simulated annealing to find the optimal set of network weights to maximize the memory capacity of the network. The main drawback of the initial version of the model was its slow learning speed compared to, say, the backpropagation algorithm. However, more recently Hinton (Hinton and Salakhutdinov 2006) has developed a restricted version of the Boltzmann algorithm that overcomes many of the performance limitations of the earlier model (see next section).

Another paradigm of artificial neural network learning is reinforcement learning (RL; Sutton and Barto 1998). The neural network variant of RL involves a neural network modifying its behavior on the basis of a single scalar reward value. So, unlike the backpropagation or Boltzmann algorithms, the precise details of the desired outputs that the network must produce are unknown. All that the algorithm has to go on is some reward value it obtains from its action or sequence of actions over time. The goal of the learning algorithm is to maximize reward over time. Typical applications of the RL involve the control of complex real-time systems such as found in the field of robotics.

Recurrent connections are a dominant feature of real brains and the computational advantages they afford in terms of dealing with temporally varying information such as speech and other time-series data have been exploited in a number of artificial neural network learning algorithms (Jordan 1986; Williams and Zipser 1989; Elman 1991; Hochreiter and Schmidhuber 1997). They have also been particularly important in providing a modeling framework for the cognitive modeling of the brain as a dynamical system.

Important Scientific Research and Open Questions

The flowering of artificial neural network research in the 1980s and 1990s led to major contributions to the fields of artificial intelligence (AI) and cognitive science. In the case of AI, artificial neural networks provided a reliable and easy-to-use tool for a myriad of classification and recognition tasks ranging from speech (Lippmann 1989) and handwriting recognition (Plamondon and Srihari 2000), through to medical diagnosis (e.g., Koss et al. 1994) and stock market prediction (Adya and Callopy 1998). The key feature of neural network classifiers and predictors is their ability to make reasonable, human-like generalizations when classifying input data on which they have not been trained.

Another strand of application was to cognitive science where artificial neural networks provided a productive tool in modeling a range of cognitive processes from visual perception and reading through to language acquisition and language understanding (Rumelhart et al. 1986; Seidenberg and McClelland 1989). The successful models in this area have not only provided compelling accounts of the phenomena they modeled, but also when "damaged" they demonstrated patterns of error and degraded performance similar to patterns found in reality.

An attractive feature of artificial neural network models is their ability to create internal representations that have many of the features of brain representations. These representations are distributed across the

weights of the network analogous to the synaptic encoding of memories in the brain, they demonstrate graceful degradation in quality of performance when noise is added or when some connections are eliminated, and they have capacity limitations similar to those found for representations in the brain.

Several major achievements of cognitive science have been facilitated by artificial neural network models. The first and arguably still the most impressive example is the Interaction Activation (IA) model of Rumelhart and McClelland (1986) which, in a *tour de force* of modeling and model-driven experimentation, accounted convincingly for the word-superiority effect in visual letter-recognition (Reicher 1969). The IA style of neural network has proved its worth in the years since then (Grainger and Jacobs 1998).

Another significant contribution to cognitive science came with the publication of the two volumes of collaborative research from the PDP Research Group at the University of California at San Diego (Rumelhart et al. 1986; McClelland et al. 1986). These two volumes brought together a wide range of computational cognitive science models under the banner of parallel distributed processing and much of the research described there served as a template for cognitive science modeling over the next 25 years. However, probably the most significant contribution of the volumes was the first broadly disseminated description of the backpropagation learning algorithm (Rumelhart et al. 1986b).

The increased sophistication of neural network learning algorithms helped to open up the field of computational modeling of cognitive development. Particularly influential in this respect has been the work of Elman (1991, 1993) and latterly Christiansen and Chater (2001) in the field of language acquisition. Their work has provided a new class of language acquisition model that has challenged the dominance of generative accounts of the human language capacity (Chomsky 1965; Pinker 1984).

The typical multi-layer perceptron (or backpropagation network) comprises a layer of visible or input units, a layer of hidden units, and a layer of output units. The input layer usually fully connects to the hidden layer, which in turn fully connects to the output layer. While the backpropagation learning algorithm (Rumelhart et al. 1986a) is capable in principle of learning an appropriate set of weights for a multi-layered perceptron, it is slow to converge when there is more than one layer of hidden units. This arises because the information used to adjust weights based on some external error signal must be propagated back over the layers of weights of the network and is thus systematically attenuated by successive hidden layers. What is required, therefore, is some means of learning deep networks without the error attenuation penalty. One solution is to use a variant of the Boltzmann machine, called the restricted Boltzmann machine (RBM) developed recently by Hinton et al. (2006). The restricted Boltzmann machine (RBM) is a hybrid generative/discriminative network. In effect, the RBM algorithm comprises two phases: a generative phase in which the hidden layers of the network are trained to reproduce as best they can their inputs. In so doing, they develop a set of abstract features that can form the basis for effective input classification. The RBM can be used to train networks comprising many layers of hidden units and can do so faster and more effectively than classical backpropagation networks.

Another more recent development has been a renewed focus on networks of spiking neurons. Since the development of the backpropagation algorithm, the focus of the artificial neural network community has been almost exclusively on model neurons that produce continuous valued output. These outputs are often considered analogous to the firing rate of real neurons. Real neurons emit discrete voltage spikes and it is the collective action of cascades of such spikes that is the basis of brain computation. There have been a number of important research efforts seeking to analyze and harness some of the rather specific properties of networks of spiking neurons, in particular their usefulness in real-time processing of rapidly varying sensory inputs (Gerstner and Kistler 2002; Maass et al. 2002).

Finally, two other features of natural neural architectures have inspired some recent promising developments in artificial neural networks. The first feature is the somewhat random nature of the neural interconnectivity, at least on a local scale. The second is the apparent multi-functionality of some neurons and neural circuits. For example, the same neuron may be involved in several distinct circuits. This feature of brain computation was hypothesized as far back as Hebb (1949) and has found more recent empirical support (e.g., Gluck and Myers 1997). These and

other features have been implemented in two new neural network paradigms developed simultaneously and independently as Echo State Networks (Jaeger 2003) and Liquid State Machines (Maass et al. 2002). Both paradigms are collectively referred to as Reservoir Computing and they hold out considerable promise for applications in the area of sensory motor information processing.

There are arguably two dominant trends in current ANN research: (1) there has been a steady increase the depth of our understanding of the fundamental learning principles underlying artificial neural networks and this is set to continue; (2) there has been an increased use of neurobiological sources of inspiration for the development of new paradigms, particularly in the area of modeling large scale neural networks. The major challenge facing the field is scaling up the performance of networks into systems of collaborating networks. The most likely driver for this will be the use of artificial neural networks in the next generation of autonomous robotic systems.

Cross-References

- ► Hebbian Learning
- ► Learning Algorithms
- ► Neural Network Assistants for Learning
- ► Reinforcement Learning
- ► Reinforcement Learning in Spiking Neural Networks
- ► Supervised Learning in Spiking Neural Networks

References

Ackley, D. H., Hinton, G. E., & Sejnowski, T. J. (1985). A learning algorithm for Boltzmann machines. *Cognitive Science, 9*, 147–169.

Adya, M., & Callopy, F. (1998). How effective are neural networks at forecasting and prediction? A review and evaluation. *Journal of Forecasting, 17*, 481–495.

Bryson, A. E., & Ho, Y.-C. (1969). *Applied optimal control: Optimization, estimation, and control*. Waltham: Blaisdell.

Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Christiansen, M. H., & Chater, N. (2001). Connectionist psycholinguistics: Capturing the empirical data. *Trends in Cognitive Science, 5*, 82–88.

Elman, J. L. (1991). Distributed representation, simple recurrent networks, and grammatical structure. *Machine Learning, 7*, 195–225.

Elman, J. L. (1993). Learning and development in neural networks: The importance of starting small. *Cognition, 48*, 71–99.

Gerstner, W., & Kistler, W. (2002). *Spiking neuron models: single neurons, populations, plasticity*. Cambridge: Cambridge University Press.

Gluck, M. A., & Myers, C. E. (1997). Psychobiological models of hippocampal function in learning and memory. *Annual Review of Psychology, 48*, 481–514.

Grainger, J., & Jacobs, A. M. (1998). *Localist connectionist approaches to human cognition*. Hillsdale: Erlbaum.

Hebb, D. O. (1949). *The organization of behavior: A neuropsychological theory*. New York: Wiley.

Hinton, G., & Salakhutdinov, R. (2006). Reducing the dimensionality of data with neural networks. *Science, 313*, 504–507.

Hinton, G. E., Osindero, S., & Teh, Y. (2006). A fast learning algorithm for deep belief nets. *Neural Computation, 18*, 1527–1554.

Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation, 9*, 1735–1780.

Hopfield, J. J. (1982). Neural networks and physical systems with emergent collective computational abilities. *Proceedings of the National Academy of Sciences of the USA, 79*, 2554–2558.

Jaeger, H. (2003). Adaptive nonlinear system identification with echo state networks. In S. Becker, S. Thrun, & K. Obermayer (Eds.), *Advances in neural information processing systems 15* (pp. 593–600). Cambridge, MA: MIT Press.

Jordan, M. I. (1986). Attractor dynamics and parallelism in a connectionist sequential machine. In *Proceedings of the eighth annual conference of the cognitive science society* (pp. 531–546). Englewood Cliffs: Lawrence Erlbaum. (Reprinted in IEEE Tutorials Series, New York: IEEE Publishing Services, 1990).

Kohonen, T. (1982). Self-organized formation of topologically correct feature maps. *Biological Cybernetics, 43*, 59–69.

Koss, L. G., Lin, E., Schreiber, K., Elgert, P., & Mango, L. (1994). Evaluation of the PAPNET cytologic screening system for quality control of cervical smears. *American Journal of Clinical Pathology, 101*, 220–229.

Lippmann, R. P. (1989). Review of neural networks for speech recognition. *Neural Computation, 1*, 1–38.

Maass, W., Natschlaeger, T., & Markram, H. (2002). Real-time computing without stable states: A new framework for neural computation based on perturbations. *Neural Computation, 14*, 2531–2560.

Mahony, S., Benos, P. V., Smith, T. J., & Golden, A. (2006). Self-organizing neural networks to support the discovery of DNA-binding motifs. *Neural Networks, 19*(6), 950–962.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88*, 375–407.

McClelland, J. L., & Rumelhart, D. E. (Eds.). (1986). *Parallel distributed processing: Explorations in the microstructure of cognition* (Vol. 2). Cambridge, MA: MIT Press.

McCulloch, W., & Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *Bulletin of Mathematical Biology, 5*, 115–133.

Minsky, M., & Papert, S. (1988). *Perceptrons*. Cambridge, MA: MIT Press.

Pinker, S. (1984). *Language learnability and language development*. Cambridge: Harvard University Press.

Plamondon, R., & Srihari, S. N. (2000). Online and off-line handwriting recognition: A comprehensive survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 22*, 63–84.

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81*, 275–280.

Ritter, H., & Kohonen, T. (1989). Self-organizing semantic maps. *Biological Cybernetics, 61*, 241–254.

Rosenblatt, F. (1958). The perceptron: A probabilistic model for information storage and organization in the brain. *Psychological Review, 65*, 386–408.

Rumelhart, D. E., McClelland, J. L., The PDP Research Group (Eds.), *Parallel distributed processing: experiments in the microstructure of cognition* (Vol. 1). Cambridge: MIT Press.

Rumelhart, D. E., & McClelland, J. L. (1986). Learning the past tense of English verbs. In J. L. McClelland & D. E. Rumelhart (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition* (Vol. 2). Cambridge, MA: MIT Press.

Rumelhart, D. E., Hinton, G., & Williams, R. J. (1986a). Learning representations by back propagating error. *Nature, 323*, 533–536.

Rumelhart, D. E., Hinton, G., & Williams, R. (1986b). Learning internal representations through error propagation. In D. E. Rumelhart, J. L. McClelland, & The PDP Research Group (Eds.), *Parallel distributed processing: Experiments in the microstructure of cognition* (Vol. 1). Cambridge: MIT Press.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed developmental model of word recognition and naming. *Psychological Review, 96*, 523–568.

Sutton, R. S., & Barto, A. G. (1998). *Reinforcement learning: An introduction.* Cambridge, MA: MIT Press.

Williams, R. J., & Zipser, D. (1989). A learning algorithm for continually running fully recurrent neural networks. *Neural Computation, 1*, 270–280.

Learning in Computers

Learning in Conflictual Practice

KLAUS NIELSEN
Department of Psychology, Aarhus University,
Aarhus, Denmark

Synonyms

Learning and paradoxes

Definition

The word "conflict" comes from the Latin words *conflictus*, and *confligere*, which mean "to combat" (Merriam-Webster's Collegiate Dictionary 1999). Conflicts are often understood as a state of disharmony between incompatible or antithetical individuals, ideas, or interests. When we address learning in conflictual practice, we focus on how learning is closely linked to conflictual processes. Learning in conflictual practice can be defined as processes in which learning is a dynamic part of a conflictual process or an important outcome of conflictual processes between individuals or groups in everyday life.

Theoretical Background

The notion of learning and conflict is often discussed within the framework of a Marxist dialectical materialistic understanding. In that perspective, history can be fundamentally understood as the struggle between social classes. In Marxist dialectical thinking, the productive capacity of society is the foundation of society, and as this capacity increases over time, the social relationships of production, or class relations, evolve through the struggle among the classes.

In Marxist thinking, the idea of contradiction plays a central role in social and political life. Contradiction is the key to the dynamic development of new ways of understanding ourselves and others. This process is based on dialectical processes where interruption of gradualness, leaps, negation of the initial moment of development, negation of this same negation, and repetition at a higher level of some features and aspects of the original state are central. Marx's analysis stressed that contradictions and dialectics are important in everyday work when carrying out labor activity. Humans do not simply transform nature; they themselves are also transformed in the process. The tools available at a particular stage in history reflect the level of labor activity. New types of instruments are needed to carry out continually evolving forms of labor activity. The other side of the dialectical coin is that each new tool or instrument creates yet another set of ways to conceptualize and impact the world. Applying this perspective to learning theory means that the analysis of contradictions and conflicts is a central tool for learning and understanding.

When addressing issues of learning, introducing Marxist dialectical thinking is also a matter of

becoming aware of the basic implicit functionalistic assumptions inherent in much of the research on learning and education. A basic presumption in functionalism is that there is an unproblematic unit that can be called "society" or "culture." There is consensus on this unit, and it defines every operation in relation to how it maintains the whole unit (society). This argument is in contrast to a conflictual model of society that springs from the idea of disagreement and conflicts. Functionalism has guided mainstream social research and originates from Durkheim and Spencer, and was developed further by Parson. A central tenet of this theory is the notion that society can be compared to an organism, and organizations can receive legitimacy only through their relationship with other institutions in society. For example, a heart can only be defined in relation to its function of pumping blood through other organs. Like an organism is a unit, society is a homogeneous unit based on social order and founded on a fundamental consensus among participants (Lave 1988). Notions of learning and conflict within functional units inspired theories of managing conflicts, and were often seen as ideas to be handled, resolved, and laid to rest. However, in recent years, there has been tendency to see conflicts as an opportunity to learn new ideas.

Important Scientific Research and Open Questions

Before exploring the different Marxist-inspired learning researchers, it is important to note that other scholars have been aware of the importance of conflict in relation to learning. The anthropologist, Gregory Bateson was one of the first to discuss this idea. According to Bateson (1972/2000), context is the dynamic presupposition for learning something. Instead of thinking of processes of learning as different kinds of learning processes, he suggested that we conceptualize learning at different levels, differentiated in relation to the pragmatic consequences to individuals in real-life settings. The primary levels of Bateson's theory are what he termed processes of "proto-learning" and "deutero-learning." Proto-learning can be defined as a learning process related to problem-solving, the kind of processes researched in laboratories and experimental settings. However, deutero-learning is the habits that create a contextual frame for proto-learning. Bateson introduced contradictions as a central element in his theory of learning when he presented the notion of "double-bind" as a dynamic facet when individuals learn. A double-bind situation is one in which there is a contradiction in a situation which demands a prototypical learning activity, in contrast with what is expected from the context of the situation (deutero-learning). This creates a situation in which a successful response to the problem always results in a failed response, so individuals will be automatically wrong regardless of what they choose. The nature of a double-bind is that individuals cannot confront the inherent contradiction, and therefore cannot comment on the conflict, resolve it, or escape from the situation. Bateson argued that double-bind situations could be harmful and lead to psychological problems, but such situations could also lead to an outcome in which people changed significantly (Bateson 1972/2000).

As already mentioned, the notion of learning in conflictual practice is closely linked with Marxist ideology, especially the cultural history of activity theory. The underlying ideas of cultural historical activity theory were initially formulated in the 1920s and 1930s in Russia as a solution to the problems of traditional psychology, which was seen as unable to describe the relationship between individuals and society or the historical development of psychological processes. Some important researchers in this field were Vygotsky, Luria, and Leontjev. According to activity theory, activity is defined in relation to the concept of the object. In cultural historical activity theory, the concept of contradiction is of crucial importance. According to Leontjev, the object determines the horizon of possible goals and actions that function as the motive force driving the activity forward. Goals or objectives can be understood in relation to the object and motive of collective activity. To understand the relationship between an individual goal and the motive of collective activity, Leontjev's (1978) example of a tribal community's hunting activity is helpful. In hunting, the mutual efforts of tribal members are motivated by the game as an object to get food and clothing. To catch the game, the tribe assigns different tasks to its members; some dislodge the game, others kill it. The goal of dislodging game is actually contrary to the motive of the activity as a whole. Beaters frighten animals away; they do not try to catch and kill them. To make this action reasonable, an individual must be able to see it in connection with the motive and meaning of the activity as a whole.

As the example above indicates, the objects and motives of activity are collective. Activity theory and developmental work research examine locally and temporally concrete activity systems, that is, work processes and organizations. According to more recent tendencies in cultural historical theory, activity systems are internally contradictory. In this perspective, the object itself can be internally contradictory. To develop and learn is to resolve those real contradictions intellectually and practically. The Finnish researcher Yrjö Engeström has been central to integrating contradictions and learning. Engeström has developed a conceptual model of an activity system where subject, object, instruments, rules, divisions of labor, and communities are central concepts (Engeström 1987). The model of an activity system can describe relationships between individuals and communities in workplace activity. An activity system contains a variety of different viewpoints or "voices," as well as layers of historically accumulated artifacts, rules, patterns, and divisions of labor. Engeström (1996) stressed that this multi-voiced nature of activity systems was both a resource for collective achievement and a source of conflict.

Engeström (1987) stated that a conceptual model of the activity system was particularly useful when individuals sought to make sense of features behind seemingly accidental disturbances that occurred in daily practices in workplaces. Contradictions can be identified as tensions between two or more components of the system. When analyzing and trying to understand these contradictions, it is necessary to interpret them against a historical analysis of the evolution of the activity system. As a new element enters the activity system, a contradiction appears among the elements in the system. For example, in teaching, the contradiction may appear when a new object, such as the planning of a thematic element, emerges in a teacher's daily practice. Teachers must expand their collaboration with others, but as yet there are no proper collectives or shared instruments to change planning and teaching patterns. Conflicts emerge between thematic elements as objects and the traditional individual instruments of teaching.

Change and learning in work and organizations require the construction of new objects; in this way, new motives are developed. From the viewpoint of activity theory, collaborative learning among different participants in an organization can be analyzed as a process of object formation. Engeström (1987) introduced the notion of expansive learning as the expansion of objects, which suggested that participants in an organization learned something that did not yet exist when they began the learning process. According to Engeström (1987), expansive learning primarily indicates the expansion of the object and a change in the motive of activity. Questions regarding the aim of an activity (what is produced and why) are formulated and reformulated, often leading to the formation of new collaborative relationships among participants in an organization (Engeström 1996).

The situated theory of learning as presented by Lave and Wenger (1991) is another example of a theory inspired by cultural historical thinking, in which conflicts and contradictions play an important part in the processes of learning. The theory of situated learning begins with the supposition that the individual is located or *participant* in a context. This context is what Lave and Wenger (1991) generally call community of practice and define as "participation in a system of actions where the participants share a common understanding of what they are doing, of what it means to their lives and to the community" (p. 98). To participate in community of practice highlights that action is always embedded in the social world and directed toward different forms of communities. Based on Lave's examination of apprenticeship in Liberia and a number of other surveys (see Lave and Wenger 1991 for an overview), it must be emphasized that learning is connected with changes in participation in a certain community of practice. Lave and Wenger (1991) mobilize the concept of *legitimate, peripheral participation* as an analytical concept in connection with an understanding of learning. This puts into focus the fact that the beginner is in a peripheral position with regard to knowledge-inherent forms of practice. This position is socially accepted by all parties as legitimate. The newcomer is in an asymmetrical position in relation to the community of practice. What is important for the process of learning, from the perspective of the learner, is what potential resources for learning exist in the community of practice (the curriculum of learning). The emphasis on a curriculum of learning is vital to the process of learning, as shown in a number of surveys, and indicates that the process of learning is not centered on teacher/student or master/apprentice relationships.

On the contrary, the process depends the apprentice's *access* to a practice and environment of learning with plentiful *resources to learn*, such as the ability to work with other apprentices or professionals, testing certain skills, and stories. The conflictual negations between newcomers and old-timers in the community of practice are central to the learning processes. According to Lave and Wenger (1991), a community of practice is continuously subject to negotiation to ensure continuity; the community of practice must be seen as an *emergent* structure. A community of practice is the result of participants' active negotiation of meaning. The community of practice is determined neither by structures imposed from outside, nor an underlying structure that controls the community. The contradictory relationship between old-timers and newcomers in this negotiation of meaning is often central. These negations are essential to how each group understands the activities in which they participate. On the one hand, it is important that newcomers become a part of the community of practice, but newcomers pose a threat to the habits and routines developed by the old-timers. Newcomers want to learn from the old-timers, but they have their own ideas about how things should be done. Relationships between newcomers and old-timers are at the same time conflictual and cooperative.

Cross-References

► Activity Theories of Learning
► Anthropology of Learning and Cognition
► Bateson, Gregory (1904–1980): Anthropology of Learning
► Collaborative Learning
► Context-based Learning
► Cross-Situational Learning
► Incidental Learning
► Informal Learning
► Learning and Conflict in Agent-based Models of Behavior
► Learning Dynamics in Social Dilemmas
► Learning, Social Practice and Gender
► Marx, Karl (1818–1883)
► Situated Learning
► Workplace Learning

References

Bateson, G. (1972/2000). *Steps to an ecology of mind*. London: Paladin.

Engeström, Y. (1987). *Learning by expanding: An activity – Theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Engeström, Y. (1996). Developmental work research as educational research. *Nordisk Pedagogik: Journal of Nordic Educational Research, 16*(5), 131–143.

Lave, J. (1988). *Cognition in practice: Mind, mathematics, and culture in everyday life*. Cambridge: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Leontjev, A. N. (1978). *Activity, consciousness, and personality*. New York: Prentice-Hall.

Merriam-Webster. (1999). *Merriam-Webster's Collegiate Dictionary* (10th ed.). Springfield: Marriam-Webster, Incorporated.

Learning in Context

► Learning in the Social Context

Learning in Groups

► Learning in the Social Context

Learning in Honeybees: Associative Processes

PATRICIA A. COUVILLON
Department of Psychology & Bèkèsy Laboratory of Neurobiology, Pacific Biosciences Research Center, University of Hawaii at Manoa, Honolulu, HI, USA

Synonyms

Conditioning

Definition

Honeybees (*Apis mellifera*) have a remarkable capacity for learning and memory. They readily associate environmental events and adopt new and long-lasting behaviors. This adaptability stands in sharp contrast to the traditional, popular representation of honeybees as finely tuned, robot-like machines. Indeed, much of their well-known behavior *is* species-typical,

genetically-determined, and controlled by phero-mones, but the results of literally hundreds of studies of honeybee learning and memory all point to a behavioral complexity that challenges the traditional representation.

Theoretical Background

It has been known since the early part of the twentieth century that virtually all animals learn. Given that fact, it seemed reasonable to psychologists that serious inquiry into the associative properties of learning and the discovery of basic principles of learning might best be accomplished by intensive research with only a few species (e.g., rats, pigeons). Much was learned about learning using both Pavlovian and instrumental procedures including principles for the formation of associations, for the role of reward and nonreward, and for the generation of new behavior. As a result, there was again interest in a comparative approach, and the work broadened to include systematic study with other vertebrate species. The principles turned out to be surprisingly robust and conserved across the vertebrates, with only a few instances of divergence. But *invertebrates* received very little attention despite the fact that they comprise at least 95% of existing animal species.

Interest in invertebrate learning finally began to build in the 1970s. Advances in the techniques of neuroscience held the promise that the underlying biological mechanisms of learning might, at last, be discoverable, and the most tractable nervous systems for such analysis were found in invertebrates. The neurobiologists were captivated by the possibilities of the readily identifiable nerve cells of a sea slug, *Aplysia*, and the giant axons of a freshwater crustacean, the crayfish. Rudimentary studies of learning accompanied these predominantly electro-physiological investigations, but it became clear that neither species was perfectly suited to a serious exploration of associative learning. At about this time, Corning et al. (1973, 1975) published a three-volume review of invertebrate learning documenting hundreds of studies with a surprising variety of species. Despite the large numbers, it was obvious that only with a few species had the analysis extended beyond simple demonstrations. The honeybee stood out as one of a few candidates for a formal analysis of learning. Its remarkable sensory abilities and motivational attributes were well documented by von Frisch and colleagues (1967), and its response

repertoire already had led to techniques for working with freely flying and restrained subjects.

The comparative approach to the study of learning in honeybees is to examine their performance in experiments analogous to experiments already conducted with vertebrate species (Bitterman 1996). From the outset, however, there was no reason to presuppose that the learning of honeybees would resemble that of vertebrates. The honeybee nervous system is *not* structurally similar to the vertebrate brain, and their common ancestor lived about a half a billion years ago. Nonetheless, the performance of honeybees in a variety of experiments is virtually identical to the performance of vertebrate species. The main techniques used to generate these findings are described below followed by discussion of the pattern of results and a glimpse of the future of learning research with honeybees.

Important Scientific Research and Open Questions

There are two major experimental techniques used for investigations of learning in honeybees, the *proboscis-extension reflex (PER) procedure* and the *free-flying procedure*. The PER procedure is an analog of Pavlov's familiar paradigm for study of the conditioned salivation reflex in dogs. Developed originally for sensory work on olfaction in restrained honeybees (Frings 1944), the PER procedure has proved to be ideal for the study of Pavlov's basic conditioning phenomena as well as for the more complex phenomena central to the development of theories of associative learning today. The *free-flying procedure* was developed initially to assess the sensory capabilities of foraging honeybees. It was used extensively to explore color and pattern vision as well as detection of odors (von Frisch 1967). It has proved to be an excellent and widely used template for the design of novel experiments focused on associative learning, memory, and cognition. Other techniques are used as well, including mazes, shuttleboxes, stinger-extension procedures, etc., but none has been exploited to the same extent.

Proboscis-Extension Reflex (PER) procedure. Of the two techniques, the PER procedure affords the most control of both the events and temporal sequence in an experiment. Honeybees are captured, cooled, and harnessed in small tubes with the antenna and proboscis free to move. A drop of sucrose touched to the antenna with a syringe needle reliably elicits vigorous

extension of the proboscis, the PER, and if the sucrose drop is offered to the extended proboscis, the bee will feed readily. (Feeding is illustrated in Fig. 1.) Of note is that neither air blown across the antenna nor a dry syringe needle touched to the antenna will elicit the proboscis-extension reflex. In a typical trial, scented air (e.g., peppermint) is blown across the antenna for several seconds, followed immediately by a touch of sucrose to the antenna which is then followed by feeding a small amount of sucrose to the extended proboscis. After only a few such pairings of odor and sucrose, the proboscis-extension reflex is elicited by the odor *before* the sucrose is applied. This learned reflex likely emerges from the association of the odor with the subsequent sucrose.

The PER procedure is highly efficient; 12–16 bees can be trained in a session of a few hours in length with successive trials for each bee separated by intervals of 5–7 min. The response measured is proboscis-extension to the odor on each trial. Although the number of trials possible *is* limited by satiation, learning typically is fast with small amounts of sucrose. (Though typically highly concentrated sucrose is used to elicit the reflex, other dilutions, other sugars, or even honey may be substituted.) Discrimination experiments also are easy to implement; one odor (e.g., peppermint) is paired with sucrose on some trials and another odor (e.g., jasmine) is presented on other trials, either without sucrose or with an unpleasant solution (e.g., salt). Successful discrimination learning is indicated by proboscis-extension to the odor paired

Learning in Honeybees: Associative Processes. Fig. 1
A sucrose drop touched to the antenna of a restrained honeybee elicits the proboscis-extension reflex (PER)

with sucrose and not to the odor never paired with sucrose. While the PER procedure is used in laboratories throughout the world, its utility for studies of associative learning is limited by the range of stimuli to which the bees will learn to extend the proboscis. Successful conditioning has been demonstrated with odors, air movement, and tactile stimuli, but not with visual stimuli, vibration, or magnetic field.

Free-flying Procedure. For hundreds of years, naturalists observed the foraging behavior of honeybees (Romanes 1882). Many were inspired to offer the bees sucrose or honey on various artificial flowers and then to observe their preferences. These primitive learning experiments were the foundation for more formalized procedures (von Frisch 1967). Von Frisch conducted hundreds of experiments to discover the sensory capacities of honeybees and their foraging habits. He often used the technique to observe choice behavior, and although his interests were not in learning and memory per se, he used learning as an assay to answer sensory questions. His techniques have since been adapted for formal studies of the *learning* capacities of honeybees.

Foragers are recruited to feeders which provide a very sweet sucrose solution (e.g., 50%). Once bees are visiting the feeders, the concentration is reduced (10–15%) maintaining a small number for use in experiments. In typical laboratory experiments, individuals are caught at the feeders, brought to a window shelf in the laboratory or a table outside, and released on a feeding target containing a drop of highly concentrated sucrose (e.g., 50%). The target can be a colored or scented stimulus, an image projected on an inverted flat-screen computer monitor, a 3-D object, etc. The forager, while feeding on the target, is marked for identification with a drop of paint, a tiny plastic number, or a bar code tag. (A bee drinking on a feeding target is shown in Fig. 2.) The marked bee leaves the feeding target and flies back to the hive to unload the sucrose. Preferring the higher concentration of sucrose, the bee is likely to return repeatedly to the feeding target rather than resume foraging at the feeder.

In choice experiments, the bee is required to distinguish two or more feeding targets labeled with colors, odors, patterns, shapes, etc. Usually one contains sucrose while the other contains water, distinguished from sucrose only by taste and unacceptable to honeybees foraging for sucrose. If the bee chooses the target containing the water, it is free to correct its choice and

Learning in Honeybees: Associative Processes. Fig. 2
A forager honeybee feeds at a drop of sucrose on a petri dish. Holes allow odor to escape from the scented cotton inside the dish

find the sucrose target. The bee drinks to repletion, flies to the hive to deposit the sucrose, and returns within a few minutes for another training trial. Typically bees are trained one at a time in a single training session. The interval between trials often is the time required for the bee to fly to the hive, unload, and return, usually 1–5 min. Training seldom exceeds a single day, because of diminishing likelihood that the bee will return to the situation on successive days. Choice is defined as landing on one of the targets, and all choices are recorded on every trial for each bee. Performance is plotted as mean number of correct choices over training trials for each group of bees trained, and the course of learning is shown by a gradual increase in correct choice.

Training then may be followed by a preference (extinction) test with both targets now containing water and the relative number of contacts with each target taken as the measure of preference. Alternatively, training on the first choice problem may be followed by training in a new choice problem. An advantage of the free-flying procedure over the PER procedure is the range of possible stimuli – colors, odors, 3-D objects, shapes, projected images, landmarks, etc. A disadvantage is less control by the experimenter over the events of the experiment which are determined by the free-flying bees themselves.

Pattern of results. In experiments, using both techniques that were designed to be analogs of vertebrate learning experiments, honeybees perform very much like vertebrates. The similarities are dramatic and

compelling. (See below for a partial list of the vertebrate learning phenomena found in honeybees.) The early experiments focused on the basic processes of associative learning: the role of reward and nonreward in acquisition, the effects of amount of training or variation in reward quality and quantity on both acquisition and extinction, transfer of learning in reversal problems and easy-to-hard discriminations, generalization, probability learning, pseudo-discrimination, reward downshifts, and inhibition. As the list of similarities grew, the work progressed to include some of the more challenging topics for theories of associative learning including overshadowing, blocking, compound-component discriminations, conditional discrimination, and the role of stimulus salience in compound and configural learning. With very few exceptions, the results mirror those for vertebrates.

Vertebrate Learning Phenomena Found in Honeybees (Partial List):

- Overlearning extinction effect
- Partial delay of reward extinction effect
- Overshadowing
- Potentiation
- Summation of excitation
- Within-compound association
- Compound uniqueness
- Conditional discrimination
- Successive negative contrast
- Partial reinforcement effect
- Positive behavioral contrast
- Progressive improvement in reversal
- Probability-matching
- Dimensional transfer
- Transfer along a continuum
- Ambiguous cue discrimination
- Second-order conditioning
- Spontaneous recovery in extinction
- Feature negative discrimination
- US pre-exposure effect
- Escape learning
- Avoidance learning – unsignaled
- Avoidance learning – signaled
- Place learning
- Position learning
- Risk-aversion
- Matching to sample
- Nonmatching to sample

In a surprising twist, some work on choice discrimination in honeybees exemplifies the vertebrate tradition of quantitative theory development. With simple rules for the growth and decline of the strength of association between a stimulus and reward along with a relative choice rule, the performance of honeybees is predictable in an amazing variety of choice problems. Furthermore, the parameters that best account for all of the data provide information about the relative effects of reward and nonreward on associative strength as well as the kind of choice rule employed by foragers (Couvillon and Bitterman 1991). In fact, the theory accounts for the risk-aversion that emerges in investigations of risk-sensitivity in the foraging decisions of honeybees.

Open questions. There are many more vertebrate-learning phenomena to be explored in honeybees, and even the phenomena already in the list above have not been fully investigated. Nonetheless, the work has captivated the interest of researchers in very diverse fields including ecology, evolutionary biology, development, genomics, sensory biology, psychology, and neurophysiology, so work on associative learning in honeybees now is proceeding on many fronts. Of particular interest are cognitive topics including memory, attention, categorization, concept-learning, and navigation as well as the neurophysiological correlates of learning (Menzel et al. 2006; Giurfa 2007). While the pace of research on honeybee learning and cognition has accelerated, it is important to keep in mind a fundamental question. If the learning of honeybees is functionally the same as that of vertebrate species, to what extent is this due to common biological (e.g., synaptic, genomic) and psychological (associative processes) mechanisms and to what extent is this a dramatic case of convergent evolution?

Cross-References

▶ Animal Learning and Intelligence
▶ Associative Learning
▶ Comparative Psychology
▶ Learning in Invertebrates
▶ Pavlovian Conditioning

References

Bitterman, M. E. (1996). Comparative analysis of learning in honeybees. *Animal Learning & Behavior, 1996*(24), 123–141.

Corning, W. C., Dyal, J. A., & Willows, A. O. D. (Eds.). (1973, 1975). *Invertebrate learning* (Vol. 1–3). New York: Plenum.

Couvillon, P. A., & Bitterman, M. E. (1991). How honeybees make choices. In L. J. Goodman & R. C. Fisher (Eds.), *The behavior and physiology of bees* (pp. 116–130). Oxford: CAB International.

Frings, H. (1944). The loci of olfactory end-organs in the honey-bee. *The Journal of Experimental Zoology, 97*, 123–134.

Giurfa, M. (2007). Behavioral and neural analysis of associative learning in honeybees: a taste from the magic well. *Journal of Comparative Physiology A, 193*, 801–824.

Menzel, R., Leboulle, G., & Eisenhardt, D. (2006). Small brains, bright minds. *Cell, 124*, 237–239.

Romanes, G. J. (1882). *Animal intelligence.* London: Paul Kegan, Trench & Co.

von Frisch, K. (1967). *The dance language and orientation of bees.* Cambridge: Harvard University Press.

Learning in Informal Settings

HEATHER KING, JUSTIN DILLON
Department of Education & Professional Studies, King's College London, London, UK

Synonyms

Learning beyond the classroom; Out-of-school learning

Definition

Learning in informal settings refers to the opportunities and environments for learning that exist beyond traditional or "formal" schooling. Such opportunities and environments include those provided by museums, galleries, science centers, zoos, botanic gardens, and wildlife parks. They may also be considered to include afterschool programs, Saturday science clubs, as well as those afforded by books, television programs, new media, and the Internet (Bell et al. 2009; Rennie 2007).

Theoretical Background

The use of the terms "formal" and "informal" does not mean that the processes of learning that take place in out-of-school settings are any different to those that occur in school: rather the terms simply refer to the site of learning. Indeed, the nature of learning – that is, the relatively permanent change in the thought or behavior that results from experience – is the same wherever it

takes place. Moreover, thinking of learning as being defined by the location in which new experiences are presented is contrary to our understanding of learning as being cumulative and, as such, straddling place and time. Nonetheless, it is important to note that the learning that occurs, or is at least initiated, in informal settings is affected by a number of influences distinct from those that usually operate in schools. Such influences include the impact of novelty, for example, with respect to a visit to an imposing museum; the lack of any externally imposed curricula and thus the freedom to follow one's own route of choice; the particular nature of the facilitation; and the social context in which the experience occurs.

A second point of difference with learning in formal settings is that, for the most part, learners actively choose to engage with an informal learning opportunity, often paying for the privilege. As Csikszentmihalyi and Hermanson (1995) have argued, it is this desire and freedom to select and then engage with content that holds personal interest that leads to a fostering of intrinsic motivation which in turn may engender deeper learning.

While some informal experiences occur on a regular basis, such as attendance at a club, most visits to museums, galleries, and other institutions are much less frequent. Furthermore, the time spent in such places is often relatively short. Unlike in formal settings, where teachers come to know their students over the course of a year, educators in informal settings must attempt to gauge learners' interests and abilities, and modify their interactions accordingly in the space of just a few minutes. To this end, informal educators require a set of skills that are quite distinct from those of teachers (Tran and King 2007). These skills also include the use of specimens, objects and exhibits as instructional media, and the use of particular modes of talk – re-voicing, repeating, summarizing – to guide, structure, and scaffold learner engagement.

Finally, learning in informal settings may be distinguished by its social nature. Most learner experiences, such as visits to museums, occur as part of a group. As a result, the learning experience of the individual is mediated by the meaning-making that occurs within the group: children learn as their parents or carers point to and talk about particular objects; adults refine their interpretations of artworks in discussion with friends, and so on.

Given the highly social nature of learning, together with the importance of personal choice, it is not surprising that the main theoretical frameworks guiding research into learning in informal settings build on socio-cultural and constructivist traditions. Early research in museums focused on the physical behavior of visitors or the measurement of content knowledge gain pre- and post-visit. More recently, researchers have moved away from a focus on factual recall on the basis that it is impossible to disaggregate a learning experience in one setting from that which occurred in another. Thus, research studies have examined the manner by which learners construct meaning from their experiences, and how such efforts are mediated over time by the social environments in which they occur. Falk and Dierking's (2000) Contextual Model of Learning framework, for example, highlights the ways in which learning is affected by the interaction of a learner's personal context with their socio-cultural context and the physical context, over time. The personal context includes a learner's motivation and expectations, prior knowledge and experience, and interest and personal choice. The socio-cultural context acknowledges the role played by mediators such as museum educators, or even the members of one's social group. Thirdly, the physical context refers to the impact of setting, design, the extent of advanced preparation, and the subsequent reinforcement of events and experiences.

The significance of a learner's prior knowledge and experience in interpreting novel situations and building new mental representations has been highlighted by Hein (1998) in his description of the "constructivist museum." Hein argues that visitors to informal settings should be supported in choosing their own learning paths to enable personal meaning-making. This is not to say, however, that learners should be left to make up their own explanations. Rather, it calls for the design of exhibitions and programs, or the actions of educators to provide new experiences for learners and, moreover, to challenge any notions developed by learners to ensure they are robust and logically consistent with the accepted canon of knowledge.

To explore the ways in which learners construct their understandings in informal settings, a growing body of research has focused on the nature of visitor talk. For example, Feinberg and Leinhardt (2002) analyzed visitor talk for three elements – identification, evaluation, and expansion, with expansion comments

being further examined for level of explanatory engagement. Allen (2002) similarly coded talk into a number of categories: perceptual, conceptual, connecting, strategic, and affective.

More recently, researchers have experimented with making modifications to exhibits with the aim of generating certain types of talk. For example, Hohenstein and Tran (2007) amended the label text of objects in a history of science exhibition by adding the key question "Why is this here?" They found that such questions prompted an increased level of talk on the part of visitors, and in particular a greater number of causal explanations regarding the provenance of the exhibit.

In exploring the nature of visitor talk and visitor engagement, scholars have built upon research traditions used in formal environments. However, they have also developed new theories and approaches designed to reflect the particular situation of learning in informal settings. For example, the desire to understand visitors' motivations for learning in informal contexts has led to a focus on visitors' enacted identity – that is how they justify the visit, how they wish to be perceived, with whom they visit, and so on (Rounds 2006). New analytical frameworks, meanwhile, designed to capture learning in informal settings include the identification of explanatory fragments offered by parents and other mediators (Crowley et al. 2001). Such explanations may not support full conceptual change, but as Crowley and colleagues have argued, the cumulative effect of several such fragments may constitute the mechanism through which parents and children co-construct scientific thinking.

Important Scientific Research and Open Questions

That informal settings provide opportunities for learning is not in doubt. Measuring the extent and depth of that learning is, however, difficult. Indeed, justifying future financial support for opportunities for learning in informal settings may require establishing levels of value in comparison with experiences provided in more formal environments. But given that informal environments seek to provide affective experiences as well as support more cognitive gains, can we realistically compare the impact of a visit to an informal setting with an experience in school?

Other questions shaping ongoing and future research address the need for new pedagogic strategies to support learning in informal settings. For example, what skills are required on the part of education staff to best support interactions that may only last a few seconds, and that seek to engage a visiting group with a range of ages and interests? What theoretical knowledge and practical training do they require? Indeed, is there a need for a theory of pedagogy distinct to the informal sector?

Finally, researchers are increasingly exploring ways in which informal settings can contribute to broader educational reform questions around the design of education systems and notions of public engagement and citizenship. Such questions ask to what extent programs developed in museums, galleries, etc. may lead to a more informed and empowered populace? Can novel strategies such as inviting the general public to create exhibitions, via co-curation, shift the balance of power away from institutions more toward the public? And to what extent can initiatives developed in informal settings – for example, around gender equity and the design of learning resources – positively impact upon traditions in the formal sector?

Cross-References

► Conceptual Change
► Constructivist Learning
► Explanatory Support for Learning
► Identity and Learning
► Motivation and Learning: Modern Theories
► Scaffolding
► Social Construction of Learning

References

Allen, S. (2002). Looking for learning in visitor talk: A methodological explanation. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 259–304). Mahwah: Lawrence Erlbaum.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Research Council. Available from http://www.nap.edu/catalog/12190.html.

Crowley, K., Callanan, M. A., Jipson, J. L., Galco, J., Topping, K., & Shrager, J. (2001). Shared scientific thinking in everyday parent-child activity. *Science Education, 85*(6), 712–732.

Csikszentmihalyi, M., & Hermanson, K. (1995). Intrinsic motivation in museums: What makes visitors want to learn? *Museums News, 74*(3), 34–37 & 59–61.

Falk, J. H., & Dierking, L. D. (2000). *Learning from museums: Visitors experiences and the making of meaning*. New York: Altamira Press.

Feinberg, J., & Leinhardt, G. (2002). Looking through the glass: Reflections of identity in conversations at a history museum. In

G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 167–212). Mahwah: Lawrence Erlbaum.

Hein, G. E. (1998). *Learning in the museum.* London: Routledge.

Hohenstein, J., & Tran, L. U. (2007). The use of questions in exhibit labels to generate explanatory conversations among science museum visitors. *International Journal of Science Education, 29*(2), 1557–1580.

Leinhardt, G., Crowley, K., & Knutson, K. (Eds.). (2002). *Learning conversations in museums.* Mahwah: Lawrence Erlbaum.

Rennie, L. J. (2007). Learing science outside of school. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 125–167). Mahwah, NJ: Lawrence Erlbaum Associates.

Rounds, J. (2006). Doing identity work in museums. *Curator: The Museum Journal, 49*, 133–150.

Tran, L., & King, H. (2007). The professionalization of museum educators: The case in science museums. *Museum Management and Curatorship, 22*(2), 129–147.

Learning in Information-Rich Environments

Delia Neuman
College of Information Science and Technology,
Drexel University, Philadelphia, PA, USA

Synonyms

Twenty-first-century skills; Information literacy

Definition

An information-rich environment is any venue – formal or informal, actual or virtual – that contains information in any format that could be used for learning. Today's information-rich environments exist in brick-and-mortar schools, libraries, and museums; in "traditional" media outlets like newspapers, television, and radio; in the natural world around us; and, of course, on the Internet and the World Wide Web. Information-rich environments can be found in all kinds of educational settings and can bypass those settings entirely, offering possibilities for learning disguised as recreation and entertainment – a movie theater, a concert hall, or even a website hosting a game in which a players must use critical-thinking skills to solve a particular problem. All these environments provide a wealth of information and therefore abundant possibilities for learning.

Theoretical Background

The concept of learning in an information-rich environment is so broad that it draws on research and theory from across a wide spectrum of disciplines – the full range of learning theories, work on various dimensions of communication, discoveries from pedagogical practice, and more. Most salient to the present discussion is the grounding of the concept in two primary disciplines: (1) instructional systems design and development and (2) information studies and science. Taken together, core concepts from these two areas suggest a complementarity between the disciplines' definitions of "information." Further, this understanding of "information" is also closely related to contemporary definitions of "learning," providing a theoretical basis for looking at information itself as the basic building block for meaningful learning.

Contemporary definitions of information from information studies draw largely on Buckland's (1991) conceptualization of information as a process (i.e., the communication act); as knowledge (i.e., as an increase in understanding or a reduction in uncertainty); and as a thing (i.e., an object that imparts information). A series of discrete yet interrelated elements that appear along a continuum ranging from the purely physical to the fully abstract, information "includes objects in the world, what is transferred from people or objects to a person's cognitive, system, and the components of internal knowledge in people's minds" (Marchionini 1995, p. 5). Similar definitions come from the perspective of instructional development and design. Here, information is seen as "what is to be learned" and is classified by Anderson and Krathwohl (2001) in their revision of ▶ Bloom's *Taxonomy* into four categories of knowledge: factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge. Factual knowledge includes basic elements of a discipline, conceptual knowledge consists of the interrelationships among these elements that enable them to function together, procedural knowledge is the knowledge of how and why to perform tasks, and metacognitive knowledge includes knowledge of one's own cognitive strategies and processes.

Taken together, these parallel conceptions of information – one from the theory of information studies and one from the theory of instructional design – suggest that "information" is a holistic

construct that incorporates (1) discrete content entities that are (2) linked by processes. In this construct, information has both physical and abstract dimensions that can be put to different uses depending on their inherent characteristics and possible interrelationships. One of those uses is, of course, learning.

A single, universal definition of "learning" is difficult to find: because it is so complex and there are so many ways of looking at it, scholars from various perspectives tend to focus on their particular areas of interest rather than on the concept itself. In its basic form, however, learning can be defined as "knowledge acquisition. . . the process of absorbing and storing new information in memory." Knowledge is organized in memory in semantic networks, and "a semantic network is a method of representing knowledge as a system of connections [among] concepts in memory" (Bloome 2002, p. 1431). In other words, learning is both the process and the outcome of (1) acquiring new concepts and skills through instruction or direct experience and (2) organizing those concepts and skills into personally coherent structures within our minds.

Thus, learning – like information – consists of multifaceted and interrelated elements that exist in some kind of organized structure. And while definitions of information only allude to the processes by which this organizing takes place, definitions of learning are concerned primarily with those processes and how they "work on" various kinds of knowledge/information: what the sensory register, short- and long-term memory, metacognitive strategies, and so forth contribute to the creation of organized cognitive structures. Learning and information are, therefore, two sides of the same coin that complement each other in unique ways. Each side of that coin represents a dynamic, complex, and multifaceted reality. As a whole, the coin suggests that information is the basis for learning in today's dynamic, complex, and multifaceted world.

Important Scientific Research and Open Questions

Both information science and instructional design have contributed to an emerging understanding of learning with information, but the implications of looking at information itself as the basic building block for learning have not been fully explored and exploited. One

structure for doing so is Neuman's (2011) I-LEARN model, drawn from research and theory in both fields. The six steps of the model unite steps in information seeking and steps in the learning process to suggest a holistic framework that describes learning in information-rich environments: **I**dentify a question or problem that can be resolved with information, **L**ocate candidate information that might be useful, **E**valuate the information to determine its most salient aspects, **A**pply the information to answer the question or solve the problem, **R**eflect on the process and outcome of these first four steps, and instantiate the results as personal k**N**owledge.

Research about several of these steps has been the province of information studies for decades: dozens of journals and scholarly databases in that field report on how various user groups *locate* information and *evaluate* information sources. Similarly, the literature of instructional design contains extensive research into how to encourage learners to *identify* essential problems, *apply* learning strategies and techniques to master them, and *reflect* on the learning that results. Two movements, one within each field, have also contributed significant insights: the ▶ information-literacy movement, which began in the 1980s within the world of information studies, and the current ▶ twenty-first-century skills movement, which comes largely from the world of instruction and learning. The two worlds have yet to be combined, however, into a research framework that investigates holistically the process of learning with information in today's information-rich environments.

Questions arising from that holistic framework both extend the questions that concern the separate fields and suggest some new areas of investigation. Among the most intriguing involve the learning processes, strategies, and outcomes that are uniquely supported by today's most visible information-rich environment – the virtual world of the Internet/ World Wide Web. This environment allows learners to access, evaluate, and apply information across the full range of media formats (from visual, auditory, and interactive to combinations of all three) and the full range of levels of sophistication (from novice to expert) and quality (from whimsical to serious and from polemical to scholarly). Unvetted and unorganized, this environment poses serious challenges to learners

in their construction of coherent and reasonably accurate cognitive structures.

One general area involves the highly visual nature of the Internet/Web. Although learners often prefer visual information to printed information, we have yet to understand fully how they extract key information from visuals – especially those presented in the rapid pace and according to contemporary design conventions that are characteristic of visual information on the Internet/Web. Another area involves the implicit requirement for synthesis embedded in this environment. Although many websites are reasonably well-organized themselves, the way users click and surf and collect bits of information across multiple sites means that, in order to learn, learners must organize that information in their own minds without much guidance from the environment itself. In an environment that, as a whole, is devoid of the conventions of headings and subheadings, consistent placement of important information, etc., we do not yet understand what concepts and skills learners need in order to create reasonable cognitive information structures.

Looking at this Internet/Web environment as a collection of content entities linked for various purposes – particularly learning – provides a new perspective that allows researchers to consider core ideas from several well-established disciplines as they investigate the unique learning possibilities and challenges inherent in this information-rich environment. As more and more people turn to it to learn such straightforward lessons as how to solve simple math problems and such complex ones as how to select appropriate medical care, it is imperative that researchers find ways to understand the kind of learning involved and that designers find ways to create instruction that supports this learning. A view of learning and information as complementary and of information itself as the basic building block for learning holds the promise of improving learning in both formal and informal settings.

Cross-References

► Bloom's Taxonomy of Learning Objectives
► Cognitive Strategies for Digital Media
► Interactive Learning Environments
► Knowledge Acquisition: Constructing Meaning from Multiple Information Sources
► Multimedia Learning
► Resource-Based Learning

References

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. New York: Addison Wesley Longman.

Bloome, D. (2002). Language and education; subsection on Learning: knowledge acquisition, representation, and organization by D. S. McNamara and T. OReilly. In J. W. Guthrie (Ed.), *Encyclopedia of Education* (2nd ed., Vol. 4, pp. 1431–1435). New York: Macmillan Reference USA.

Buckland, M. (1991). *Information and information systems*. New York: Praeger.

Marchionini, G. (1995). *Information seeking in electronic environments*. Cambridge, MA: Cambridge University Press.

Neuman, D. (2011). *Learning in information-rich environments: I-LEARN and the construction of knowledge*. New York: Springer.

Learning in Invertebrates

Jesse E. Purdy
Department of Psychology, Southwestern University, Georgetown, TX, USA

Synonyms

Cognition in invertebrates; Comparative cognition

Definition

Invertebrates possess neither backbones nor vertebral columns and comprise more than 95% of earth's animal population. Invertebrates offer a rich but relatively untapped resource for comparative studies of learning despite the fact that knowing the role of invertebrates in adapting to a changing world is critical to understanding the evolution of intelligence.

Theoretical Background

Thomas (1980) argued that qualitative differences in learning abilities exist and can be used to compare cognition across species. He suggested a hierarchy of eight learning abilities, of which only the first six levels are considered here: (1) habituation, (2) signal learning, (3) stimulus–response learning, (4) chaining, (5) concurrent discrimination learning, and (6) absolute and relative affirmative concepts.

Level 1: Habituation. Habituation occurs when an organism stops or considerably reduces responding to a stimulus that has been presented continuously over

time or successive times. Typically, such stimuli are not associated with events of biological significance to the animal and can safely be ignored. To demonstrate the process of habituation one needs to rule out explanations based on physiological changes not related to learning such as response fatigue and stimulus or receptor adaptation. In addition it is important to distinguish habituation from associative learning. To this end researchers present a different stimulus. If the response to the habituated response is reinstated, habituation has been demonstrated. Habituation learning has been observed in every invertebrate studied to date. From fruit flies, to honey bees, to squid, octopus, and even the lowly nautilus, all habituate. The physiological basis of habituation has been documented through research with aplysia, a marine snail. Habituation results from a decrease in the quantity of a neurotransmitter that causes the contraction of a muscle on the postsynaptic side. Habituation learning appears to be ubiquitous in the animal kingdom and may well be the form of learning most critical to survival.

Level 2: Signal Learning. Signal learning, or more commonly classical conditioning or Pavlovian conditioning, occurs when a contingency is arranged between a stimulus (the conditioned stimulus) and an outcome (the unconditioned stimulus). The outcome is response-independent. Pavlovian conditioning prepares the animal for the unconditioned stimulus whether it be appetitive or aversive in nature. For example, to capture food, the ant lion digs a funnel-shaped pit in the sand and then buries itself at the bottom and awaits prey to venture past. When prey step into the hole, they lose their balance, tumble into the pit, and are attacked before they can escape. When researchers signaled the arrival of food, ant lions acquired food more readily, they learned to build better pits, and they extracted food more efficiently, with the result that they molted sooner on average than nonsignaled animals.

Signal learning has been observed in numerous invertebrates, including crickets, houseflies, fruit flies, beetles, honeybees, bumblebees, grasshoppers, the coleoid cephalopods (cuttlefish, octopus, and squid), and the nautilus. Examples include conditioned proboscis extension in honeybees when bees receive paired presentations of novel odors or tastes as the conditioned stimulus, and sucrose water as the

unconditioned stimulus. Attack behavior in cuttlefish also exhibits signal learning when a flashing light is paired with frozen or live prey. Classical conditioning has also been observed in a caterpillar species using a defensive or aversive conditioning technique (Blackinston et al. 2008). An odor, ethyl acetate, was presented for 10 sec to fifth-instar Manduca sexta caterpillars followed by the odor and mild electric shock for an additional 10 sec. Eight pairings of the odor and shock were sufficient to demonstrate conditioning as evidenced by the animal avoiding one arm of a Y-maze which had the ethyl acetate odor. Remarkably, the learning was retained through metamorphosis. That is, when the aversively trained group was tested again as adults, the adult moths avoided the ethyl acetate odor.

Level 3: Stimulus–Response Learning. When an organism learns to make a particular response for reinforcement in the presence of a discriminated stimulus it has exhibited stimulus–response learning. Methodologically, psychologists have studied this form of learning in either of two ways. If the experimenter determines when the animal should respond, the method is referred to as instrumental conditioning, and if the animal itself determines when to respond the method is known as operant conditioning. Instrumental conditioning typically requires the animal to navigate through a maze in order to receive a reward. Other forms include jumping from a stand to one of two windows on a wall, removing a cover from one of two covered depressions in a wooden floor to find food, poking one's nose into a hole in a wall, and so on. In every case, the method requires a response that is well within the animal's repertoire of responses used to find food or avoid danger. In operant conditioning, the animal is placed in an experimental chamber in which there is some device the animal has to manipulate to receive reward. For example, when rats press a bar for reward or pigeons peck a key, they are exhibiting operant conditioning.

Stimulus–response learning has been demonstrated in a large number of invertebrate species including insects (ants, blowflies, crickets, honeybees) and cephalopods (cuttlefish, octopus). In an extensive series of studies Bitterman, Couvillon, and their colleagues (Bitterman 1996; see also "▶ Learning in Honeybees: Associative Processes") trained honeybees to fly from one window sill to another to sample targets

distinguished by color or odor and by the concentration of sucrose in the reward. Rates of response and choice behavior were affected by changes in the quality or quantity of reward. Ants *Formica cunicularia* have also been found to display stimulus–response learning. These studies involved discrimination of color in a Y-maze. *Formica cunicularia* were able to discriminate between wavelengths in the UV range separated by 40 nm using a differential conditioning method. Blowflies (*Protophormia terrae novae*) were trained to enter and reenter a hole in order to receive a reward. With just a few trials of continuous reinforcement the response rate increased as a function of reinforcement and decreased as a function of nonreinforcement.

Numerous experiments have shown that cephalopods are also capable of stimulus–response learning. For example, cuttlefish can learn to turn left or right in a T-maze and to go to a particular place. Although their performance can be erratic, octopuses (*Octopus bimaculoides*) have learned to swim down a straight alley maze to obtain food and to turn left or right in a T-maze in order to escape. Perhaps, most surprising of all the cephalopods, the nautilus, with its very simple neural system relative to the coleoid cephalopods, is able to locate a goal within a three-dimensional space and remember the location for longer than 2 weeks. These examples document that cephalopods can be instrumentally conditioned. Interestingly, it appears to be more difficult to train them using operant conditioning. Only two attempts have been published and neither of these came close to the level of responding one sees with rats, pigeons, monkeys, or even fish.

Level 4: Chaining. When an organism performs an ordered series of responses, each signaled by a stimulus, it is said to exhibit chaining. Cuttlefish and octopus are adept at chaining, as evidenced by their ability to use multiple landmarks to find foraging sites and to return to their dens at the end of the bout. Honeybees are masters of spatial learning and navigation, and show responses chaining in their navigation. In fact, honeybees have been shown to be capable of chaining seven turns in a maze in order to receive a reward. In another demonstration of chaining, ants (*Myrmica sabuleti Hymenoptera: Formicidae)* were trained with either a series of visual or odor cues to solve a maze problem. The ants were able to negotiate the maze using either the visual or odor cues to find a meat reward. The above studies notwithstanding, studies of chaining are rare in the invertebrate learning literature. However, what evidence there is suggests that cephalopods and a variety of different insects are capable of the task.

Level 5: Multiple Discrimination Learning. At this level the animal learns to solve multiple discrimination problems either in series or simultaneously. In the first method, the animal receives hundreds of two-choice discrimination problems presented one pair at a time until each is mastered. As the animal solves more and more problems, it appears to switch strategies from using specific stimulus–response associations, to using a more general "win-stay; lose-shift" strategy. This ability to "learn how to learn" is known as learning set formation and is documented by an improvement in Trial 2 performance across discrimination tasks. In the second method, the animal learns to solve multiple concurrent discrimination problems. Here, the animal might be required to solve to criterion eight different two-choice discrimination problems. The number of discrimination problems that the animal can solve at any one time is a measure of its cognitive ability. Thomas (1980) has argued that an animal able to solve two discrimination problems at the same time is demonstrating a higher level of cognition than an animal able to chain any number of stimulus–response events.

Learning set formation and multiple concurrent discrimination problem solving have not been directly tested with invertebrate subjects. However, invertebrates are certainly capable of solving discrimination problems and some of the experiments hint at learning set formation. Sakura et al. (2002) trained cockroaches (*Periplaneta Americana*) to discriminate between three types of odors. One of the odors was associated with sucrose water, and the other two stimuli were associated with saline water, for which cockroaches will not work. Following training, cockroaches were given nonrewarded preference trials. Sometimes, the cockroaches were tested with three different odors and sometimes they received binary choices. Regardless, performance was the same, indicating an ability to retain elements of information about positive and negative stimuli and to use that information in novel situations. Learning psychologists contend that determining how one stimulus differs relative to another involves a more complex cognitive process than simple S-R bonds. Honeybees and bumblebees have also been

found to make finer discriminations when given an opportunity to compare stimuli.

Species that do not show learning set formation may nevertheless show conditional cue discrimination learning. Conditional discriminations may be considered to fall between multiple discrimination learning and learning set formation in terms of cognitive complexity. In a conditional discrimination, whether or not responding will be reinforced in the presence of a cue depends on the presence of another stimulus, the conditional cue. Invertebrates appear to be able to solve conditional cue discriminations. Conditional cue discrimination learning has been demonstrated in three species of Coleoid cephalopods, as well as cockroaches and drosophila. In addition, a cuttlefish improves performance when given repeated reversal discrimination problems. In this task, the cuttlefish learns a two-choice discrimination and is then required to learn its reversal. Once the cuttlefish solves the reversal task to criterion, the problem is reversed again. The improvement in learning across successive reversal problems (habit reversal learning) is similar to learning set formation in that the animal may be "learning how to learn." Habit reversal learning has been reported in a variety of insects, but recent evidence questions whether honeybees show improved performance with multiple reversal events.

Level 6: Affirmative or Class Concepts. Affirmative or class concepts can be characterized as "absolute" or "relative." Concept formation requires the ability to classify certain stimuli as all belonging to the same group, or as being an example of some larger stimulus set. Concept formation necessitates generalizing from training exemplars to novel instances of the category and discriminating examples of the target category from other stimuli. Thomas distinguished between absolute and relative concepts. He considered stimuli that were classified on the basis of their physical features as "absolute" concepts. Many concept formation studies with nonhuman animals have involved these types of stimuli. Thomas suggested that the learning of "relative" concepts provides more convincing evidence of concept formation. In a relative concept problem, the animal has to compare two stimuli. Research on same–different learning satisfies Thomas's definition of a relative concept, since same–different judgments require comparing stimuli. Another discrimination problem requiring this level of cognition is the "oddity" problem, in which the animal's task is to observe three stimuli and choose the "odd" stimulus or the one that is not like the other two.

According to Thomas (1980), Level 6 relative concept performance has never been demonstrated in any nonprimate. Contrary to that conclusion, Giurfa et al. (2001) used a delayed matching to sample task to demonstrate that honeybees could learn the concept "sameness" and a non-matching-to-sample task to show acquisition of the concept of "difference." Remarkably, performance improved to the point at which novel or new discrimination problems were solved virtually without error. Interestingly, Giurfa et al. also showed that it did not matter whether the sensory modality of the test problem was the same or different from the original problem.

Important Scientific Research and Open Questions

Conclusion. In many respects, invertebrate learning appears to be on par with learning in vertebrates. These learning abilities either occurred very early in evolutionary history, or, more likely, these abilities have evolved multiple times independently over millions of years. Either way, the findings tell us that the abilities to ignore irrelevant stimuli, associate two stimuli, acquire new responses, learn a sequence of stimulus–response problems, solve multiple concurrent discriminations, and form concepts, both absolute and relative are critical to life on this planet. That a bee can understand the difference between "same" and "different" must mean that such ability gives the bee an advantage either in terms of reproductive success directly or because it increases the bee's probability of surviving to reproduce. Regardless of the reason, the ability to learn can be considered so important to survival that all animals possess the ability and possess it to great complexity.

Cross-References

▶ Abstract Concept Learning in Animals
▶ Aversive Learning in Drosophila Melanogaster
▶ Conditioning
▶ Habituation
▶ Learning in Honeybees: Associative Processes
▶ Learning Set Formation and Conceptualization
▶ Operant Learning
▶ Pavlovian Conditioning
▶ Simultaneous Discrimination Learning

References

Bitterman, M. E. (1996). Comparative analysis of learning in honeybees. *Animal Learning & Behavior, 24*(2), 123–141.

Blackinston, D. J., Silva Casey, E., & Weiss, M. R. (2008). Retention of memory through metamorphosis: Can a moth remember what it learned as a caterpillar? *PLoS ONE, 3*(3), e1736. doi:10.1371/journal.pone.0001736.

Giurfa, M., Ahang, S. W., Jenett, A., Menzel, R., & Srinivasan, M. V. (2001). The concepts of 'sameness' and 'difference' in an insect. *Nature, 410*(6831), 930–933.

Grasso, F. W., & Basil, J. A. (2009). The evolution of flexible behavioral repertoires in cephalopod mollusks. *Brain, Behavior and Evolution, 74*, 231–245.

Sakura, M., Okada, R., & Mizunami, M. (2002). Olfactory discrimination of structurally similar alcohols by cockroaches. *Journal of Comparative Physiology A-Neuroethology Sensory Neural and Behavioral Physiology, 188* (10), 787–797. doi:10.1007/s00359-002-0366-y.

Thomas, R. K. (1980). Evolution of intelligence: An approach to its assessment. *Brain, Behavior and Evolution, 17*, 454–472.

Learning in Mixed Realities

▶ Mixed Reality Learning

Learning in Networks

▶ Networks, Learning Cognition, and Economics

Learning in Practice (Heidegger and Schön)

Klaus Nielsen
Department of Psychology, Aarhus University,
Aarhus C, Denmark

Synonyms

Apprenticeship; Constructionist thinking; Phenomenology; Situated learning

Definition

Today, the concept of *practice* is often used in everyday language to describe a sense of hands-on craftsmanship, in contrast to mental activities common in schools. Different theories that address this concept (see Nielsen 2007 for an overview) define practice and practical knowledge in contrast to proportional theoretical knowledge. They argue that central and important aspects of our lives are beyond theoretical knowledge and only learned through practice. There is an implicit understanding of practice as being craftsmanlike and connected to non-intellectual actions aimed toward the mundane.

The concept of practice will be interpreted more broadly in this article due to the influence of the Austrian philosopher Ludwig Wittgenstein. Practice is the *background* against which we understand and discuss different aspects that stand out in our perception (Wittgenstein 1996). We are not solipsistic minds outside the world trying to understand it. From this perspective, learning in practice can be defined as processes whereby we develop an understanding of practice.

Theoretical Background

Within the last decade, learning in practice has been a key subject in discussions of learning (Nielsen 2007). There has been growing awareness in the field of education that it is vital to understand the processes of learning outside school institutions (Nielsen 2007). There are a number of different understandings of learning in practice. This article will focus on learning in practice from a constructivist and phenomenological perspective. Donald Schön will represent the constructivist perspective, while Martin Heidegger will represent the phenomenological perspective. Constructivist thinking focuses on epistemological perspectives inspired by Kant, who, in line with later constructivist thinking, proposed that space, time, causality, and objects are forms which the human mind brings to its experience. Our experience of the world is objective and certain – spatial and temporal, with objects interacting causally – and constituted through the mind's application of these cognitive structures to basic sensory impressions. Consequently, constructivism places great emphasis on knowledge and knowing the world. Central to Schön's approach to learning in practice is the idea of reflection in practice, whereby the practitioner relates to practical problems like an intellectual would respond to an academic problem. Practitioners reflect, experiment, and

construct new ways of solving the practical problems they face (Schön 1983, 1987). Practical reflection is based on making experiments in relation to the subject matter, just as a scientist would, until an appropriate solution has been reached.

There are various versions of phenomenology extant. The outline of phenomenology in this context focuses on meaning and interpretation, which is also central for Heidegger (1988). In hermeneutical phenomenology, interpretive structures of experience are studied, or how we understand and engage things, including ourselves and others. In positivism, it is often taken for granted that the world consists of physical entities which we recognize unproblematically. However, if we take a phenomenological approach to knowing something, it always involves a process of interpretation. What constitutes a fact always depends on interpretation. Social and psychological phenomena are not understood as brute facts, but produced by interpretations of these facts and dependent on specific human practices. Being part of everyday life practices gives us a background from which we tend to interpret certain phenomena as facts, but we forget that "facts" are a result of an interpretive process. Like Rubin's gestalt, the background makes the foreground stand out as meaningful. To "know" something is dependent on the background of individuals and the practices they are a part of. According to Heidegger, our relationship to the world is not merely an epistemological one; it is of another nature altogether (Nielsen 2007). Fundamentally, we live in the world before we recognize it. We are, first and foremost, concerned with the world around us, with each other, and with our particular everyday lives before we begin to wonder how and what we know of the world. The relationship between subject and object must be determined by actual activities (*Umgang*) with objects in the world. Heidegger specifically states that *Umgang* – our interactions – precede our epistemological recognition of the world (*Erkentniss*) (Nielsen 2007).

According to Heidegger, "[t]o learn means to make everything we do answer to whatever essentials address themselves to us at a given time" (Heidegger 1999, p. 14). In order to illustrate his definition of learning, Heidegger provides an example taken from craft and apprenticeship: a cabinetmaker's apprentice who builds cabinets. The apprentice in Heidegger's example is learning to be responsive to the wood he is working with. To become a true cabinetmaker, the apprentice must learn to answer and respond to different kinds of wood. In fact, this relationship to wood is what maintains the craft of the cabinetmakers. To Heidegger, learning a craft is only meaningful if our basic metabolism with the world constitutes its basic point of departure. Without an understanding of the essentials (like wood for the carpenter), the use of different kinds of tools does not make sense. The referential character of tools is not a closed system. It refers to our dealings with the world.

How does the apprentice learn to be responsive to wood? Heidegger indicates that the apprentice learns from a teacher being present. According to Heidegger, the teacher demonstrates to the apprentice how to be open to the material and the subject matter of the craft; the cabinetmaker stays responsive to the wood. Heidegger places this openness at the center of his approach to learning, when he claims that "[t]eaching is more difficult than learning because what teaching calls for is this: to let learn." The priority of the teacher is to make sure that the apprentices remain responsive to the material of the craft (Heidegger 1999). The teacher must arrange for apprentices to make their own experiences ("to let learn"). However, in another interpretation of Heidegger, the apprentice learns from the teacher, who provides arrangements based on the trade and the apprentices' abilities to allow them to develop into competent individuals.

Important Scientific Research and Open Questions

According to Heidegger, the aim of learning processes is for learners to develop a sense of understanding in relation to practice. This understanding shows itself when learners are able to handle practical tasks in a confident fashion – what Heidegger termed "familiarity" (*Vertrauenheit*) (Heidegger 1988). Learners should be able to handle tasks and equipment in a confident fashion. This confidence in practice provides us with a *background* for our activities. In this sense, familiarity is the concrete, lived sense of what it means to understand. Heidegger speaks of familiarity as fundamental to being in the world and calls it a nonthematic circumspective absorption of the assignments that make up the elements of an equipmental whole (Heidegger 1988). The competent practitioner is able to do several things simultaneously in a competent

manner. In several studies on learning in practical settings, there are similar descriptions of what a competent practitioner is able to do (Nielsen 2007). A characteristic feature of competent practitioners is the ability to multi-task, meaning that their attention is divided among many projects.

Even though Heidegger does not propose a specific theory of learning, he argues that learning can happen through repetition and experience. When learning something new, the learner makes mistakes that provide important learning resources. In Heidegger's perspective, misfits and breakdowns play a significant role in the processes of learning precisely because our understanding is limited in relation to the surrounding world. Disruptions happen constantly when we are doing something in practice (Heidegger 1988, p. 105). In this sense, the surrounding world disrupts our understanding of our environment. By taking a closer look at disruptions, central aspects of shared practice reveal themselves as "un-ready-to-hand." For instance, a situation in which central aspects of material or equipment stand out, are missing, or are in the way can be a disruption. Missing or incorrect equipment is already embedded in the whole of which it is part. Heidegger (1988) speaks of un-ready-to-hand as a way in which "[t]he environment announces itself afresh" (Heidegger 1988, p. 105) or is "lit up" (ibid). The surroundings are not lit up in a solipsistic sense; it is not the person's consciousness that lights up objects. Rather, there is a disruption in the person's understanding of what is happening in the ongoing social practice. This disruption calls for attention and, possibly, discloses new aspects of the surrounding world in the workshop. In this respect, mistakes provide the possibility for learning something new if individuals are open to them.

In Schön's perception, the practitioner's learning process is a method of constructing a new theory of what is happening. The practitioner constructs knowledge-in-practice through reflection-in-practice; from that perspective, reflection-in-action is the dynamic center in the learning process. Schön (1987) compares reflection-in-action to a process of trial and error, but emphasizes that reflection-in-action is not characterized by random trials; rather, that one trial and its outcome set the stage for the next trial (p. 27). Metaphorically speaking, it is a matter of making a succession of experiments (trial and error) in order to construct adequate knowledge-in-practice when solving a particular problem through a multiplicity of experiments with the subject matter that the practitioner comes to understand (Schön 1987).

Schön perceives reflection-in-action as a dialogue carried out between practitioners and their previous knowledge of a phenomenon (knowing-in-action), which does not act concurrently with practitioners' expectations. When a phenomenon does not occur as we expect it to, according to Schön, we ask ourselves: "What is this?" and "What have I been thinking about it?" Our thoughts turn back to the surprising phenomenon and, at the same time, back to themselves (Schön 1987). Schön (1987) uses the example of an architectural designer's reflective conversation with the materials, consisting of the designer speaking aloud when making a sketch of a building. He constantly changes, evaluates, and re-evaluates the sketch, working his way toward a satisfactory solution (Schön 1987). The practitioner constructs knowledge through the conversation with the sketch and the images.

According to Schön, mistakes and misfits play a significant role in the learning process. They are *preconditions* for reflections-in-action. Schön emphasizes that knowing-in-action usually gets us through the day. However, on some occasions, it does not. A familiar routine produces an unexpected result; an error stubbornly resists correction. All experiences contain elements of surprise. Something fails to meet our expectations. In some situations, we may respond to the surprise by reflecting (Schön 1987). According to Schön, mistakes, disruptions, and breakdowns are the dynamic foundation for reflection-in-action. A mistake reveals a new perspective on the problem at hand, which then must be reconsidered and reformulated.

Cross-References

References

Heidegger, M. (1988). *Being and time*. Oxford: Basil Blackwell.

Heidegger, M. (1999). *What is called thinking*. New York: Harper & Row.

Nielsen, K. (2007). Aspects of a practical understanding: Heidegger at the workplace. *Scandinavian Journal of Educational Research, 51*(5), 455–470.

Schön, D. A. (1983). *The reflective practitioner. How professionals think in action*. New York: Basic Books.

Schön, D. A. (1987). *Educating the reflective practitioner – Toward a new design for teaching and learning in the professions*. London: Jossey Bass.

Wittgenstein, L. (1996). *Philosophical investigations*. Oxford: Basil Blackwell.

Learning in Practice and by Experience

Linda Kragelund
National Centre of Competence Development,
The Danish School of Education, Aarhus University,
Copenhagen, NV, Denmark

Synonyms

Clinical placement; Everyday learning; *Internship*; Learning by experience; Learning through working; *Modern apprenticeship*; On-the-job training; *Practicum*; *Vocational learning*; Work experience; Work-based learning

Definition

Learning in Practice is a broad and not clearly defined concept. In spite of that, the essential point of Learning in Practice is that to learn to act in life, we have to practice and train again and again to be capable of performing. This applies no matter what the context is, whether it is at home, at work, or in relation to education, etc. A central point in recent learning theories is that a great deal of our learning takes place during routine actions. The more often we repeat routine actions, the greater the chance we will become experts. We develop expertise in five steps beginning with novice, moving to advanced beginner, then to competent, proficient, and, in some cases, reach the expert stage (Dreyfus and Dreyfus 1986).

The concept of Learning in Practice can be seen from at least three perspectives.

Firstly, Learning in Practice can be seen in relation to everyday learning, which is informal and more or less seems to be incidental. It takes place as we live our everyday lives without being aware of learning. We do our everyday activities such as eating, driving, cooking, interacting with other people, or doing job-related tasks in a taken-for-granted manner. We do not think about how we act in a specific situation because we have handled many similar situations previously and have not learned to critically examine and question our society's traditional norms and rules. It means we have been ▶ primarily socialized to live in the culture we are a part of. We have learned to react automatically to the functions, demands, and expectations our specific everyday life confronts us with. In everyday life, we act according to routine, but sometimes what seems like a routine situation turns out to be nonroutine, either because the situation is slightly different from other situations or because the outcome of the situation is something other than what we expected. Then we have to think or talk with others about another way to handle similar situations. If we change the way we act in a similar situation in the future, there is a scope for learning. A characteristic of everyday life is that it gives us a lot of stimuli. We have to find our own strategies to cope with and act in response to the stimuli in order to emerge as fully functioning, well-adjusted human beings (Heller 1970/1984).

Secondly, Learning in Practice can be seen from the employee's perspective. In this case, Learning in Practice means both informal learning, which employees participate in as part of their everyday life at work (Learning by Experience, Learning through Working), and formal learning in the workplace. Newcomers can, for example, participate in a formal training program at work (Work-Based Learning, On-the-Job Training). The employees can also participate in a program of study in which they use the learning opportunities in their own job or within their own organization.

Thirdly, Learning in Practice can be seen as part of formal education which combines learning at educational institutions and in the workplace. The aim of such education is to combine theoretical learning with supervised practical experience.

Seen from that perspective Learning in Practice has different names, depending on the field where employees are going to work; for example, the term *internship* is used in relation to business education.

Clinical placement is used in the health sciences, *practicum* is used in teacher education, and *vocational learning* is used in Modern Apprenticeship.

As illustrated above, it is possible to distinguish between Learning in Practice in everyday life, for employees and for students. In this article, the focus will be on the latter, and *not* on everyday life or employees. Furthermore, the term *practice* refers to the activities involved in performing work at workplaces.

Learning in Practice for Students can be defined as the learning students undertake in the workplace as part of formal vocational or professional education (Billett 2001). Their position in the workplace is that of a student, not an employee. Learning in Practice is part of the student's preparation for future employment in the sector and is where their education takes place. Learning in Practice is used in education, where there is an alternation between theory and practice. This is the case in vocational education, where students are educated as plumbers, mechanics, or carpenters, and in relation to some professional education, where students are educated to work in a specific profession as occupational therapy, nursing, teaching, etc.

Over the recent years, Learning in Practice has been more regulated and organized to ensure the students a particular learning outcome. Educational institutions and workplaces have been, and are still, improving their cooperation in relation to development of the curriculum, including both theoretical and practical learning outcomes. Those efforts notwithstanding there is still potential for development of systematic approaches to Learning in Practice.

Theoretical Background

The concept of Learning in Practice can be seen from different theoretical points of view. Here, the focus will be on two different viewpoints which can be seen as positioned at opposite ends of the spectrum of views of Learning in Practice.

The concept can be understood from a sociocultural and situated learning perspective; some representatives of this position are Lave and Wenger. Learning in Practice can also be seen from an individual learning perspective and one representative of this position is Jarvis.

Learning in Practice as a concept had been around for many years, but it was reintroduced by Lave and Wenger in 1991 when their book *Situated Learning: Legitimate peripheral participation* was published.

Lave and Wenger see learning as a process of participation in communities of practice. Learning is a situated activity, which has a characteristic process that they call *legitimate peripheral participation*. Participation is the cornerstone in their theory, and participation is a necessity for newcomers (students as well as employees) to be able to gain access to learning situations and to be part of the community of practice. In the beginning, the newcomers' participation is legitimately peripheral. Over time, the newcomers' participation increases gradually in engagement and complexity, and after some time, the newcomers become full members of the community of practice.

In the situated learning perspective, it is the community of practice that learns, and focus on individual learning is absent. A risk with the situated learning perspective is that practice is reproduced rather than developed. That is one way ▶ secondary socialization, in which society and its structures remain unquestioned and unaltered, can take place. The individual "internalizes" the knowledge, values, attitudes, and beliefs of the society. Often, students learn a craft without asking questions and reflecting critically on why tasks are done the way they are. In such cases, practice is reproduced rather than developed.

From Jarvis' point of view, learning is a complex set of processes having different outcomes. It is a process of interaction between individuals and their social environment. It is the person who learns, but they do it in a social context (Jarvis 2006).

Jarvis is of the opinion that education combining theoretical courses with workplace learning helps the learner to be secondarily socialized to the field where they are going to work after their education.

Nevertheless, he also sees it as a risk if students, without questioning, take over norms and rules of a craft or profession. Therefore, he argues that it is important that students are trained to have a critical view of the fields in which they are going to work (Jarvis 2006).

Jarvis also claims that to be able to act, to do job-related tasks, it is important to get ▶ primary experience, which he defines as direct experiences that occur through action and are experienced through the senses. By getting primary experiences, learners are actually in the social situation and impose their own meanings upon them. That is one reason why Learning in Practice

is important for many educational areas. It is not enough to get ▶ secondary experiences, which are a mediated or indirect form of experience that comes through communicative actions. Students getting secondary experiences are not truly engaged in a situation which is communicated to them (Jarvis 2006). Jarvis is aware that learning through imitation and the adapting of role models gained a bad reputation in the days when practical knowledge was not emphasized, maybe because educators at learning institutions and in practice were afraid that it could result in nonreflective practice. Nevertheless, educators at learning institutions and in practice had to rediscover the need for ▶ modern apprenticeship (understood as education which combines theoretical courses at educational institutions and training in the workplace) and mentoring since the apprentice-master and practical educator cannot learn the skills for the students. Learning the skill must be done through the act of doing. In preparing students for occupations, Learning in Practice has become an increasing necessity (Jarvis 2006).

Jarvis encourages teachers at learning institutions and practice educators at workplaces to teach students to become critical reflectors and reflective practitioners. If they become that, there is a chance that they will be capable of developing practice. If not, there is a risk that they are going to reproduce rather than develop practice, and that is not the aim of workplaces in today's learning societies.

Important Scientific Research and Open Questions

Lave's research on craft apprenticeship among Vai and Gola tailors in Liberia from 1973 to 1978 is an important scientific contribution to understanding the concept of Learning in Practice as it applies to everyday life, students, and employees. In her research, Lave focused on the apprenticeship of tailors, and she became aware that learning through ▶ traditional apprenticeship, meaning education without scholastic learning, was a matter of legitimate peripheral participation in a community of practice for the apprentices. She found that the apprentices over time learned to think, argue, act, and behave with more and more competence in relation to the master-craftsmen, who were already able to do what the apprentices had to learn to do. The apprentices were appreciated, but peripheral participants in real-life activities in the field where they

did their education. Over time (5 years), they became full members of the communities of practice. Lave saw that there was no distinction between learning and doing what was learnt. The apprentice tailors' education was characterized by informal and context-bound learning processes. It can, in nonindustrialized societies without learning institutions, be understood as a kind of everyday learning with aims (Lave 1990). After Lave's research in Liberia, she and Wenger developed the theory about situated learning (see above) (Lave and Wenger 1991).

Researchers in many countries have taken on Lave and Wenger's perspective on Learning in Practice. The perspective has been used in relation to research among midwives, naval quartermasters, meat cutters, and nondrinking alcoholics (Lave and Wenger 1991).

Jarvis' research among adult learners has also made an important contribution to the understanding of the concept of Learning in Practice, and he has developed a model for human learning. Jarvis says that his model and concepts related to it have been unfolding over the past 25 years, which is why they change in every new publication written by him. In Jarvis' model of learning, Learning in Practice is one of three ways of learning. The two others are learning through reflection and learning through emotions (Jarvis 2006). As Lave's research and Wenger's and her situated perspective on learning has been the basis for much research, so has Jarvis' research and his individual perspective on learning. His perspective has been used in relation to research about student nurses' learning processes during their clinical placement, teacher education, international health counseling, and leader counseling.

Development of the concept of Learning in Practice is an ongoing challenge because of its diversity in meaning. There is a need to investigate the concept with reference to Learning in Practice in education, combining teaching at learning institutions, and in workplaces, and with the aim to reduce the theory–practice gap in such education. Theoretical teaching has to be followed up and supplemented with Learning in Practice to make the education effective.

Readers are, when they use the concept of Learning in Practice, encouraged to be clear about what they mean by it and write about their understanding and viewpoint of the concept in relevant scholarly journals. That is one way to get closer to a clear definition of Learning in Practice in the future.

Cross-References

- ▶ Apprenticeship Learning in Production Schools
- ▶ Communities of Practice
- ▶ Episodic Learning
- ▶ Experiential Learning Theory
- ▶ Situated Learning
- ▶ Social Learning Theory
- ▶ Workplace Learning

References

Billett, S. (2001). *Learning in the workplace: Strategies for effective practice*. Sydney: Allen & Unwin.

Dreyfus, H., & Dreyfus, S. (1986). *Mind over machine – The power of human intuition and expertise in the era of the computer*. Oxford: Basil Blackwell Ltd.

Heller, A. (1970/1984). *Everyday life*. London: Routledge & Kegan Paul.

Jarvis, P. (2006). *Towards a comprehensive theory of human learning*. London: Routledge Taylor & Francis Group.

Lave, J. (1990). The culture of acquisition and the practice of understanding. In J. W. Stigler, R. A. Shweder, G. Herdt, & G. Herdt (Eds.), *Cultural psychology: Essays on comparative and human development*. Cambridge: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Learning in Robots

- ▶ Robot Learning

Learning in the CHREST Cognitive Architecture

Fernand Gobet[1], Peter C. R. Lane[2]
[1]Department of Psychology, Brunel University, Uxbridge, UK
[2]School of Computer Science, University of Hertfordshire, Hatfield, Hertfordshire, UK

Synonyms

Template theory

Definition

▶ CHREST (Chunk Hierarchy and REtrieval STructures) is a ▶ *cognitive architecture* that closely simulates learning and the ▶ acquisition of expertise in humans. The key features of CHREST include self-organization, an emphasis on ▶ bounded rationality (cognitive limitations), a close link between perception, learning, memory, and decision making, and the use of naturalistic data as input for learning. CHREST has successfully simulated behavior in domains such as the psychology of expertise, the acquisition of language by children, concept formation, and the learning of multiple representations in physics.

Theoretical Background

The use of a *cognitive architecture* (a computational theory applied to several domains) to study learning offers several advantages. First, the similarities between models lead to a consistent and unified theoretical framework being applied to multiple domains. This parsimony strengthens claims that the underlying learning mechanisms are general. Second, well-specified computational models provide the only realistic means for identifying and evaluating major factors in learning from large, noisy and dynamically changing sources of information. Third, the use of computational models enables predictions to be made about the structures that are acquired, rather than simply explaining behavior *post hoc*. The extent to which simulations of actual human behavior are successful can be evaluated by comparing the behavior of the models with that of humans, using measures such as eye movements, reaction times, and types of errors.

CHREST (Gobet et al. 2001; Gobet and Lane 2010) is a cognitive architecture that has been developed to understand the phenomenon of ▶ chunking in multiple domains and in its multiple forms: how chunks are created, stored, retrieved, and used. It is an implementation of the *template theory of expertise* (Gobet and Simon 1996) and derives from an earlier computational theory called EPAM (Elementary Perceiver and Memorizer; Feigenbaum and Simon 1984), which was mostly applied to the understanding of ▶ *verbal learning* (i.e., learning of simple, semantically poor verbal material).

CHREST consists of a number of memories and of mechanisms for interacting with the external environment (see Fig. 1). It postulates two main types of memory store: short-term memories (STMs), which hold information from diverse input modalities and long-term memory (LTM), which holds information

Learning in the CHREST Cognitive Architecture. Fig. 1
Key components of the CHREST architecture

in a *chunking network*. A chunking network is a discrimination network containing nodes (*chunks)* that grows dynamically as a function of the previous states of the system and the inputs from the environment.

The key learning mechanisms are the growth of the chunking network by the addition of nodes, enrichment of these nodes by supplementary information, and creation of links between nodes. A mechanism called *discrimination* creates new nodes and a process called *familiarization* incrementally adds information to existing nodes. Under suitable conditions, a mechanism called *template formation* creates ▶ schemata (templates) from existing chunks. This mechanism uses both stable information (for creating the *core* of the template) and variable information (for creating its *slots*). Templates are essential for explaining how experts can recall briefly presented positions very well, even with a presentation time as short as 1 or 2 s. They are also important for explaining how experts carry out planning – that is, search at a level higher than that of local actions. Other mechanisms create

a number of *lateral links* (similarity links, production links, equivalence links, and generative links) between nodes. All these mechanisms are carried out automatically when a new scene is perceived. In simulations of the development of expertise, learning is carried out autonomously by scanning a large number of domain-representative stimuli (e.g., chess games played by grandmasters). In simulations of language acquisition, large corpora of child-directed speech are used.

With CHREST, cognition is the product of the interaction of several processes, including learning, memory retrieval, and decision-making. Knowledge directs attention and perception, and, in turn, perception directs the learning of new knowledge. As such, CHREST is in line with de Groot and Gobet's (1996) axiom that "cognition is perception." Another critical emphasis of the architecture is that human cognition is characterized by *bounded rationality*. The behavior of CHREST is constrained by several cognitive limits, such as limited capacity of visual short-term memory (assumed to be three chunks), the relatively slow rate at which new elements can be learned (assumed to be 10 s for creating a new chunk), and the time it takes to transfer information from LTM to STM (50 ms). All cognitive operations have a cost, which is measured by approximate but fixed time parameters. These parameters enable a close comparison to be carried out between human behavior and simulated behavior. While CHREST's structures and mechanisms are rather simple, it draws its explanatory power from the interaction of these mechanisms with the environment. As such, it is a complex dynamical system able to account for a wide range of behaviors.

A considerable number of simulations have been carried out with chess, the first domain of application of CHREST (Gobet et al. 2001). These include the eye movements of chess novices and Masters when seeing a position for the first time; recall performance in numerous memory experiments where chess boards have been distorted in various ways or where the presentation mode has been manipulated (the measures include the percentage correct, the number and type of errors, and the grouping of the piece placements); and evolution of look-ahead search as a function of skill. Most of these phenomena are primarily explained by the acquisition of a large number of chunks (more than 300,000 for simulating Grandmaster level) and templates.

Phenomena in other domains of expertise have been investigated as well. Simulations with the African game of Awele indicated that CHREST can play at a fairly good level by sheer pattern recognition, while at the same time simulating several phenomena about the development of memory for Awele positions. Similarly, simulations about memory for computer programs replicated differences of recall as a function of the level of meaningfulness of the material. Finally, simulations on multiple representations in physics (basic material on electricity) focused on the acquisition of multiple diagrammatic representations and the use of these representations to solve new problems.

Beyond expertise, CHREST has been used to account for a number of phenomena in implicit learning, verbal learning, and concept formation. The presence of different perceptual modalities in the architecture and the provision for eye movements were exploited for exploring the role of expectations in cognition. Humans more readily direct attention to objects when they are placed in a likely location than in an unlikely location. With CHREST, perception is modeled as a cycle, with the eye guided by long-term memory knowledge to look at the parts of the scene where beneficial information is expected to be present. To explore the role of expectations in cognition, CHREST encoded information both in the visual and verbal modalities. The interaction between the two sources of information produced various measurable effects, such as the result that prior expectations improve speed and accuracy of recognition with partially obscured stimuli.

Most of the applications discussed so far dealt primarily with visual information. Two other strands of research on how children acquire their first language have investigated linguistic information. In the CHREST framework, first language acquisition can be seen as a kind of expertise, where children master their native language through the implicit acquisition of a great number of chunks. Simulations of the acquisition of vocabulary (Jones et al. 2007) focused on the mechanisms whereby information in short-term memory interacts with information in long-term memory – a topic that had been surprisingly neglected in the literature. CHREST provides a natural mechanism for this: the creation and use of chunks. Simulations of the non-word repetition task obtained an excellent fit with the human data, not only with normally developing children but also with children with specific language impairment (SLI).

Another variant of CHREST, known as MOSAIC (Model of Syntax Acquisition in Children), has focused on the acquisition of syntactic categories, and more specifically the "optional infinitive" phenomenon. The optional infinitive phenomenon concerns typical errors made by children between 2 and 3 years of age in their use of finite verb forms (for example, *goes*, *went*) and nonfinite verb forms (for example, *go*, *going*). For example, a child would say "her do it" instead of "she does it." In this example, not only is the verb misused, but also the pronoun. MOSAIC has successfully simulated several aspects of the optional infinitive phenomenon (Freudenthal et al. 2007), not only in English but also in Dutch, German, French, Spanish, and Q'anjobalan (a Mayan language). The success of the simulations can be explained by three factors that interact in interesting ways: the model carries out rote learning; it creates and uses generative links; and it captures the statistical structure of the input. Together, four features make MOSAIC unique in our understanding of language development. First, the input given to the model is naturalistic (utterances spoken by parents interacting with their children in a play setting). Second, MOSAIC provides detailed simulations of the pattern of errors and their developmental trend. Third, the same model is used for simulating different phenomena (i.e., it is not the case that different phenomena are simulated by different models). Finally, simulations have been made in several languages with the same model – the maternal input used for training was the only thing that changed.

Important Scientific Research and Open Questions

CHREST, a symbolic system integrating perception with learning, captures many characteristics of high-level processing in human cognition while also accounting for lower-level aspects such as the details of eye fixations. The two-way interaction between perception and cognition was paramount in accounting for empirical phenomena, just like the incremental learning carried out by the chunking networks. Another important aspect of this modeling approach concerns the strong constraints inherent to the architecture, such as slow learning times or the limited capacity of the short-term memories. In this respect,

the research with CHREST takes bounded rationality very seriously indeed.

A number of issues are still unanswered with the CHREST research. The role of strategies has sometimes been investigated within this framework, but we still know little about how they mesh with perceptual chunking. Although progress has been made in the last years about the neurobiological substrate of chunking, there are still many unknowns. In addition, the mapping between CHREST's components and brain areas still remains to be done. More generally, it is unknown whether aspects of CHREST – in particular the chunking mechanisms – could be extended to nonhuman primates and other animals. Another intriguing avenue for research that has remained untouched is the possibility of linking CHREST with a mobile robot. How would the presence of sensors and effectors affect what is being learned by CHREST? Finally, to what extent can a theory based on chunking mechanisms lay any claims toward being a successful unified theory of cognition?

Cross-References

► Bounded Rationality and Learning
► Chunking Mechanisms and Learning
► Decision Making and Learning
► Development of Expertise
► Schema

References

de Groot, A. D., & Gobet, F. (1996). *Perception and memory in chess: Heuristics of the professional eye*. Assen: Van Gorcum.

Feigenbaum, E. A., & Simon, H. A. (1984). EPAM-like models of recognition and learning. *Cognitive Science, 8*, 305–336.

Freudenthal, D., Pine, J. M., Aguado-Orea, J., & Gobet, F. (2007). Modelling the developmental patterning of finiteness marking in English, Dutch, German and Spanish using MOSAIC. *Cognitive Science, 31*, 311–341.

Gobet, F., & Lane, P. C. R. (2010). The CHREST architecture of cognition: The role of perception in general intelligence. In E. Baum, M. Hutter, & E. Kitzelmann (Eds.), *Proceedings of the third conference on artificial general intelligence* (pp. 7–12). Amsterdam: Atlantis Press.

Gobet, F., & Simon, H. A. (1996). Templates in chess memory: A mechanism for recalling several boards. *Cognitive Psychology, 31*, 1–40.

Gobet, F., Lane, P. C. R., Croker, S. J., Cheng, P. C.-H., Jones, G., Oliver, I., & Pine, J. M. (2001). Chunking mechanisms in human learning. *Trends in Cognitive Sciences, 5*, 236–243.

Jones, G., Gobet, F., & Pine, J. M. (2007). Linking working memory and long-term memory: A computational model of the learning of new words. *Developmental Science, 10*, 853–873.

Learning in the Social Context

Som Naidu[1], Danny R. Bedgood, Jr[2]
[1]Learning & Teaching Quality Enhancement and Evaluation Services, Charles Sturt University, Albury, NSW, Australia
[2]School of Agricultural and Wine Sciences, Charles Sturt University, Wagga Wagga, NSW, Australia

Synonyms

Collaborative learning; Cooperative learning; Learning in context; Learning in groups; Learning in the workplace; Social cognition; Social constructivism; Social learning theory

Definition

Learning in the social context refers to all learning that occurs in and among groups of people. These groups may be made up of students in a class, employees at a worksite, or volunteering community workers at a village fair. They may comprise members with uniform or diverse social, political, cultural, linguistic, and educational backgrounds. They can be informal or formal, large or small, and exist for any length of time. Such groups may meet occasionally or regularly, anywhere and at anytime, and in either face-to-face or online, or in a combination of modes. Learning activities in such social contexts may be cooperative, collaborative, planned or unplanned, and they can be led by one or more individuals, or be completely self-organizing.

Theoretical Background

Humans can learn in a variety of ways, and with or without structure and guidance. However, one of the ways in which humans learn most efficiently and effectively is when learning is situated within the social context. The social context comprises other people as well as artifacts such as learning resources. Together they provide learners with the anchors and scaffolding that they need for meaning and understanding to take place most efficiently and effectively (see Naidu et al. 2007).

The basic premise of this situated cognitive view of learning is that unlike information, knowledge does not exist in a vacuum or outside of its context. Knowledge refers to our individual and collective

understanding and interpretation of information and real-world phenomena. It is best captured in the experiences of the social group, and often articulated in the stories of practitioners and group members.

According to this situated cognitive perspective, knowledge is most efficiently and effectively developed within the social context rather than outside it (see Brown et al. 1989). In their seminal article, "*Situated cognition and the culture of learning,*" Brown, Collins, and Duguid argue that the acquisition of knowledge is an outcome of the interaction among learning activities, the context, and the culture within which it occurs.

As such, learning is the result of a great deal of argumentation within the individual, and between the individual and the social group about what constitutes knowledge in that context and the community. In the end, however, individuals will construct their own understanding of various bits and pieces of information and phenomena in light of their own perceptions and belief systems (see Vygotsky 1978).

This view of learning does *not* mean that different people understand different things such as medical practices and procedures (i.e., what), differently. It means that different people *come to* understand different things differently, depending upon their readiness for learning, and which includes our personal attributes such as prior knowledge and experiences, motivations, approaches to learning, and learning styles.

When this is the case, our understanding of what is known about the *what* (such as medical practices and procedures) is the result of the set of experiences of the social group. In this manner knowledge and understanding is socially constructed and owned (see Bandura 1977). It is the sum total of the accumulated wisdom of the social group about the subject matter, and each person's understanding of a set of facts, principles, and procedures is the result of their own interpretation of the experiences of other members of the social group and the larger community (see Lave 1991; Wenger 1998).

Important Scientific Research and Open Questions

Misconceptions about learning in the social context arise from people's perceptions of what constitutes knowledge and understanding. Those who see knowledge as a set of facts, principles, and procedures that resides out of context, in artifacts such as repositories, textbooks, and manuals, would argue that this kind of knowledge can be learned by anyone, usually with tried and tested methods of study. Proponents of this view would argue that knowledge such as that about medical procedures and air traffic control has to be understood by everyone in the same way.

On the other hand, those who see knowledge as the collective experience and wisdom of a group of people about various facts, procedures, and principles would argue that this kind of knowledge is embedded in its social context and that it can be understood only by meaningful interaction with it within its context and culture.

Proponents of the situated cognitive view of learning would argue that those who attempt to acquire knowledge outside of its context and culture will find it more difficult to apply it to novel situations. While those who acquire knowledge *within* its social context, will possess a much deeper understanding of its foundations and can more easily apply this knowledge to solve complex and novel problems within real contexts.

The important research question in this regard is the *nature* and *extent* of the role of context in promoting not only learning achievement, but also meaningful learning, and expert performance. How, and to what extent, does context support learning, and how do we know what works, when, and how?

Cross-References

► Shared Cognition
► Situated Learning
► Social Construction of Learning
► Social Learning
► Socio-emotional Aspects of Learning

References

Bandura, A. (1977). *Social learning theory.* Englewood Cliffs: Prentice-Hall.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Lave, J. (1991). Situating learning in communities of practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 63–82). Washington, DC: American Psychological Association.

Naidu, S., Menon, M., Gunawardena, C., Lekamge, D., & Karunanayaka, S. (2007). How scenario-based learning can engender reflective practice in online and distance education. In M. Spector (Ed.), *Finding your online voice: Stories told by experienced online educators* (pp. 53–72). Mahwah: Lawrence Erlbaum.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes, chapter 4. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Internalization of higher psychological functions* (pp. 52–57). Cambridge, MA: Harvard University Press.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity.* Cambridge: Cambridge University Press.

Learning in the Vocational and Educational System

► Apprenticeship-Based Learning in Production Schools

Learning in the Workplace

► Learning in the Social Context

Learning Interventions

► Research of Learning Support and Retention

Learning Journal

► Self-Reflecting Methods of Learning Research

Learning Knockouts

► Learning Mutants

Learning Management System

DIRK IFENTHALER
Institut für Erziehungswissenschaft, Albert-Ludwigs-University Freiburg, Freiburg, Germany

Synonyms
Learning platform; LMS

Definition
Learning management systems (LMS) integrate interactive learning environments and administration and facilitate customized online instructional materials. An LMS is a web-based software application using a database on which various types of information are stored. Comprehensive drag-and-drop tools enable instructors to easily create their individual online courses. Administration of instructors, users, courses, and content is centralized and automated within an LMS. More than 200 different commercial and open source LMS products are currently available.

Theoretical Background
The rapid and substantial introduction of information and communication technologies (ICT) generates an ever-growing amount of information which is rapidly distributed and widely available at any time and any place. The general proliferation of computer-based information and communication technologies is irreversible, and computers now play an important role in human learning in everyday life as well as at educational institutions. There is widespread agreement among educational theorists on the point that educational applications of modern ICT can be made more effective when they are embedded in *multimedia learning environments* created to enable productive learning. Learning environments should be designed to enable learners to explore them with various amounts of guidance and construct knowledge and develop problem-solving methods independently (Ifenthaler 2009). The key to success is seen not so much in how the information is presented as in how well the learners can manipulate the different *tools* available in the multimedia learning environment on their own. Extensive use of a computer as a *tool* for solving problems can help learners to concentrate on understanding and solving problems rather than the finished product or the acquisition of declarative knowledge and can awaken their curiosity and creativity. Indeed, when one considers that modern computers can represent all forms of information and knowledge needed for learning and problem solving, the current state of computer technology seems to make the tedious process of integrating traditional media (such as texts, graphics, video) technically superfluous and obsolete. Moreover, recent developments in the area of interactive software provide unique possibilities for creating virtual learning environments

and modeling complex systems without professional guidance. The options for independent development of interactive environments are manifold, and the graphical capabilities of new software programs include exciting animations and simulations of highly complex processes. Last but not least, everything is comparatively inexpensive and thus readily available to the broader public. LMS is a prime example for these developments.

Comprehensive characteristics of an LMS include the management and administration of courses, authors, learners, and instructors and involve several possibilities to circulate important information, change access permissions, and give them rights to use certain functions of the LMS. Authoring tools help instructors and course creators by developing courses, content, and assignments. Numerous evaluation and diagnostic features help to asses and analyze the student's knowledge, provide examples for feedback, and help instructors with grading of students' assignments. Additionally, communication via chat, forums, and email connects all users of an LMS (e.g., instructors and students; authors and instructors; authors and administrators, etc.). By providing multiple language versions and implemented translation functions, a worldwide networked learning can be realized with minimal effort. Personal security functions of LMS typically include passwords and encryption.

LMS were developed to support learning in several ways (Black et al. 2007). There are several common features which are included in various LMS (Cole 2005): The feature *assignment* enables instructors to provide written feedback or a grade to the learner on his or her online submission. Implementation of *chat* features allows real-time synchronous discussion. Using *resources* supports uploading files for distributing among learners (e.g., text documents, spreadsheets, slides, sound, graphic, or video). The *forum* feature allows asynchronous discussions among learners and the instructor. Creating a list of definitions is realized within a *glossary*. The feature *journal* enables learners to reflect on a particular topic. Entries within the journal can be edited and refined over time. Delivering content in a flexible and interactive way is realized with the feature *lesson*. This feature even includes grading as well as additional questions and tasks. The *quiz* feature allows the instructor to design a set of quiz tests. *Wiki* enables authoring documents collectively in a simple markup language. Using a *workshop* feature gives learners access to all available projects in a number of

ways. All the above described features can be implemented and customized by the course creator with simple drag-and-drop functions. Various control functions help instructors to track the individual learning processes of all enrolled learners.

New Developments in LMS include the implementation of Shareable Content Object Reference Model (SCORM). SCORM contains guidelines for interaction between learner and instructor, among multiple learners, and across multiple systems (Sampson and Karampiperis 2006). Other developments include the continued expansion of existing features and the introduction of additional features.

Important Scientific Research and Open Questions

More than 200 different commercial and open source LMS products (e.g., Blackboard, eCollege, Moodle, Sakai, WebCT) are currently available. Falvo and Johnson (2007) identified the most popular LMS used at colleges and universities in the United States. Based upon a random sample of 100 institutions they report that the most frequently used LMS were Blackboard (www.blackboard.com) and WebCT (www.webct. com). However, besides these studies, more research is needed to investigate many critical questions about online instruction (Falvo and Johnson 2007). Accordingly, the technological progressions of LMS offer new opportunities for course designers, instructors, and students. However, the quick introduction of LMS into almost every university and organization as a teaching, learning, and management tool (see Falvo and Johnson 2007) was not accompanied by a precise investigation of these technology-based systems from an instructional point of view (Ifenthaler 2008).

Effectivity of LMS has been studied in several research projects. Coates, James, and Baldwin (2005) present a critical examination of LMS on teaching and learning in universities. Potential impacts on teaching practices, student engagement, and on the nature of academic work are critically examined. Klobas and McGill (2010) report on the role of student and instructor involvement in LMS success. Findings show that the more students are involved in an LMS environment, the stronger the reported benefits of students are. Additionally, instructor involvement contributes to student benefits by affecting the information quality students will use. Furthermore,

studies report relationships between LMS quality and student satisfaction (e.g., Roca et al. 2006).

In a recent study, it is argued that the application of LMS means a regression with regard to the design of online learning and many available features are hardly used at all (Ifenthaler 2008). Although LMS's such as Moodle have the technological and instructional potential to support a wide range of learning activities, such as exploring, constructing, and manipulating models, solving authentic problems of the world, or articulating and discussing individual ideas, they are simply used for sharing documents. Therefore, it seems to be necessary to provide a taxonomy of the instructional value of the available features within the LMS. Being aware of this instructional regression, a taxonomy of common LMS features is required (see Ifenthaler 2008). The LMS taxonomy includes a definition of the available LMS features, the key purpose, benefits for learning and teaching, and a guideline for course developers and instructors. However, further research studies are needed to validate such an LMS taxonomy. Using all of the available features of an LMS will not necessarily improve the learning process, an aspect which will be investigated in future research projects.

Cross-References
▶ Blended Learning
▶ Collaborative Learning
▶ Computer-Based Learning
▶ eLearning
▶ Integrated Learning Systems
▶ Online Learning

References

Black, E. W., Beck, D., Dawson, K., Jinks, S., & DiPietro, M. (2007). The other side of the LMS: Considering implementation and use in the adoption of an LMS in online and blended learning environments. *TechTrends, 51*(2), 35–53.

Coates, H., James, R., & Baldwin, G. (2005). A critical examination of the effects of learning management systems on university teaching and learning. *Tertiary Education and Management, 11*(1), 19–36. doi:10.1007/s11233-004-3567-9.

Cole, J. (2005). *Using Moodle: Teaching with the popular open source management system*. London: O'Reilly Community Press.

Falvo, D. A., & Johnson, B. F. (2007). The use of learning management systems in the United States. *TechTrends, 51*(2), 40–45.

Ifenthaler, D. (2008). Implementation of web-enhanced features for successful teaching and learning. The utility of technological progressions of learning management systems. In M. R. Simonson (Ed.), *Annual proceedings of selected research and development papers presented at the national convention of the Association for Educational Communications and Technology (31st, Orlando, FL, 2008)* (Vol. 1, pp. 134–146). Bloomington: AECT.

Ifenthaler, D. (2009). Using a causal model for the design and development of a simulation game for teacher education. *Technology, Instruction, Cognition and Learning, 6*(3), 193–212.

Klobas, J. E., & McGill, T. J. (2010). The role of involvement in learning management system success. *Journal of Computing in Higher Education, 22*(2), 114–134. doi:10.1007/s12528-010-9032-5.

Roca, J. C., Chiu, C.-M., & Martinez, F. J. (2006). Understanding e-learning continuance intention: An extension of the technology acceptance model. *International Journal of Human Computer Studies, 64*(8), 683–696.

Sampson, D. G., & Karampiperis, P. (2006). Towards next generation activity-based learning systems. *International Journal on E-Learning, 5*(1), 129–149.

Learning Mechanism

▶ Associative Learning of Pictures and Words

Learning Mechanisms of Depression

IDA MOADAB[1], DON M. TUCKER[1,2]
[1]Department of Psychology, University of Oregon, Eugene, OR, USA
[2]Electrical Geodesics, Inc, Eugene, OR, USA

Synonyms

Acquisition of depression; Mechanisms in human learning

Definition

Learning mechanisms are patterns or frameworks in which learning is processed by the brain and how a person subsequently behaves consistently.

Depression is a mental disorder that is associated with depressed mood, loss of interest or pleasure, feelings of guilt or low self-worth, low energy, and poor concentration. These problems are learned but can become chronic or recurrent and lead to substantial impairments in an individual's learning.

Theoretical Background

The etiology of depression has been described from a number of perspectives that are not well integrated. By focusing on common mechanisms that bridge different models, a more cohesive conceptualization emerges. After summarizing modern behaviorist and cognitive theories of depression, we propose that expectancy generation and frustration theory integrate these learning models. We will then describe research suggesting that there are individual differences that promote differential risk for developing depression, and how these biological and learning models converge.

Current behavioral models of depression propose that depression results from problems in an individual's interaction with the environment (Martell et al. 2001). An individual with depression rarely engages in behaviors that are positively reinforced. They may not learn to take actions that result in positive consequences and potentially rewarding experiences. Instead, behaviors are maintained through negative reinforcement: individuals with depression are primarily motivated to escape or withdraw from aversive stimuli. This pattern of interaction (responding to potential aversives with withdrawal and avoidance) influences the individual's observations about the environment. Attention is attuned for potentially harmful events to be avoided and rarely focused on approaching possible rewards. Because behaviors are aimed at alleviating pain and feelings of depression, the person does not develop a behavioral repertoire that supports contact with reinforcing events. Habits are formed to avoid and escape from both internally and externally aversive events as the primary motivation.

Cognitive accounts of depression focus on the cognitive antecedents and consequences of depressed individuals' narrowed repertoire. Perception and interpretation of experience is seen as an active process, and individuals' cognitions represent a synthesis of how they appraise internal and external stimuli (Beck et al. 1979). Individuals with depression are thought to view themselves, their future, and their current experience in negative ways. They attribute unpleasant experiences to defects in themselves, interpret present experiences in inherently negative ways, and anticipate hardships and obstacles in the future. From this perspective, individuals with depression restrict their behaviors as a consequence of their negative cognitions. Because they expect negative outcomes, they choose not to act. Cognitive theory also asserts that individuals with depression have formed schemas that result in filtering out information that does not fit their negative views. They are unable to view events objectively, attending to and interpreting events through stable negative cognitive patterns. They consistently interpret events in distorted ways that fit their negative view of themselves, the world, and the ongoing experience (Beck et al. 1979).

To bring together the models described above, it may be useful to focus on the learning mechanisms associated with the emergence of depression. Both theories propose that an individual learns to withdraw from situations that elicit emotional discomfort. How does this learning occur? Research suggests that *predictive processing* represents a fundamental neural function (Bubic et al. 2010). Making predictions and generating expectancies is an essential capacity given the level of uncertainty always present in the environment. It allows individuals to make predictions about what is expected next based on previous experience instead of simply reacting once all the information is processed (Bubic et al. 2010). However, if the predictive process always accesses information about negative expectancies, an individual may learn to think and behave in ways that produce vulnerability for depression.

Insights into prediction and expectancy generation can be gleaned from failures to traditional associative learning models. In traditional Pavlovian associative learning, a neutral stimulus is paired with a biologically relevant, unconditioned stimulus (US) that elicits a reflexive or unconditioned response (UR). As a result of this pairing, the previously neutral stimulus becomes a conditioned stimulus (CS), which can on its own now evoke a conditioned response (CR). Pavlov argued that the conditioned reflex developed based on an associate between the CS and US. This model proved to be insufficient to describe many learning situations. Examples from animal learning suggest that a *cognitive representation* or *expectancy* of a stimulus plays an active role in learning.

Two examples in particular demonstrate the role of expectancy and cognitive representations in associative learning. When an animal has learned an association between a conditioned and unconditioned stimulus, it will be unable to learn to associate a second

conditioned stimulus if presented simultaneously with the first. The acquisition of learning the second stimulus is blocked by the predictive nature of the already conditioned stimulus. This is called *blocking*: the new cue is uninformative, so even though the unconditioned stimulus is paired with the new stimulus, this associate remains unlearned. Similarly, *latent inhibition* refers to an inability to form an association with a stimulus that the animal has had previous exposure to without any consequence. Because previous learning has suggested that the stimulus is uninformative, the animal uses this knowledge and will disregard it, not learning a new association (Tucker and Luu 2007; Cardinal et al. 2002).

Blocking and latent inhibition effects demonstrate the importance of the cognitive representation that goes along with the stimuli that are being learned. It is not simply that a neutral stimulus is being associated with the unconditioned stimulus. Rather, the predictive nature of the previously neutral stimuli is being learned, so cues that are not predictive are not conditioned. An animal judges and represents the value of something in the world, and responds accordingly (Tucker and Luu 2007; Cardinal et al. 2002).

Similarly, instrumental conditioning provides evidence for a less than straightforward account of learning associations between stimuli and responses. In instrumental learning, a contingency is arranged between the animal's behavior and a reinforcing outcome. By rewarding the behavior, instrumental conditioning is thought to strengthen the association between the stimuli and a particular response. The *negative contrast effect* provides one example of a more complicated relationship between a stimulus and an instrumental behavior. If an animal has been trained to expect a high quality reward by performing an action, when a lower quality reward is provided, the animal will greatly decrease responding to the less reinforcing stimulus (Cardinal et al. 2002). Being given a reward when expecting something of higher quality is actually viewed as aversive. The contingency is not simply between a behavior and a reinforcer, but between a behavior and a certain affective experience elicited by the reinforcer. This suggests that the representation in instrumental contingency is not only between an action and a particular outcome, but also a representation of the *affective expectancy* that comes with the outcome (Tucker and Luu 2007).

Expectations thus result in forming *affective* associations as well as the specific associations between stimuli and responses. For example, fear will be associated with a sound when it is paired with foot shock, and the anticipation of reward is paired with lever pressing when acting to obtain a reinforcer. Similarly, when an animal expects a reward of a certain value and does not receive it (an event called *surprising nonreward*), a new negative cognitive and affective representation of the stimulus is formed (Amsel 1962). *Frustration theory* provides a model for how surprising nonreward drives new learning and new behaviors, and provides a model for the cognitions and behaviors that make an individual vulnerable to depression that may be learned.

As described above, *surprising nonreward* refers to the omission, reduction in magnitude, or quality degradation of an appetitive reinforcer (Papini 2003). In response to surprising nonreward, frustration theory suggests that there are important learning consequences. First, surprising nonreward results in a change in the internal state. Expecting reinforcement, the animal instead experiences something akin to frustration, disappointment, or anxiety. The negative emotional tone then *becomes* an aversive reinforcer. The stimulus that was paired with only an appetitive reinforcer previously now also triggers an expectation of aversive affect, resulting in interference with the animal's approach behaviors that once resulted in reward. If the action is still rewarded on some trials, however, the animal will develop a tolerance to the aversive affect (and to the surprising nonreward), and actually *increase* persistence for the possibility of reward. The stimulus will become ambiguous, activating opposing expectations of reward and frustration, inducing an approach-avoidance conflict. This helps explain why intermittent reinforcement is more resistant to extinction than continuous reinforcement. Any kind of reward inconsistency actually increases persistence and increases the time to extinction (Papini 2003).

Importantly, if the appetitive reinforcer is removed altogether, the behavior will be suppressed. There is a loss of reward expectancy, but continued pairing of frustration with the stimulus. The acquisition of frustration and fear will be more firmly associated with the stimulus. As a result, there will be a decrement in approach behavior and increased engagement in withdrawal behavior to escape from the aversive

stimulus. The new learning about the aversive quality of the stimulus may even be generalized to other similar stimuli, such that there may be withdrawal motivations beyond just the specific stimulus that was paired with surprising nonreward. New stimuli that are similar may be met with withdrawal as well (Tucker and Luu 2007).

Frustration theory helps explain the learning mechanisms that increase risk for developing depression. Episodes of depression are often triggered by life stressors, which may be viewed as events of surprising nonreward. The loss of a relationship, the death of a loved one, the loss of a job, or similar types of life stressors often precede the emergence of depression. With functional coping, an individual could seek out social support and make contact with other reinforcers. The event would be viewed in isolation, and expectancies about other events would not be altered. While painful and distressing, the difficult life event would not lead to changes in reward expectancies or internal representations more generally. However, if the triggered negative affect generalized to other contexts, resulted in negative expectancies about the self and other events, and new reinforcers are not available or sought out, the individual may begin to think and act in ways that result in depression. This may be similar to descriptions of "learned helplessness," such that an individual no longer expects positive experiences or alleviation from pain and so does not act to elicit reinforcers (Tucker and Luu 2007). Global loss of reward expectancy and vigilance for aversives could lead to the changes in cognitions described in the cognitive theory, and alterations in behaviors to avoid distress stressed in behavioral theory. If these changes become stable ways of interpreting reality, they could result in an increased risk for experiencing depression.

Important Scientific Research and Open Questions

Why do some individuals respond to stressful life events (and instances of surprising nonreward) by creating global negative expectancies, decreasing access to rewards, and increasing withdrawal from potential aversives? Research suggests that certain individuals are more vulnerable to depression than others. Temperament research demonstrates that individual differences in children's responses to novel stimuli can be predictive of emotional problems into adolescence and adulthood (Fox 2004). Two independent biobehavioral systems are thought to be involved in responses to novelty (Rothbart and Bates 2006). The *avoidance system* is involved in attending to potential threats and disengaging from the environment in response to perceived dangers. In contrast, *the approach system* involves moving toward new experiences in pursuit of rewards. Individuals *high in avoidance* respond to novel situations with greater levels of vigilance and withdraw from unfamiliar people or objects. More avoidant children have a tendency toward discomfort, fear, low soothability, and respond to novelty with higher physiological reactivity (Fox et al. 2005). Similarly, individuals *low in approach* may be less likely to make contact with reinforcers and experience fewer rewards, producing fewer positive expectancies when interacting with the environment.

A predisposition toward lower levels of approach and higher levels of avoidance may produce biases in information processing and behavior that together increases risk for developing depression. In response to surprising nonreward, individuals higher in avoidance are biased to respond to threat and withdraw from the negative experience. They may increase vigilance for threats and aversive experiences generally. An individual low in approach would be less likely to approach new reinforcers that could replace the lost reward. Together, these tendencies promote learning to attend to aversives and forgo contact with rewards.

Cross-References

▶ Conditioned Suppression
▶ Discrimination Learning Model
▶ Fear Conditioning in Animals and Humans
▶ Group Schema Therapy
▶ Metaphor Therapy

References

Amsel, A. (1962). Frustrative nonreward in partial reinforcement and discrimination learning: Some recent history and a theoretical extension. *Psychological Review, 69*, 306–328.

Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1979). *Cognitive therapy of depression*. New York: Guilford.

Bubic, A., von Cramon, D. Y., & Schubotz, R. I. (2010). Prediction, cognition, and the brain. *Frontiers in Human Neuroscience, 4*, 1–15.

Cardinal, R. N., Parkinson, J. A., Hall, J., & Everitt, B. J. (2002). Emotion and motivation: The role of the amygdala, ventral striatum, and

prefrontal cortex. *Neuroscience and Biobehavioral Reviews, 26*, 321–352.

Fox, N. A. (2004). Temperament and early experience form social behavior. *Annals of the New York Academy of Sciences, 1038*, 171–178.

Fox, N. A., Henderson, H. A., Marshall, P. J., Nichols, K. E., & Ghera, M. M. (2005). Behavioral inhibition: Linking biology and behavior within a developmental framework. *Annual Review of Psychology, 56*, 235–262.

Martell, C. R., Addis, M. E., & Jacobson, N. S. (2001). *Depression in context: Strategies for guided action*. New York: W.W. Norton.

Papini, M. R. (2003). Comparative psychology of surprising nonreward. *Brain, Behavior and Evolution, 62*, 83–95.

Rothbart, M. K., & Bates, J. E. (2006). Temperament. In W. Damon, R. Lerner, & N. Eisenberg (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (pp. 37–86). New York: Wiley.

Tucker, D. M., & Luu, P. (2007). Neurophysiology of motivated learning: Adaptive mechanisms underlying cognitive bias in depression. *Cognitive Therapy and Research, 31*, 189–209.

Learning Metaphors

PAUL J. HAGER
University of Technology, Sydney, Broadway, NSW, Australia

Synonyms

Learning concepts; Learning perspectives

Definition

It is a surprising, though not a widely noted, fact that whenever humans talk or think about learning they often resort to metaphors. The *Concise Oxford Dictionary* defines metaphor as the application of a name or descriptive term to an object to which it is not literally applicable, such as "a glaring error" or "abysmal ignorance." Thus, a metaphor suggests an analogy (i.e., likeness in certain respects) between two very different sorts of things. An error is not literally glaring in that it is normally not shining dazzlingly or disagreeably, but it may be like a glaring object in being prominent or difficult to miss. It is worth noting that though a metaphor posits at least one respect in which two disparate things are alike, there will be many other respects in which they are not alike. This means that

uncritical deployment of metaphors can mislead people who assume that the likenesses are more extensive than is actually the case.

This entry will consider diverse metaphors that have been used to depict learning and the ways that many of them have shaped public understandings of what learning is. It will become apparent that taking the metaphorical to be literal has resulted in widespread misperceptions about the nature of learning.

Theoretical Background

Educational thought is awash with learning metaphors. For instance, Plato's *Theatetus* presents learning as analogous to childbirth, with the teacher akin to a midwife. The likeness of learning to childbirth is that both make external something that was latent within a person. For Plato, learning is a matter of bringing to conscious attention what is already latent in the mind. The metaphor may be taken to suggest further that the bringing of knowledge to consciousness may well be a difficult and painful process.

In contrast with Plato's view that learning comes from within the learner, prominent nineteenth century theories of learning employed the metaphor of learning being akin to external substances being incorporated into the learner's mind. An example is Herbart's theory of apperception (Curtis and Boultwood 1970) according to which newly presented ideas are assimilated or not depending on how well they relate to existing apperception masses in the learner's mind. Ideas that are assimilated are thought of as expanding the apperception masses to which they belong. Apperception masses are viewed as sinking below the threshold of consciousness until recalled to the surface by the next relevant idea that enters the learner's mind. Teaching becomes a matter of arranging the presentation of suitable sequences of ideas selected so as to assimilate readily into the learner's existing apperception masses. Overlying Herbart's outside-in metaphor is a second, physical, metaphor that likens the mind to a mental reservoir in which floating massed clumps of learned ideas operate according to hydraulic principles. It might be interesting to see what misconceptions of learning results from this metaphor.

Botanic metaphors that viewed education and learning as akin to the cultivation of plants were also widely favored in the eighteenth and nineteenth centuries. Prominent advocates of such metaphors included

Pestalozzi, Rousseau, and Froebel (Curtis and Boultwood 1970). These botanic metaphors suggest a middle course between the views of Plato and Herbart. As with Plato, these metaphors have an inside-out dimension, since learning involves bringing to actuality something that is latent in the learner (innate biological potentialities). This is accompanied by an outside-in dimension since, just as plant growth is contingent upon suitable conditions and resources (water, soil, nutrition, etc.), so the right external conditions are required if learning is to flourish.

Although the kinds of metaphors for understanding learning that have been discussed so far exhibit significant differences, they all share one crucial feature in that they all encourage the further assumption that learning is a thing or substance of some kind. As Bowen and Hobson observe: "To this day we find ourselves using physical metaphors to explain what are still obscure mental processes: our mind conceives, we get fertile thoughts; in universities we deliberately call some kinds of classes 'seminars'" (Bowen and Hobson 1974, p. 26).

This assumption that learning is akin to a physical thing remains widely influential today. It underpins the common-sense or folk theory (Bereiter 2002) understanding of learning which views the mind as a container or filing cabinet, and learning as adding more substance to the container or further files to the cabinet.

This common-sense story is bolstered by two key metaphors: *acquisition* and *transfer*. These two metaphors dominate popular thinking about learning. Their influence has been entrenched over the century and more that formal education has been compulsory. The public has been well schooled to view learning as being self-evidently the stocking of the mind with the right kinds of things. Traditional testing situations have been the ubiquitous way to measure what level of learning a student has attained (*acquisition* metaphor). If learning has been successful, students will be able to reproduce it in the exam room or in other appropriate situations (*transfer* metaphor).

However, recent influential theories of learning employ metaphors that do not assume that learning is a thing or substance. According to these theories there is no external, reified entity that is learning. Rather, people construct and label certain processes/activities/ products as learning (Saljö 2003). As well these theories

reject the key assumption, characteristic of all traditional accounts of learning, that individuals are the main or only locations of learning. These more recent learning theories include situated learning, sociocultural activity theory, cognitive apprenticeship, and more. A separate account of each theory will not be attempted here (see Hager 2005 for a critical overview of these theories). Instead, the various alternative metaphors that they employ will be considered, as well as how our understanding of learning is creatively changed by these alternative metaphors. The main metaphors, which will be discussed briefly here, are: *participation*, *construction*, and *becoming*.

The Participation Metaphor

This metaphor gained wide currency through the seminal work of Lave and Wenger (1991). Their key proposal was that learning arises from learners participating in communities of practice. This is also referred to as *situated* learning, since it views learning as being highly contextual, making it inseparable from its sociocultural setting. The participation metaphor has gone on to become a dominant metaphor for learning, through being employed widely by diverse theorists.

The participation metaphor creates a somewhat different understanding of learning from that portrayed by the "common-sense" account and its associated acquisition and transfer metaphors. Participation represents learning as a complex social construction in which the individual learner is subsumed. In place of the thing or substance of the "common-sense" account, we have learning being a complex entity, one that extends well beyond the learner. Put differently, learning is a social construction, a set of complex practices, which undergo continuous change. The learner is regarded as learning by actively participating in, and gradually being subsumed into, this set of complex social practices.

Novice learners progress from insignificance in the practice to greater prominence as they increase their participation. Rather than learning being a thing moving to the inside of their head or body (the common-sense view), increased participation (learning) suggests movement by the learner from legitimate peripheral participation to full participation in a preexisting practice. Whilst early theories employing the participation metaphor concentrated on the learning of novices, later work (e.g., Wenger 1998) regards legitimate peripheral

participation as a special case. Because practices continually evolve, even the most able and experienced practitioners need to learn continuously from their practice.

Using the participation metaphor for understanding learning provides insights that are inconsistent with the acquisition and transfer metaphors. The participation metaphor makes learning significantly contextual in direct contrast with the common-sense view that learning transcends context. As against the *acquire it and transfer it* story, the participation metaphor suggests that the norm is for practitioner-learners to modify and adapt previous learning to deal with related but different situations in novel contexts. Since learning is no longer a thing located in individuals' heads or bodies, both learning by individuals and learning by teams or groups are possibilities for the participation metaphor.

Like all metaphors, the participation one has some limitations. It can be said to embed learning so completely within contexts that there is no account of what happens to individuals as they are changed by their learning; as their identity progresses from novice to full participant (e.g., Hager and Hodkinson 2009).

Construction and Related Metaphors

Construction (and associated metaphors such as *reconstruction* and *transformation*) portrays learning as the remaking of either the learner or of the whole package that is the learner together with their environment. The construction metaphor focuses centrally on matters to do with identity and identity change (Hager and Hodkinson 2009). Two main types of theories employ the construction metaphor. First, there are those theories that are often labeled as *constructivism*. The essential feature of these theories is their focus on transformation or construction happening *within* individual learners. This theorizing has had most impact on the teaching of subjects involving learning of significant amounts of propositional knowledge, such as mathematics and science education. The major concept is that learning consists of the transformation and reconstruction of what the learner already knows. A key associated metaphor is *scaffolding* which conveys the idea that new learning is built onto existing understanding akin to the way that extensions are made to an existing building. Novices are transformed into proficient practitioners in much the same way that a small

building is transformed into a larger building. Since learning may be continuous, construction/reconstruction is potentially an ever evolving process. Though this may appear to have some resonance with the participation metaphor, the crucial difference is that constructivism views the learning context as an external container, of marginal significance for the learning. Thus, constructivism regards the individual as changing while the context stays the same. But constructivism comes in more or less extreme versions. The more extreme versions regard the content of learning as differing across individuals, because each individual constructs their own particular unique understanding. Less extreme versions accept that much knowledge, such as the content of mathematics and science, remains relatively unchanged (Phillips 1995).

The second major group of theories that use the construction and associated metaphors are more holistic in that they center on the learner(s) continually changing along with their environment. So, they portray learning as an evolving, complex, relational web that transcends the individual learner. A prominent feature of the learning within this complex, evolving, relational web is the likely emergence of novelty both in understandings and in contexts. Prominent in these theories is Engeström's (2001) version of sociocultural activity theory. Learning is located in the activity system as a whole, which changes via either internal or external contradictions or pressures. Both the context and the individual learners change symbiotically, though most of this literature centers on the effects of a changing context on individual learners, rather than the other way around. This second group of construction metaphor theories brings to prominence the notion of collective learning. By focusing on holistic learning systems, the possibility is raised that "collective entities can learn" (Salomon and Perkins 1998, p. 10).

In common with other learning metaphors, construction and associated metaphors have limitations. A main one is that little of the construction metaphor literature addresses both individual change and the changing context.

The Becoming Metaphor

The metaphor of learning as becoming has recently been proposed as providing a more holistic way of understanding learning as a process (Hager and Hodkinson 2009). It combines features of the

participation and construction metaphors to offer understanding of learning as social and embodied (practical, physical, and emotional, as well as cognitive). The becoming metaphor emphasizes that when a learner constructs or reconstructs knowledge or skills, they are also reconstructing themselves. This personal reconstruction is sometimes explicit and agentic, but more often it is unconscious. Put generally, people become through learning and learn through becoming whether they wish to do so or not, and whether they are aware of the process or not. This metaphor has the advantage of linking the many diverse contexts, both across time and space, which jointly stimulate a person's ongoing becoming. It is still too early to estimate what the ultimate value of this learning metaphor might be.

Important Scientific Research and Open Questions

Because the vital role and significance of metaphors in thought and talk about learning is not well appreciated, learning remains an important human activity which is poorly understood. There may well be clear social benefits in remedying this situation. How might this public education need best be achieved?

Does the becoming metaphor offer significant understanding of learning that is not available from the use of earlier metaphors?

Are there other metaphors that might serve to enhance our understanding of learning of various kinds?

Precisely, why the use of metaphors is inescapable when we try to understand learning is a complex matter that cannot be treated here. This is a topic for ongoing research. (For some suggestive ideas on this matter see Lakoff and Johnson 1980, 1999).

Cross-References

► Activity Theory
► Constructivism
► History of the Sciences of Learning
► Metatheories of Learning
► Situated Learning
► Theory Construction

References

Bereiter, C. (2002). *Education and mind in the knowledge age.* Mahwah/London: Lawrence Erlbaum.

Bowen, J., & Hobson, P. (1974). *Theories of education: Studies of significant innovation in western educational thought.* Sydney: John Wiley & Sons Australasia.

Curtis, S., & Boultwood, M. (1970). *A short history of educational ideas* (4th ed.). Foxton: University Tutorial Press.

Engeström, Y. (2001). Expansive learning at work: Towards an activity-theoretical reconceptualisation. *Journal of Education and Work, 14*(1), 133–156.

Hager, P. (2005). Current theories of workplace learning: A critical assessment. In N. Bascia, A. Cumming, A. Datnow, K. Leithwood, & D. Livingstone (Eds.), *International handbook of educational policy. Part Two* (pp. 829–846). Dordrecht: Springer.

Hager, P., & Hodkinson, P. (2009). Moving beyond the metaphor of transfer of learning. *British Educational Research Journal, 35*(4), 619–638.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought.* New York: Basic Books.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constuctivism. *Educational Researcher, 24*(7), 5–12.

Saljö, R. (2003). From transfer to boundarey-crossing. In T. Tuomi-Gröhn & Y. Engeström (Eds.), *Between school and work: New perspectives on transfer and boundary-crossing* (pp. 311–321). Amsterdam: Elsevier Science.

Salomon, G., & Perkins, D. N. (1998). Individual and social aspects of learning. *Review of Research in Education, 23*, 1–24.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* Cambridge: Cambridge University Press.

Learning Methods

► Cognitive Learning Strategies for Digital Media
► Multistrategy Learning

Learning Mode

► Kolb's Learning Styles

Learning Motivation

► Learning Retention

Learning Motivation of Disadvantaged Students

József Balázs Fejes
Institute of Education, University of Szeged, Szeged, Hungary

Synonyms

Academic motivation of at-risk learners; Learning motivation of students with low socioeconomic status

Definition

The phrase *learning motivation of disadvantaged students* refers to the assumption that learning motivation, being different from, and usually lower than that of students from average or advantaged environments, plays a crucial role in the educational failures of students with low socioeconomic status. On a theoretical basis it is effortless to verify the motivational deficit of disadvantaged students that can be traced back, on one hand, to the parents' influential role in the formation of learning motivation, and, on the other hand, to school failures evolving as a consequence of less-advanced cognitive skills. However, unequivocal empirical evidence supporting the central role of unfavorable family background in the development of a lower level of learning motivation is unavailable.

Theoretical Background

The relationship between family background and school success has been well documented. It is a well-known fact that disadvantaged children's skills and learning outcomes are poorer than those of their peers from average or advantaged environments. One possible explanation of these differences is the lower level of learning motivation disadvantaged children exhibit. Theoretically it is effortless to verify the association between the unfavorable family background and the low learning motivation which is usually traced back, on the one hand, to parental influence on children's motivation, and on the other hand, to school failures evolving as a consequence of less advanced cognitive skills.

According to empirical studies parents have a crucial role in how children approach achievement in the academic area through (1) parents' practices with children, (2) parents' thinking about children, and (3) relatedness between parents and children (Pomerantz et al. 2005). Research investigating the relationships between socioeconomic status and characteristics of family life has revealed differences in all three fields between parents with low and medium or high socioeconomic status (Bradley and Corwyn 2002). Therefore, the linking of the attributes of poor families with the role of parental influence on children's learning motivation supports the view that learning motivation of disadvantaged students is lower than that of their peers from families with favorable background.

Parents' practices with children exert influence on the creation of an environment that supports children's competence. It involves offering cognitively stimulating materials and experiences, as well as suitable information, guidelines, expectations, and feedback. Children from poor families have limited access to cognitively stimulating materials and experiences, for example, in their homes there are fewer resources that facilitate learning or reading, and they are less likely to participate in educational, cultural, and recreational activities. Parents in poor environment read to their children and engage in conversations with their children more rarely, and these conversations are poorer, and include fewer efforts to elicit child speech. Another component of parents' practices with children affecting subsequent learning motivation is parental support of autonomy. Autonomy support involves allowing children to explore their own environment, initiate their own behavior, and play an active role in solving their own problems. Parents with low socioeconomic status use control strategies and restrictions more often, and are less likely to encourage autonomous behavior.

One dimension of *parents' thinking about children* is parental expectations for children's performance. Parents with high expectations are more involved in their children's schooling than are other parents, and in an indirect way, through parental messages they exert influence on children's belief systems. However, in case of mothers, economic hardships reduce the likelihood of setting optimal developmental goals for their children, which entails children's limited involvement in activities fostering skills development.

Relatedness between parents and children shapes the orientation children adopt toward achievement in

academic domains in numerous ways. Optimal attachment and closeness have an effect through children's confident and autonomous exploration of their environment, as well as through a positive internal representation of themselves and their parents who allow them to explore their environment without having to worry over their relationships. Another form of relatedness between parents and children is children's sense of obligation to their family. Students with a strong sense of family obligation report spending more time studying and having higher educational aspirations and expectations than others. When children define themselves in terms of their relationships with their parents, i.e., children hold parent-oriented interdependent self-construals, they put more effort into realizing the educational goals set for them by their parents, and are more likely to internalize these. Stresses, uncertainties, and low social standing can lead to such negative emotional states as anxiety, depression, and hostility, all of which negatively affect the relationships among family members. Additionally, harsh and neglectful parenting, which is also more common among poor families, is conducive to an unfavorable parent–child relationship.

Motivational weaknesses deriving from family background might be intensified by the school. Students whose skills necessary for school-based learning are underdeveloped, and have unfavorable motivational patterns, which are both highly probable in case of disadvantaged students, are prone to long-term motivational disadvantages right in the first years of schooling. This phenomenon is experienced in the case of learning to read, which is the core achievement context for school beginners. Low-achieving students without sufficient instruction fall increasingly behind their normally achieving peers. They often feel that they are being compared to their classmates with optimal reading trajectories, experience loss of personal control, and feelings of inferiority. Consequently, students at risk fall back upon maladaptive motivational reactions, such as passivity, task-avoidance, acting-out, or dependency. Although low-achievers are given more help and incentives than normal achievers, they also have to face more direction, criticism, reprimands, and rejection. Maladaptive motivational patterns stabilize rapidly after school start, and are likely to contribute to resistance to

subsequent teaching and treatment (Vauras et al. 2001). Teachers' expectations, that can be different for students with favorable and unfavorable family backgrounds, are regarded as an additional element in the intensification of the motivational deficit (Bradley and Corwyn 2002).

Important Scientific Research and Open Questions

Although theories about the motivational deficit in low social class school populations have long been present (e.g., Lawton 1968), the number of empirical studies focusing on the relationships between motivation and disadvantaged status is relatively small. In case of some motivational constructs, these empirical investigations have revealed a connection with socioeconomic status, while in case of others no such relationship has been found.

The survey including the largest sample size, on which we can rely in the investigation of relationships between family background and learning motivation, is linked to The Programme for International Student Assessment (PISA) 2000 data collection (Artelt et al. 2003). Out of the 32 countries participating in PISA 2000, students from 26 countries completed the questionnaires. Nationally representative samples of 15-year-olds consisted of more than 120 thousand students. Constructs investigated are primarily linked to the theory of self-regulated learning, from which instrumental motivation, interest in mathematics and reading, persistence and effort, self-efficacy and reading (verbal), mathematics and academic self-concepts can be regarded as variables describing learning motivation. Students were ranked by their parents' occupational status. Analysis compared the top quarter and the bottom national quarter of the student population in each country. Whenever significant differences were found in motivational variables, those usually meant the advantage of top quarter students. The difference between the two groups is the most remarkable in the case of self-efficacy. Students with disadvantaged background are less likely to believe in their capacity to face learning challenges. This difference was present everywhere with the exception of one country. Children of low occupational status parents are less confident regarding their skills in mathematics, in reading as

well as in learning in general (academic self-concept). There are also significant differences in interest in reading in most countries. Results regarding interest in mathematics and learning stimulated by external rewards such as grades (instrumental motivation) are the least consistent. In some countries these motivational constructs show more favorable characteristics in case of students belonging to the top quarter, while in others these more advantageous profiles were reported by students in the bottom quarter. Although significant differences were found in more variables describing learning motivation, it is not evident, to what extent the family and to what extent the school is responsible for the emergence of these differences, since the study does not discuss effects of selective education.

In the school systems of numerous countries students are sorted into separate schools, classes, or groups in their early school years on the basis of their past school achievements or abilities. As opposed to the originally declared goals, in many cases the decision to assign a student to a low ability group, a low prestige school or training program tends to be based on their socioeconomic status. Students in lower ability groups or in low prestige environments usually perform far below expectations, which is partly attributable to motivational reasons. Selective schooling has an adverse impact on self-esteem, and it can lead to anti-school attitudes and alienation from school in case of pupils in the lower groups or in low prestige environments. The negative impacts of selectivity on motivational variables may be mediated by stigmatization and teachers' expectations (Ireson and Hallam 2001).

Although according to some studies the motivational level of disadvantaged children is lower than that of their peers from privileged backgrounds, there is no clear empirical evidence that disadvantaged background itself plays a crucial role in the development of learning motivation, and through this, in the school failures of disadvantaged students. This situation may be attributable to the relatively small number of studies concentrating on the relation between family background and learning motivation, to the lack of a coherent theoretical foundation of learning motivation, and as a consequence, to the various operationalizations of motivation existing in the literature, and

finally, to the fact that the negative effects of selectivity based on socioeconomic status are hardly separable from direct effects of socioeconomic status. Moreover, there is a wide variability in the definition of disadvantaged background in studies, which also hinders the synthesis of available results.

Cross-References

► Ability Grouping and Effects on Learning
► Achievement Motivation and Learning
► At-Risk Learners
► Family Background and Effects on Learning
► Interests and Learning
► Motivation and Learning: Modern Theories
► Motivation to Learn
► Motivational Variables in Learning
► School Motivation
► Self-efficacy and Learning
► Self-regulated Learning
► Socialization-related Learning

References

Artelt, C., Baumert, J., Julius-Mc-Elvany, N., & Peschar, J. (2003). *Learners for life. Student approaches to learning. Results from PISA 2000*. Paris: OECD.

Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology, 53*(1), 371–399.

Ireson, J., & Hallam, S. (2001). *Ability grouping in education*. London: Chapman.

Lawton, D. (1968). *Social class, language and education*. London: Routledge and Kegan Paul.

Pomerantz, E. M., Grolnick, W. S., & Price, C. E. (2005). The role of parents in how children approach achievement: A dynamic process perspective. In A. Elliot & C. Dweck (Eds.), *Handbook of motivation and competence* (pp. 259–278). New York: Guilford.

Vauras, M., Salonen, P., Lehtinen, E., & Lepola, J. (2001). Long-term development of motivation and cognition in family and school contexts. In S. Volet & S. Järvelä (Eds.), *Motivation in learning contexts: Theoretical advances and methodological implications* (pp. 295–315). Amsterdam: Pergamon.

Learning Motivation of Students with Low Socioeconomic Status

► Learning Motivation of Disadvantaged Students

Learning Mutants

Danielle C. Colas-Zelin, Louis D. Matzel
Department of Psychology, Program in Behavioral
Neuroscience, Rutgers University, Piscataway, NJ, USA

Synonyms

Learning knockouts; Learning transgenics

Definition

The term "learning mutants" refers to animals with
targeted genetic modifications that are intended to
modulate (e.g., to impair or enhance) some specific
cognitive function, often as a consequence of its alter-
ation of a neural mechanism that is presumed to
underlie the storage or retrieval of memories. The
application of transgenic technologies to investigations
of behavior is technically complex, but moreover, pre-
sents a daunting interpretative challenge. The latter
reflects the fact that mutations that influence learning
may do so as a consequence of their impact on a specific
component of the learning *mechanism*, or alternatively,
as a consequence of their impact on often inestimable
cellular events that contribute to sensory, motor, emo-
tional, or other processes that *indirectly* influence
learning or the expression of a learned behavior.

Theoretical Background

Sir Francis Galton was among the first to apply statis-
tical methods to the study of human differences, and
his book *Hereditary Genius* (1869) served as the foun-
dation for systematic investigations of the relationship
between heredity and cognitive abilities. While his
methods were rudimentary, the question of whether
one's intellectual capacity may be delimited, in part,
by his or her genetic constituents is still of paramount
interest.

Contemporary studies of the relationship between
genetics and cognitive function often exploit transgenic
technologies to elucidate the cellular and molecular
substrates of learning and memory. Transgenic mice
are generated in a process that begins with the injection
of a DNA strand fragment (representing a gene) into
the male pronucleus of a newly fertilized mouse
embryo, after which the DNA is incorporated into
a random site on one of the chromosomes. Since the
embryo is at the single-cell stage, the newly incorpo-
rated gene is replicated and is ultimately expressed in all
of the animal's cells, including its germline. This heter-
ologous expression of a DNA fragment is commonly
referred to as a "transgene" and the gene's product is
made in *addition* to the endogenous gene expression
pattern.

Embryonic stem cells can be altered to induce more
specific genetic modifications. When introduced into
a host embryo, stem cells can contribute to all cell types
as the embryo develops. By homologous recombina-
tion of stem cells maintained in culture, modifications
can be introduced into specific genetic loci and intro-
duced into the mouse germline to promote mutations
of preexisting proteins. Depending on the nature of the
recombination and its location on the DNA strand,
these mutations can effect deletions or modifications
of existing genes and the expression of novel proteins.
Since the engineered strand of DNA replaces a strand
that had been endogenously expressed, the effects of the
new gene are "pure," that is, not the summed product
of the endogenous gene and the transgene.

Attempts to characterize the genetic regulation of
learning using transgenic techniques can be loosely
segregated into three categories. First, there is the
broad effort to identify genes that underlie common
dementias that impinge on an individual's capacity to
learn and remember. For example, numerous studies
have identified gene targets that model, at least in part,
the pathology seen in individuals with Alzheimers
dementia (AD). Attempts to model AD through mod-
ification of single genes have not been very fruitful.
However, researchers have begun to utilize double-
and triple-transgenic mice whose pathology more
closely resembles that seen in the clinical condition.
One "double-transgenic" model currently being stud-
ied includes a line of mice that carry mutant amyloid
precursor protein (APP) and presinilin (PS-1) genes.
While these double transgenic animals express neuro-
pathologies in early adulthood (mimicking some forms
of AD), in contrast to what is seen in clinical manifes-
tations of AD, these double transgenics are spared from
full cognitive decline (thus limiting their utility). Con-
sequently, researchers have created triple-transgenic
mutant mice to more accurately model the disease.
These 3xTg-AD express APP, PS-1, as well as Tau and
have impaired memory retention in both spatial and
non-spatial learning tasks at 6 months of age.

Importantly, these deficits in memory correlate with the emergence of disease-associated pathologies, which suggests that the triple-transgenic approach more accurately models AD.

A second line of transgenic research has emerged with the goal of enhancing cognition independent of the root cause(s) of dysfunction. While this area of research is in its infancy, at least 29 lines of mutant "smart" mice have already been identified. One class of these transgenic mice exhibit enhanced memory as a result of modifications to genes for factors known to support neuronal growth and differentiation as well as structural integrity of synapses. Another subset has genetic mutations which lead to increased RNA production and synthesis of proteins required for the stability of *synaptic plasticity*. A final group of "smart" mice express enhanced cognition subsequent to alterations to genes implicated in a specific form of synaptic plasticity, long-term potentiation. Long-term potentiation (LTP) was first described by Bliss and Lomo (1973), and is sometimes asserted to support the induction and storage of at least some forms of memory. The lion's share of work in the area of learning mutants has centered on alterations in the mechanisms thought to subserve LTP. In fact, this third and final approach to the study of learning mutants has dominated the field for some time.

LTP can be generally characterized as an activity-dependant potentiation of postsynaptic responses characterized by an increase in the amplitude and speed of excitatory postsynaptic potentials. LTP (in various forms) can be induced in the hippocampus as well as cortical and subcortical brain areas, thus potentially playing a widespread role in modulating information flow throughout the brain. Studies of learning mutants have focused on two mechanistically similar and historically prototypical forms of LTP; that observed in CA1 pyramidal cells and that seen in dentate granule cells (herein referred to as hippocampal LTP). Hippocampal LTP induction requires a transient elevation in postsynaptic intracellular calcium (CA^{2+}). The primary source of the increase is thought to be an influx of the ion through a channel pore coupled to the NMDA subtype of the glutamate receptor. The NMDA receptor is unique in that it requires glutamate binding as well as a moderate level of depolarization to displace its constituent magnesium block, allowing for opening of the pore and CA^{2+} influx. The elevation of postsynaptic CA^{2+} leads to activation of signaling cascades mediated by a variety of Ca^{2+} dependent kinases. While the precise roles of these kinases remain unclear it has been postulated that each may independently regulate different phases of LTP. For example, it is believed that the Ca^{2+}/calmodulin protein kinase IIα (CAMKIIα) phosphorylation event results in changes in AMPA-type glutamate receptors that are necessary for LTP maintenance (and normal synaptic transmission).

Evidence from a number of genetic studies suggests a key role for the NMDA receptor in synaptic plasticity and memory function. The NMDA receptor is an ionotropic receptor composed of two obligatory NR1 subunits along with other modulatory subunits including NR2 (A–D subtypes) and NR3 (A and B subtypes). *Global deletion* of the NR1 subunit of the NMDA receptor is lethal; however, mice with a deletion of the gene for the NR2A subunit are viable and show no gross neuroanatomical abnormalities. NR2A mice have abnormal expression of LTP characterized by a partial attenuation of induction and an accelerated rate of decay. Consistent with these findings, NR2A mutants demonstrate decreased performance across a range of hippocampal-dependant learning tasks. While these data indicate a role for the NR2A subunit in the regulation of memory, they are difficult to interpret. NR2A mice have sensorimotor deficits which may affect subjects' performance independent of their respective learning abilities. Also, the lack of regional control of the gene deletion makes determining its effects in a specific brain region complicated. This issue can be addressed by utilizing the *Cre/loxP* recombination system to restrict deletion of a gene of interest to a subregion or a specific cell type in the brain. Using this method, mice have been generated that lack the gene for the NR1 subunit of the NMDA receptor in either the CA1 or CA3 regions of the hippocampus. Mice with NR1 deletions in the CA1 area lack NMDA receptor-mediated postsynaptic currents and LTP. In the spatial Morris water maze (MWM), NR1/CA1 knockouts exhibit longer escape latencies in initial trials, although they reach performance levels comparable to wild-types by the end of training. While it is possible that the mutant animals develop compensatory mechanisms separate from LTP that allow them to learn the task, there is also the possibility that these mutants are able to improve their performance across trials by

utilizing a non-spatial strategy. The latter assertion was tested using a transfer test in which the hidden platform was removed from the MWM. When subjects are utilizing spatial cues, they swim preferentially in the area where the platform was last located. Mice with deletion of NR1 in the CA1 show impaired recall in this task, coupled with dysregulated firing of hippocampal place cells. Similar results were seen in NR1/CA3 mutants tested in a modified version of the transfer test in which only a portion of the original spatial cues were present. Place cell firing is asserted to act as a store of spatial memories and it is possible that the disrupted place cell firing witnessed in these knockouts is responsible, at least in part, for the deficit observed in the MWM transfer test.

The deficits in the acquisition and retention of MWM witnessed in CA1/NR1 mice are likely not the result of unintended biological changes that occur as a response to the lack of the gene during development. Mice with an inducible and regionally restricted CA1/NR1 deletion show similar deficits when gene expression was abolished just 5 days prior to training. Further, inducible and reversible deletion of the NR1 gene in the CA1 one week after completion of training interferes with consolidation of spatial memory for the MWM. Nonspatial learning is also affected in mice with deletion of the NR1 gene. NR1/CA1 mutants have deficits in trace fear conditioning, a form of aversive learning which requires temporal memory. Conditional knockouts with restricted expression of the NR1 gene in the CA1 region have impairments in the retention of contextual fear memories when gene expression is abolished 5 days before the start of training. Further, long-term retention of both contextual and cued fear memories are impaired by long term but not transient NR1 deletion throughout the forebrain.

While deletion of NMDA receptor units appears to impair synaptic plasticity and learning, increased expression has been shown to have the opposite effect. NR2B "doogie" mice are conditional transgenics that overexpress the NR2B NMDA subunit. These mice have increased postnatal expression of NR2B in the forebrain which results in an increase in LTP induction and a prolongation of its maintenance. Relative to wild-type animals, these mutants display improved performance on several different measures of learning. This facilitation of learning is long lasting as it has been recently shown that doogie mice perform better than

age-matched controls through late adulthood. Taken together with the data on learning impairments, these findings suggest a role for the NMDA receptor in LTP as well as the development and maintenance of short and long-term spatial and nonspatial forms of memory.

Important Scientific Research and Open Questions

While studies of learning mutants have already revealed a great deal about the genetic regulation of learning and memory, this work is still in its infancy. The vast majority of learning studies employing transgenic animals have manipulated genes that impinge on various components of NMDA receptor-dependent LTP; however, it is not universally accepted that LTP is an adequate device to subserve the storage of memories, and many studies have dissociated LTP from learning. For instance, GluR-A null mice show no deficits in spatial reference memory despite a complete lack of hippocampal LTP, a further illustration of how LTP may not underlie all forms of memory. Regardless of the contribution an individual mechanism makes to the actual storage of memory, there is one fundamental assumption shared across the entirety of the experiments, that is, that the biophysical modifications pursuant to learning-related synaptic interactions are a consequence of a cascade of molecular events initiated by the synaptic response (i.e., transmitter binding). When unencumbered by the interpretive difficulties imposed by the presumption of a single learning mechanism (e.g., LTP), a more parsimonious account of the genetics of learning may begin to emerge.

Cross-References

▶ Abilities to Learn: Cognitive Abilities
▶ Animal Learning and Intelligence
▶ Individual Differences
▶ Mediators of Learning
▶ Memory Codes and Neural Plasticity in Learning
▶ Neurophysiology of Motivated Learning
▶ Neuropsychology of Learning
▶ Spatial Learning in Perception

References

Bliss, T. V. P., & Lømo, T. (1973). Long-lasting potentiation of synaptic transmission in the dentate area of the anaesthetized rabbit following stimulation of the perforant path. *The Journal of Physiology, 232*, 331–356.

Eriksen, J. L., & Janus, C. G. (2007). Plaques, tangles, and memory loss in mouse models of neurodegeneration. *Behavior Genetics, 37*, 79–100.

Galton, F. (1869). *Hereditary genius: An inquiry into its laws and consequences*. London: Macmillan.

Shors, T. J., & Matzel, L. D. (1997). Long-term potentiation: What's learning got to do with it? *The Behavioral and Brain Sciences, 20*, 597–655.

Silva, A. J., Stevens, C. F., Tonegawa, S., & Wang, Y. (1992). Deficient hippocampal long-term potentiation in alpha-calcium- calmodulin kinase II mutant mice. *Science, 257*, 201–206.

Tang, Y. P., Shimizu, E., Dube, G. R., Rampon, C., Kerchner, G. A., Zhuo, M., Liu, G., & Tsien, J. Z. (1999). Genetic enhancement of learning and memory in mice. *Nature, 401*, 63–69.

Learning Networks

▶ Collective Learning

Learning Nonadjacent Dependencies

PIERRE PERRUCHET[1], BÉNÉDICTE POULIN-CHARRONNAT[1], SÉBASTIEN PACTON[2]
[1]LEAD/CNRS, Université de Bourgogne, Dijon, France
[2]LPNCog/CNRS, Université Paris-Descartes, Paris, France

Synonyms

Distant associations; Long-distance dependencies; Remote contingencies

Definition

Nonadjacent dependencies are present whenever a relation exists between two events, A and C, irrespective of the intervening events. This structure is often referred to as A*X*C, where *X* stands for a variable event that is statistically independent from both A and C. An example of nonadjacent dependencies is the relationship between auxiliaries and inflectional morphemes, as in "*is* writ*ing*" in English, which occurs irrespective of the verb stem. The mastery of this kind of structure in the language area has been endowed with major theoretical implications in a Chomskyan

perspective, and as a consequence, most research has been carried out in the language domain. However, it is worth pointing out that capturing the relationships between distant events is essential in many other situations. As claimed by Turk-Browne et al. (2005), "people are constantly bombarded with noise in space and time that needs to be segregated in order to extract a coherent representation of the world, and people rarely encounter a sequence of relevant stimuli without any interruptions" (p. 562).

Theoretical Background

By and large, most experimental studies on learning have focused on the human abilities to detect and exploit the relations between *adjacent* elements. For instance, in the traditional literature on associative learning, such as the domain of animal conditioning, or studies on paired-associate learning in humans, the to-be-associated items are displayed in close temporal or spatial proximity. Although in less obvious ways, most complex learning settings also rely on structures defined by adjacent relations. For instance, most of the finite-state grammars that are commonly used in implicit learning studies govern the transitional probability between contiguous elements. It is essential to note that event adjacency is not a fortuitous, accidental property of the materials, something that could be changed without any theoretical consequence. Indeed, from the "theory of contiguity" of Guthrie to the accounts of complex learning relying on the notion of chunks, usually defined as the grouping of a small number of contiguous events, the main theories of learning turn out to be devised for situations in which the relevant events are adjacent. Interestingly, recent studies on language acquisition have shown that learning adjacent relations are far more relevant than has been claimed in the past. For instance, a number of studies have demonstrated that the formation of the lexicon partly relies on statistical relations between adjacent syllables. More surprising, it has been shown that highly local context (the words immediately surrounding a target word) provided a considerable amount of information about the syntactic category of the target word.

However, it is unquestionable that linguistic structures also embed *nonadjacent* dependencies, which are successfully exploited by the learners. Such relations are found at different levels, from the subsyllabic level

Learning Nonadjacent Dependencies. Fig. 1 Schematic diagram of a grammar generating center-embedded sentences (the element *X* in the higher A*X*C structure is another A*X*C structure)

(e.g., the short vs. long pronunciations of vowels according to the presence of a "silent e" ending, irrespective of the intermediary consonant, as in CAP–CAPE, CAR–CARE) to morphosyntactic relationships such as the relation between auxiliaries and inflectional morphemes evoked in the definition above, and complex hierarchical structures. The current literature essentially focuses on situations in which strings are embedded within other strings, thus creating so-called center-embedded structures (Fig. 1). In the utterance "the rat the cat ate stole the cheese," for instance, one relative clause ("the cat ate") is nested within the sentence ("the rat stole the cheese").

The main theoretical issue is: Can this form of acquisition be encompassed within a general theory of associative learning, which would be able to account for both adjacent and nonadjacent dependencies? Undoubtedly, the prevalent models of learning, whether based on the associative principle of contiguity or the formation of chunks, are, as such, inadequate. Moreover, the issue does not seem easy to settle with only minor adjustments. Indeed, irrespective of their differences, most models of associative learning rely on a process of frequency-based selection among a set of possible associations. Only repeated or consistent pairs of events would be strengthened, the others being let aside or suppressed through decay or interference. This selection is a plausible mechanism whenever the number of possible associations remains limited, which is arguably the case when only adjacent events are considered. However, removing the adjacency constraint raises the well-known issue of combinatorial explosion: The number of possible associations becomes unmanageable, making the selection of the relevant associations unrealistic. This kind of theoretical considerations led Chomsky to contend that mastering the recursive structure underlying center-embedded

sentences is an innate, language-specific ability, without any relationships with basic associative mechanisms.

A number of empirical observations run against a so extreme standpoint. For instance, humans are also able to master nonadjacent dependencies in other natural domains of high-level knowledge comprising several organizational levels, such as Western music, which uses variations and ornaments. Two structurally important tones, for instance, are often separated by other, less important tones (the ornaments). If the nonadjacent dependency between the two structurally important tones was not captured by the listener, the musical structure would not be perceived. In addition, a number of studies have explored the question of whether animals and humans are able to learn nonadjacent dependencies in artificial experimental settings. While the results on animals remain controversial, the results on humans show consistently that learning arbitrary nonadjacent dependencies is possible, and so not only with linguistic stimuli (Gomez 2002) but also with tones (Creel et al. 2004) and visual patterns (Turk-Browne et al. 2005). However, this form of learning would be dependent on far more restrictive conditions than those required for learning the relations between contiguous events. A number of conditions have been identified, although none of them can be construed as a necessary prerequisite. A nonexhaustive list of potentially cumulative facilitatory conditions includes the following: (1) The fact that the A*X*C structure may be processed as a whole, that is, can be easily isolated from the surrounding sequence of events. (2) The high level of variability of the *X* event. (3) The high level of similarity between A and C. Similarity can be assessed on an acoustic dimension. Using musical tone sequences, Creel et al. (2004) showed that nonadjacent dependencies were not acquired when all elements differed equally one another, whereas learning was successful when A and C were similar in pitch or timbre, and different from *X*. Others have shown that no learning was obtained without some degree of phonological similarity between A and C syllables. (4) The membership of A and C to the same category, itself differing from the category of *X*. For instance, some studies have failed to observe learning with nonadjacent syllables (i.e., A, *X*, and C were syllables), whereas learning occurred when A and C were consonants and *X* was a vowel and, conversely, when A and C were vowels and *X* was

a consonant. (5) The occurrence of an earlier training phase during which the to-be-associated pairs have been studied in adjacent conditions. Introducing structural complexity progressively during learning would meet the general learning principle known as the "starting small" effect.

While these results make the initial Chomsky's view no longer defensible, they do not provide evidence that learning nonadjacent dependencies relies on the same associative/statistical mechanisms that are usually considered as responsible for the processing of adjacent events. Some authors contend that associative or statistical learning mechanisms are insufficient for extracting structural information, and that at least two mechanisms are required in order to learn from a complex environment: (1) an associative/statistical mechanism, essentially tracking adjacent associations, and (2) an additional rule-following mechanism dealing with more complex structures (Endress and Bonatti 2007). The issue meets here the great debate about the architecture of cognition, opposing those who argue that statistical learning mechanisms are sufficient for language acquisition and other high-level abilities, to those who advocate for the need of additional, rule-following mechanisms.

Important Scientific Research and Open Questions

A strategy that has been heavily exploited in this research context consists in exploring whether artificial neural networks are able to account for the mastery of complex structures. Given that connectionist networks embed only statistical mechanisms, without any hardwired rules, the fact that their success would provide a strong argument against a dual-mechanism framework is commonly acknowledged. Unfortunately, whether connectionist networks are actually successful in this endeavor is far less consensual. The last episode to date in the domain covered here is the Laakso and Calvo's (2011) demonstration that a standard connectionist network was able to mimic the results collected in a complex experimental setting involving long-distant dependencies, while other authors (Endress and Bonatti 2007) had previously inferred from their own failure to simulate the same data that this situation required a dual mechanism. But considering the past controversies surrounding this kind of demonstration, one may guess that the story is not over, and that

connectionist modelers will be faced with further challenges in the near future.

The (at least provisional) success of connectionist approaches to complex learning supplies a feasibility proof that rule-based mechanisms are not necessary to learn nonadjacent dependencies, but it does not provide, as such, a psychologically relevant theory of learning. In their tentative elaboration of an integrative theory, several authors have put forth the concept of attention as the possible cornerstone of a unified framework. Emphasizing the role of attention in associative learning is far from new, but empirical data suggesting that learning does not occur without a minimal level of attention have accumulated in recent years. Moreover, a few authors have suggested that associative learning is an automatic process that links together all of the components that are present in the attentional focus at a given point. In other words, the joint attention given to a pair of events would be a *necessary*, but also a *sufficient* condition for the emergence of associative learning and memory. Pacton and Perruchet (2008) have emphasized the potential of this proposal to serve as a foundational principle for an integrative, unified theory. Indeed, this account is fully compatible with the conventional focus on the condition of contiguity, because the mental content composing the attentional focus at a given moment has a high chance of representing events that are close on spatial and/or temporal dimensions in the environment. However, the attentional content may also encompass events that are not adjacent in the environment, provided that some specific reasons lead to pay joint attention to those events. Thus, an attention-based view accounts for both the easy formation of associations between contiguous events and the more limited ability to build associations between nonadjacent events (the joint attentional processing of those events requires some special conditions, such as those described in the empirical studies outlined above). Although an attention-based framework may be to date the best alternative to a dual view positing the need for rule-based mechanisms, the debate remains open. An attention-based framework trades the concept of contiguity in the environment for the concept of contiguity at the level of attentional, internal representations. This amounts to trade a directly measurable variable for another that may only be inferred from overt behavior, hence making the model harder to falsify. Further

studies are clearly needed to assert whether both adjacent and nonadjacent dependencies can be accounted for by general, all-purpose associative mechanisms.

Cross-References

References

Creel, S. C., Newport, E. L., & Aslin, R. N. (2004). Distant melodies: Statistical learning of non-adjacent dependencies in tone sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 1119–1130.

Endress, A., & Bonatti, L. L. (2007). Rapid learning of syllable classes from a perceptually continuous speech stream. *Cognition, 105*, 247–299.

Gomez, R. L. (2002). Variability and detection of invariant structure. *Psychological Science, 13*, 431–436.

Laakso, A., & Calvo, P. (2011). How many mechanisms are needed to analyze speech?: A connectionist simulation of structural rule learning in artificial language acquisition. *Cognitive Science* (in press).

Pacton, S., & Perruchet, P. (2008). An attention-based associative account of adjacent and nonadjacent dependency learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(1), 80–96.

Turk-Browne, N. B., Jungé, J. A., & Scholl, B. J. (2005). The automaticity of visual statistical learning. *Journal of Experimental Psychology: General, 134*, 552–564.

Learning Not to Fear

Clas Linnman, Mohamed A. Zeidan,
Mohammed R. Milad
Department of Psychiatry, Harvard Medical School &
Massachusetts General Hospital, Charlestown,
MA, USA

Synonyms

Fear extinction

Definition

Fear extinction is the process in which a previously conditioned fear response to a cue is reduced when the cue is presented in the absence of a previously paired aversive stimulus.

Theoretical Background

Humans, rodents, even nematode worms can learn to fear and avoid threatening situations. Fear learning is an essential skill that helps us adapt to a dangerous world, but learning *not* to fear is almost equally important, as this allows us to update our predictions in the light of new information. The ability to overcome a learned fear is critical as it allows us to go on with our daily lives even after suffering traumatic events. Imagine yourself in a bad car accident when driving through an intersection. This single event may condition you to fear intersections or cues that remind you of the accident, such as the song that was playing on the radio just before the accident, or the smell of burning rubber. Each time you pass through an intersection, hear that song, or smell burning rubber, your palms start to sweat, your heart rate increases, and you will find yourself taking shorter breaths – all physiological signs of an elevated fear response. Learning to fear these cues is called *fear conditioning*. For most of us, a few trips through intersections with no accidents will gradually remind us that the accident was an isolated incident and that intersections are predominantly safe. Our heart rates come back down to normal, and we breathe easy, and the subsequent learning not to fear the intersection is called *fear extinction* – the active process by which we learn not to fear through repetitive presentations of a previously feared cue (the intersection, the song, the smell) in absence of the once-paired aversive stimuli (the accident).

Importantly, fear extinction does not erase the initial fear memory. Learning not to fear does not occur by forgetting a traumatic event, but instead happens by creating new safety memories that compete with, and eventually overpower, the fear memory. This process forms the basis behind existing treatments for anxiety disorders such as posttraumatic stress disorder (PTSD), generalized anxiety disorder and many others. The treatment method is called Exposure Therapy and falls under the treatment umbrella of Cognitive Behavioral Therapy (CBT). During exposure therapy, a patient reads with a psychologist and discusses the

traumatic event in great detail, and gains exposure to his or her fear through a variety of stimuli including sounds and images. Over the course of several sessions, the patient learns that the cues are not dangerous in the safe context of the psychiatrist's office, and gradually reduces her fear response to the stimuli (i.e., fear extinction). Importantly, however, the patient has little information about the cue outside of the psychiatrist's office. The hope is that the extinction memory will overpower the fear memory when in a new context, a process called generalization. Clinically, adequate sleep may promote generalization of extinction memory from specific stimuli treated during exposure therapy to similar stimuli later encountered in real life.

The process of recalling an extinction memory after having gone through fear extinction is called *extinction retention.*

There are a variety of ways to examine extinction in the laboratory, and most are a variation on traditional, Pavlovian conditioning. In this model, there are three key phases:

1. *Fear conditioning.* Here, an individual is shown a cue (e.g.,, a blue light) called the conditioned stimulus (CS) that is paired with an aversive stimuli (a shock to the fingertips) called an unconditioned stimulus (US). After several trials, the individual learns that the CS is to be feared because it is paired with a shock. The individual's fear response is estimated by self-report and/or by measuring physiological markers such as heart rate, respiration, fear potentiated startle, and/or skin conductance (how much an individual sweats). This is called the conditioned response (CR) where the more fearful someone is, the higher these measures will be.

2. *Fear extinction.* After conditioning, the individual is shown the CS without the US. This is analogous to our example of repeatedly driving through an intersection without incident. After repeated trials, fear and the physiological response will decrease as the individual learns that the cue is no longer dangerous. Most people, with or without anxiety disorders, will have little difficulty extinguishing the learned fear in a lab setting because the US (a mild shock to the fingertips) is not traumatic and so, the fear response to it is relatively easy to extinguish.

3. *Extinction retention.* After conditioning and extinction, the individual is brought back the following day for the extinction retention trial. During this trial, the extinguished CS is presented again, without the US. If the participant has high extinction retention (strong safety memory), then he or she will have low fear as exhibited by low physiological responses. Studies look for variance in extinction retention in efforts to discover individual differences that may help identify predictors for anxiety disorders.

If during *extinction retention,* the individual does not exhibit a fear response, how do we know that they did not simply forget the fear memory? It is difficult to be sure that forgetting does not occur to some extent in extinction, but numerous studies show that extinction cannot be explained by forgetting. The primary evidence is that extinction requires exposure to the CS in the absence of the US as opposed to just the passage of time. If one were to always avoid cars and intersections, the fear memory would persist and sometimes even get worse. Fear memories that are not extinguished can last months or even years with little forgetting. In the lab, there are other ways to test if the fear memory persists even after extinction. They include these commonly used techniques:

1. *Spontaneous recovery.* Here, the individual is tested again after a considerable amount of time. Frequently, the individual gradually increases her fear response to the CS without any further conditioning. This reemergence of the conditioned response suggests that the original fear memory was not erased by extinction.

2. *Renewal.* If the fear memory returns when the individual is placed back in the context in which fear conditioning occurred, then this is called fear renewal and indicates the fear memory retention.

3. *Reinstatement.* If, after extinction, the US is administered without pairing it to the cue, individuals will show a rapid recovery of the fear response, again suggesting that the original fear memory indeed was not erased, but only suppressed by the extinction memory.

4. *Reacquisition.* After extinction, pairing the CS with a US will lead to more rapid relearning of the association, suggesting that the extinguished memory can still prime relearning.

The extinction retention phase along with these fear recovery phenomena, have clinical relevance as they resemble an individual's long-term response to exposure therapy. Without the ability to learn not to fear, we are susceptible to being paralyzed by anxiety.

The Neural Underpinning of Fear Extinction and Extinction Retention

Understanding the neural and behavioral processes underlying extinction learning, and knowledge of what conditions facilitate or hamper learning, may help to improve treatment outcomes. For an unfortunate number of people, fear is hard to control and extinguish, and a great deal of research is now focused on ways to enhance brain function in order to treat the many suffering from anxiety disorders. A large number of animal and human studies have allowed us to map the brain regions involved in fear extinction and extinction retention. A distinct "fear circuit" has been identified whose key structures include the brain stem, the *amygdala*, and *prefrontal cortex* (Phelps and LeDoux 2005). Each structure talks to the other when presented with a fear cue, and a decision is made about how to react. The amygdala – traditionally known for its reactivity to fearful stimuli – will communicate with the brain stem to trigger a fear response by the body (often referred to as the "fight or flight" response) unless it is regulated by some other source. One proposed regulator is the prefrontal cortex, a region known to be involved in higher cognition and executive function. It is this region that can communicate to and essentially "turn off" the amygdala when it perceives the context to be safe or the cue to no longer be dangerous (i.e., during extinction and extinction retention)(Quirk and Mueller 2008). Successful fear extinction and extinction retention seems to be dependent on the prefrontal cortex limiting the amygdala's fear reaction. When conducting fear extinction experiments in a functional Magnetic Resonance Imaging (fMRI) scanner, scientists can examine how well these regions are functioning in healthy subjects and in patients (Milad et al. 2009) while they are participating in fear conditioning experiments. Furthermore, MRI images can give information on the size and structural integrity of these regions as well as the fibers that connect them. It is important to note that this is an active field of research and that there are likely other brain regions, such as the anterior insula, that may be involved in both learning to fear and learning not to fear.

Important Scientific Research and Open Questions

Can we improve extinction retention? Exposure-based therapies are mostly effective; however, small but significant numbers of people relapse into exaggerated fear, often when faced with stressful life events. One goal in current research is to enhance the retention of fear extinction. Based on the notion that fear expression depends on whether the fear conditioning memory outweighs the extinction memory, the problem is attacked from two angles. The first and more prevalent approach is to enhance the extinction memory. Another, perhaps more controversial approach is to attempt to weaken or even delete the original fear memory.

Enhancing Fear Extinction Behaviorally

In the clinic, there are numerous strategies to enhance fear extinction processes, including performing extinction in multiple contexts, encouraging the patient to engage and expose themselves to safe, tolerable but somewhat scary situations, and also learning not to suppress fear, but to accept and tolerate it (Craske et al. 2008).

Enhancing Fear Extinction Pharmacologically

Important research is underway suggesting that pharmacologic interventions may help increase the ability to retain an extinction memory. These studies follow the study design mentioned above, but administer a drug directly before (or directly after) extinction training in the hopes of facilitating the learning process (i.e., making the extinction memory stronger). One proposed agent that has shown promising initial results in facilitating fear extinction is D-Cycloserine (Ressler et al. 2004).

Is it Possible to "Delete" a Fear Memory?

A novel approach to targeting fear memories is based on fear reconsolidation. When an association is made, the memory is stabilized through a process called memory consolidation. Once memories undergo the process of

consolidation and become part of long-term memory, they are thought of as stable. However, the retrieval of a memory trace can cause another labile phase that then requires an active process to make the memory stable again. In other words, when we remember something, that memory is made susceptible to change. When an individual recounts a traumatic event, she makes that memory labile and it may be possible to alter the emotional significance or even delete the memory. For example, pharmacological manipulations after memory retrieval may prevent the retrieval of the memories at a later time – suggesting that they are actually erased. It has also been recently demonstrated that extinction, if it occurs at the right time point after memory retrieval, may update and reduce the fear memory (Schiller et al. 2010). This suggests that there is a window of opportunity to rewrite emotional memories.

Cross-References

- ► Anticipatory Learning
- ► Behaviorism and Behaviorist Learning Theories
- ► Conditioning
- ► Context Fear Learning
- ► Cued Recall
- ► Emotional Learning
- ► Extinction Learning
- ► Fear Conditioning in Animals and Humans
- ► Habituation
- ► Neuropsychology of Emotion
- ► Pavlovian Conditioning
- ► Pavlov, Ivan P. (1849–1936)
- ► Reinforcement Learning
- ► Reinforcement Learning in Animals
- ► Skinner B.F. (1904–1990)
- ► Stress and Learning

References

Craske, M. G., Kircanski, K., Zelikowsky, M., Mystkowski, J., Chowdhury, N., & Baker, A. (2008). Optimizing inhibitory learning during exposure therapy. *Behaviour Research and Therapy, 46*, 5–27.

Milad, M. R., Pitman, R. K., Ellis, C. B., Gold, A. L., Shin, L. M., Lasko, N. B., Zeidan, M. A., Handwerger, K., Orr, S. P., & Rauch, S. L. (2009). Neurobiological basis of failure to recall extinction memory in posttraumatic stress disorder. *Biological Psychiatry, 66*, 1075–1082.

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron, 48*, 175–187.

Quirk, G. J., & Mueller, D. (2008). Neural mechanisms of extinction learning and retrieval. *Neuropsychopharmacology, 33*, 56–72.

Ressler, K. J., Rothbaum, B. O., Tannenbaum, L., Anderson, P., Graap, K., Zimand, E., Hodges, L., & Davis, M. (2004). Cognitive enhancers as adjuncts to psychotherapy: Use of D-cycloserine in phobic individuals to facilitate extinction of fear. *Archives of General Psychiatry, 61*, 1136–1144.

Schiller, D., Monfils, M. H., Raio, C. M., Johnson, D. C., Ledoux, J. E., & Phelps, E. A. (2010). Preventing the return of fear in humans using reconsolidation update mechanisms. *Nature, 463*, 49–53.

Learning Numerical Symbols

Ian D. Holloway, Daniel Ansari
Department of Psychology, University of Western Ontario, London, ON, Canada

Synonyms

Digit; Numeral

Definition

In his essay "What Is a Sign?," the semiologist Charles Sanders Peirce defined a symbol as an entity that is associated with something else in a purely arbitrary manner (Peirce 1998). In psychological terms, a symbol is generally considered a perceptual object that becomes associated with a different perceptual or semantic object through a process of learning. Symbolic information can be transmitted through any of the senses. For example, written language is made up of symbols that exist as visual or tactile information (written words, braille). The auditory sound of the school bell is a symbol that marks the beginning or end of a school day.

In popular usage, numerical symbols are synonymous with numerals, such as the ubiquitous Hindu-Arabic numerals (1, 3, 5, etc.) or the Roman numerals (I, III, V, etc.). Technically, however, numerical symbols should be defined more broadly to include the written number words (one, three, five, etc.). Defined like this, numerical symbols generally exist as visual characters and signify at least two types of information. The principal information referred to by a numerical symbol is its meaning or *numerical magnitude* (e.g., the numeral "4" represents a set of four objects).

Numerical symbols also carry linguistic information in the form of number names (e.g., the numeral 5 is associated with the number word "five"). Thus, depending on their usage, numerical symbols can express verbal or quantitative information, or, more commonly, a combination of both.

Theoretical Background

In the western world, the first numeral systems were created by using alphabetic characters as numerals. Employed by the ancient Greeks sometime after the eleventh Century B.C.E., this type of system spread into the Semitic languages of the Middle East and later into the Roman Empire. Roman numerals are still used in limited contexts to the present day, such as certain page numbering formats or the numbering of the Super Bowl. Eventually, the Greek system was replaced by the Hindu-Arabic numerals developed in ancient India and brought to Europe by the Arabic people of ancient Persia (Menninger 1969). This numeral system expressed quantities using a place value system and included a way of expressing zero. The Hindu-Arabic numerals were popularized in Europe by Fibonacci in 1202 and also spread eastward into China. Because of the widespread use of the Hindu-Arabic numerals, numerical notation systems have a much greater degree of cultural homogeneity than writing systems.

As basic education became compulsory in contemporary cultures, the learning of numerical symbols became, in part, the purview of formal education. Thus, the learning of numerical symbols is a protracted process that begins when children first learn their number words and continues into the early elementary-school years. More formally, numerical symbol learning requires two distinguishable processes. The primary process occurs prior to the onset of formal education and involves the association of verbal representations of number (number names) with a semantic representation of numerical magnitude. Subsequent to this, the secondary process occurs whereby number words are associated with visual symbols, most typically the Hindu-Arabic numerals. The second process generally takes place during early formal education as a prerequisite to later mathematical learning, since these symbols form the basis for the learning of arithmetic.

Important Scientific Research and Open Questions

Numerical symbol learning involves the integration of verbal, semantic, and visual representations. The semantic representation of number, often described as the "number sense" (Dehaene 1997) is present from infancy onward. Therefore, basic representation of numerical magnitude is not dependent on language – a fact that is also supported by evidence of numerical understanding in non-human animals. The representation of numerical magnitude has several characteristics relevant to understanding the relationship between a numerical symbol and the numerical magnitude it represents. Consistent with Weber's Law, the precision of numerical magnitude representation decreases as numerical size increases. It is, therefore, easier to decide whether 3 is smaller than 6 than it is to decide that 33 is smaller than 36. Furthermore, numbers that are closer together on the number line are thought to share more representational overlap. Thus, it is more difficult to decide that 5 is different from 6 than it is to judge that 5 is different from 8. These two phenomena, called the *size effect* and the *distance effect*, respectively, are psychophysical markers of numerical magnitude representation (Moyer and Landauer 1967). It is important to note that the size and distance effects are elicited when the numerical information is presented symbolically as well as when it is presented nonsymbolically, such as with an array of dots or a series of tones. Thus, the semantic referent of numerical symbols has its roots in the nonsymbolic processing of numerical magnitude. The similarity between the size and distance effects across symbolic and nonsymbolic formats, coupled with evidence that very young children can understand nonsymbolic numbers before they learn numerical symbols, has led to the hypothesis that numerical symbols are mapped directly onto nonsymbolic numerical magnitude representations. While this theory of how numerical symbols are learned is compelling and relatively well supported by experimental evidence, it neglects the role played by number names in the learning of numerical symbols.

The verbal representation (names) of numbers is typically learned prior to formal schooling when children learn to count. Verbal information is learned as an ordered sequence similar to the alphabet. Initially, the verbal representation of number is thought to be asemantic. Typically developing children can recite the

number word sequence, i.e., count, before they understand that these number words have quantitative referents. Over developmental time, number words are associated with representations of numerical magnitude as children acquire an understanding of the meaning of counting. This process of attaching meaning to the verbal numbers is thought to rely on the ordinal nature of the counting sequence. Children gradually intuit that a progression through the order of the number sequence is also reflective of an increase in numerical size. In other words, children discover that six comes after five in the counting sequence *because* six is one greater than five. In this way, children use the order of the counting sequence to help them connect verbal information (number names) to the semantic numerical information (Carey 2009). This theory, which highlights the importance of connecting the verbal and semantic referents of numerical symbols, also allows for an interaction between verbal numerical information and prelinguistic representations of numerical magnitude. Specifically, the mapping of semantic to verbal representations of number is thought to increase the precision with which numerical information is mentally represented. For example, discriminating the verbal representation "three hundred and fifty-seven" from "three hundred and fifty-nine" is trivially easy, while discriminating 357 from 359 dots is not possible.

In literate individuals, the verbal representation of number is also associated with a visual symbol. Such symbols can be numerals such as the Hindu-Arabic numeral "7" or the Roman numeral "VII" or they can be written words such as the English word "seven" or the simplified Chinese logogram "七." Thus, learning the visual numerical symbols involves integrating verbal and semantic numerical information with a visual form. Very little is known about the processes involved in learning to read visual numerical symbols and whether these processes are distinguishable from the processes involved in reading other types of linguistic information.

Little empirical work has been conducted to elucidate the specific mechanisms underlying numerical symbol learning, especially as it unfolds during child development. A few studies have been reported in which adults were trained to learn novel numerical symbols, or computer models were used to simulate the processes associated with the learning of numerical

symbols (Verguts and Fias 2004). The study of numerical symbol learning in children has focused primarily on very young children's learning of counting. Thus, many questions remain to be systematically addressed.

One important avenue of inquiry is how the learning of numerical symbols unfolds across developmental time. Research has indicated that individual differences in visual numerical symbol processing are predictive of individual differences in mathematics achievement. However, neither the mechanisms underlying individual differences in numerical symbol processing nor those defining the relationship between symbol processing and mathematics are well understood. A related question involves the relationship between children's learning to read and their learning of numerical symbols. Individual differences in basic reading processes, such as phonological awareness, have been related to arithmetic processing. However, it is not known how numerical and phonological processing interact to form the foundations of mathematical abilities. Longitudinal studies of numerical symbol learning during early child development are needed to investigate these underlying mechanisms.

Another set of open questions regards the brain mechanisms underlying numerical symbol processing. For example, what brain mechanisms are involved in connecting a numerical symbol to its semantic, verbal, and visual referents and how do these processes of learning interact? Does the verbal and visual processing of numerical symbols share the same neural circuits as the processing of letters? Is dysfunction in the neural processing of numerical symbols during early childhood a causal factor in mathematical learning disabilities? To address these and similar questions, various neuroimaging methodologies such as functional magnetic resonance imaging, transcranial magnetic stimulation, and electroencephalography must be employed to clarify both the spatial and temporal signatures of numerical symbol processing in the brain. Future studies must investigate numerical symbol processing across languages in adults as well as both typically- and atypically-developing children to clarify how numerical symbols are learned by the brain and how these neural processes relate to higher-level mathematical skills. In addition to granting insights that are educationally relevant, research into the neural processing of numerical symbols, as well as numerical

processing more broadly, can provide important clues into the interaction between biologically basic systems of magnitude representations which are shared across species, and cultural, symbolic representations. Thus, studies of numerical symbol learning are well suited to characterizing the interaction of biology and culture in the process of human development.

Cross-References

▶ Dyscalculia in Young Children – Cognitive and Neurological Bases
▶ Language Acquisition and Development
▶ Learning and Numerical Skills in Animals
▶ Literacy and Learning
▶ Mathematical Learning
▶ Mathematical Learning Disabilities
▶ Phonological Representation
▶ Semiotics and Learning

References

Carey, S. (2009). *The origin of concepts.* New York: Oxford University Press.
Dehaene, S. (1997). *The number sense.* New York: Oxford University Press.
Menninger, K. (1969). *Number words and number symbols: A cultural history of numbers.* New York: Dover.
Moyer, R. S., & Landauer, T. K. (1967). Time required for judgements of numerical inequality. *Nature, 215*(109), 1519–1520.
Peirce, C. S. (1998). What is a sign? In T. P. E. Project (Ed.), *The essential peirce: Selected philosophical writings* (Vol. 2, pp. 4–10). Bloomington: Indiana University Press.
Verguts, T., & Fias, W. (2004). Representation of number in animals and humans: a neural model. *Journal of Cognitive Neuroscience, 16*(9), 1493–1504.

Learning Object

▶ Competency-Based Learning

Learning Object Creation

▶ E-Learning Authoring Tools

Learning Objectives

AYTAC GOGUS
Center for Individual and Academic Development, Sabanci University CIAD, Istanbul, Turkey

Synonyms

Educational objectives; Instructional objectives

Definition

Learning objectives are statements of what a learner is expected to know, understand, and/or be able to demonstrate after completion of a process of learning. Learning objectives form a basis for curriculum, course syllabus, course development, as well as assessing the learning process.

Theoretical Background

A well-written learning objective provides a basis for planning, developing, delivering, and evaluating an educational activity. Clearly stated learning objectives have four characteristics: audience, behavior, condition, and degree (ABCD) as described below (Anderson and Krathwohl 2001; Mager 1975):

- *A*udience – Who is the target of the educational activity? What are the learner's characteristics?
- *B*ehavior – What behavior is expected from the learner?
- *C*onditions – Under what conditions will the learner be expected to demonstrate her/his knowledge?
- *D*egree – The degree to which the behavior must be performed to constitute an acceptable performance.

Behaviors can be written for one of the three *domains of learning – cognitive domain*, *affective domain*, and *psychomotor domain* – as defined below (Anderson and Krathwohl 2001; Krathwohl et al. 1964; Simpson 1966):

- *Cognitive Domain:* Acquisition of knowledge and intellectual skills (*knowledge*)
- *Affective Domain:* Integration of beliefs and ideas (*attitude*)
- *Psychomotor Domain:* Acquisition of manual and physical skills (*skills*)

In 1956, Bloom headed a group of educational psychologists who developed a classification of levels

Learning Objectives. Table 1 Taxonomy of educational objectives for the affective domain

Levels	Sample verbs
1. *Receiving phenomena:* Developing awareness of something	Choose, describe, name, use, identify, locate. *Example:* Identify the general properties of X
2. *Responding to phenomena*: Developing active participation, willingness to respond, and motivation	Answer, label, recite, write, report, discuss, help, present, perform. *Example:* Perform correctly calculations on X
3. *Valuing:* Committing oneself to a particular object, phenomenon, or behavior	Justify, propose, read, report, select, share. *Example:* Demonstrate belief in the relevance of X
4. *Organization*: Making judgments or decisions from among several alternatives	Combine, organize, prepare, synthesize, complete. *Example:* Organize the principles of X to solve Y
5. *Internalizing values* (characterization): Integrating one's beliefs, ideas, and attitudes into a total, all-embracing philosophy	Question, serve, qualify, practice, listen, discriminate. *Example:* Cooperate in group activities

of intellectual behavior important in learning. *The cognitive domain* involves knowledge and the development of intellectual and critical thinking skills. Six levels of *the cognitive domain*, called *Bloom's taxonomy*, are *knowledge, comprehension, application, analysis, synthesis*, and *evaluation* (Anderson and Krathwohl 2001). The six levels are classified hierarchically from the simplest action to the high order thinking actions. See Table 1 in the entry "▶ Bloom's Taxonomy of Learning Objectives" for sample learning outcomes and verbs used to write learning objectives.

The affective domain relates to emotions, attitudes, appreciations, and values, such as enjoying, conserving, respecting, and supporting. The affective domain is divided into five main subcategories: *receiving, responding, valuing, organization*, and *characterization*. Table 1 summarizes the meaning of the levels, sample learning objectives, and sample verbs (Krathwohl et al. 1964).

The psychomotor domain concerns things students might physically do. Although no taxonomy of *the psychomotor domain* was compiled by Bloom and his coworkers, several competing taxonomies for the psychomotor domain (e.g., Dave 1970; Simpson 1966) have been created over the years. One of the popular versions of the taxonomy for the psychomotor domain belongs to R. H. Dave (1970). Dave (1970) presents the five levels of the psychomotor domain as *imitation, manipulation, precision, articulation*, and *naturalization* as described below:

- *Imitation:* Following and patterning behavior after someone else

- *Manipulation:* Being able to perform certain actions by following instructions and practicing
- *Precision:* Refining, becoming more exact
- *Articulation:* Coordinating a series of actions, achieving harmony and internal consistency
- *Naturalization:* Having high-level performance become natural, without needing

Another popular version of the taxonomy for the psychomotor domain belongs to E. J. Simpson (1966). The seven major categories of the psychomotor domain are listed from the simplest behavior to the most complex: *perception, set* (*readiness to act*), *guided response, mechanism, complex overt response, adaptation*, and *origination*. Table 2 summarizes the meaning of the levels, sample learning objectives, and sample verbs (Simpson 1966).

Lorin W. Anderson and David R. Krathwohl revisited the cognitive domain in the learning taxonomy to reflect a more active form of thinking and made some changes such as changing the names in the six categories from noun to verb forms, and rearranging them slightly (Anderson and Krathwohl 2001). In contrast with the single dimension of the original taxonomy, the revised framework is two-dimensional. The two dimensions are cognitive process and knowledge (Anderson and Krathwohl 2001). The cognitive process dimension contains six categories from cognitively simple to cognitively complex: *remember, understand, apply, analyze, evaluate*, and *create*. The knowledge dimension contains four categories from concrete to abstract: *factual, conceptual, procedural*, and *metacognitive* (Anderson and Krathwohl 2001).

Learning Objectives. Table 2 Taxonomy of educational objectives for the psychomotor domain

Levels	Sample verbs
1. *Perception*: The ability to use sensory cues to guide motor activity	Choose, describe, detect, differentiate, distinguish, identify, isolate, relate, select
	Example: Relate the relevance of X in Y
2. *Set* (*readiness to act*): Mental, physical, and emotional sets	Begin, display, explain, move, proceed, react, show, state, interpret, volunteer
	Example: Interpret the results of X tests in Y
3. *Guided response*: Adequacy of performance is achieved by practicing, imitation, and trial and error	Copy, trace, follow, react, reproduce, respond
	Example: Follow instructions to build X by using Y
4. *Mechanism*: Developed confidence and proficiency of performance and habitual learned responses	Assemble, calibrate, construct, dismantle, display, fasten, fix, manipulate, measure, organize, sketch
	Example: Use a computer program accurately to do X
5. *Complex overt response*: The skillful performance of motor acts and automatic performance	The same key words for mechanism are used; nevertheless, the adjectives or adverbs used indicate that the performance is better, or faster, or more accurate, etc.
	Example: Operate X software quickly and accurately
6. *Adaptation*: Use well-developed skills to modify movement patterns to fit special requirements	Adapt, alter, change, rearrange, reorganize, revise, vary
	Example: Reorganize data to be able to interpret X
7. *Origination*: Creating new movement patterns to fit a particular situation	Arrange, build, combine, compose, construct, create, design, initiate, make, originate
	Example: Develop a new X program to analyze Y

Anderson and Krathwohl (2001) defined the new terms of the cognitive dimension in the revised taxonomy as:

1. *Remembering* – Retrieving relevant knowledge from long-term memory
2. *Understanding* – Determining the meaning of instructional messages, including oral, written, and graphic communication
3. *Applying* – Carrying out or using a procedure in a given situation
4. *Analyzing* – Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose
5. *Evaluating* – Making judgments based on criteria and standards
6. *Creating* – Putting elements together to form a novel, coherent whole or make an original product (Anderson and Krathwohl 2001, pp. 67–68)

Anderson and Krathwohl (2001) defined the terms of the knowledge dimension in the revised taxonomy as:

1. *Factual Knowledge* – The basic elements that students must know to be acquainted with a discipline or solve problems in it
2. *Conceptual Knowledge* – The interrelationships among the basic elements within a larger structure that enable them to function together
3. *Procedural Knowledge* – How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods
4. *Metacognitive Knowledge* – Knowledge of cognition in general as well as awareness and knowledge of one's own cognition (Anderson and Krathwohl 2001, p. 46).

Since 1956, the three domains of educational activities (cognitive, affective, and psychomotor) have been used by educational psychologists, instructional designers, and educators to write learning objectives and learning outcomes.

Important Scientific Research and Open Questions

According to Robert Mager's (1975) theory of behavioral objectives, instructional objectives which are also known as behavioral and performance objectives can be applied in Gagne's second event of instruction, which is to inform learners of objectives. Mager (1975) emphasizes that instructional designers should firstly determine the learning goals of the program, and that a learning goal should have a subset of learning objectives. In the book, *Preparing Instructional Objectives*, Mager (1975) states that a behavioral objective or a learning objective should have four components which are *audience*, *behavior or performance*, *condition or constrains*, and *degree or standard or criteria* as described below:

- *Audience:* The learner's characteristics
- *Behavior (performance):* What the student will be able to do
- *Condition (constrains):* The conditions under which behavior occurs
- *Degree (standard, criteria):* An explicit description of acceptable behavior

First, the instructional objective must state the *audience* and describe the learner's characteristics for the educational activity. The *behavior* should be specific, observable, and assessable. The *condition* under which the behavior is to be completed should be stated, including what tools or assistance are to be provided. The *degree or standard* should describe the acceptable level of behavior, including an acceptable range of answers that are allowable as correct.

Today, the performance objectives or learning objectives are written by ignoring the indication of the conditions and standards, but a written indication of the behavior using measurable or observable verbs is essential for a valuable objective.

In giving practical advices for writing learning outcomes, Moon (2002) states that well-written learning objectives should:

- Be observable and assessable
- Begin with an action verb
- Have only one verb per learning objective
- Avoid vague terms like know, understand, learn, be familiar with, etc.
- Be realistic within the timescale of the course to be able to be achieved and assessed

- Be linked with program outcomes
- Be linked with teaching and assessment methods

Writing learning objectives allow instructors to design learning activities and set up assessment tools. Learner outcomes inform learners about what are expected from them upon completion of the course, thus learners develop a sense of ownership of their own learning. Writing learning objectives allows instructors to have an effective planning for learning progress. Setting meaningful and achievable learning objectives allows learners to build on what they have previously learnt. The use of learning objectives in the classroom are listed as follows (Mager 1975, p. 1):

1. Clarify and specify learning outcomes.
2. Select and arrange learning experiences.
3. Evaluate student performance.

Mager (1975) also presents three reasons for the use of learning objectives as below:

1. Without objectives, there is no sound basis for selecting or designing instructional material.
2. Without objectives, it is impossible to determine if something has been accomplished because you do not know what is to be achieved, how to measure achievement, or how to assess the success of instruction.
3. Without objectives, it is difficult to organize student efforts and activities for accomplishment of instructional intent (p. 6).

Learning objectives contribute to describing qualifications and qualification structures throughout the European Higher Education Area (EHEA) in the Bologna process (Moon 2002). Learning objectives promote the outcome-based approach and encourage moving from a teacher-centered approach to the student-centered approach which has been increasingly adopted by European universities (Moon 2002) as well as other countries. Learning objectives contribute to the mobility of students by recognizing their diploma (Moon 2002). As a result, the answers of the question "why do instructors prepare learning objectives?" can be summarized as below:

- Learning objectives help instructors to more precisely tell students what is expected of them, to make it clear what students can hope to gain from the course, and to design course activities and course evaluation systems.

- Learning objectives help instructors select the appropriate teaching and assessment strategies.
- Learning objectives provide clear information on what the students will be able to achieve after successful study.
- Learning objectives provide clear information to help students with their choice of program.
- Learning objectives provide clear information on the achievements and characteristics associated with particular qualifications and increase the transparency as well as the comparability of standards between and within qualifications.

Cross-References

▶ Bloom's Taxonomy of Learning Objectives
▶ Learning Criteria, Learning Outcomes, and Assessment Criteria
▶ Mastery Learning
▶ Outcomes of Learning

References

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Dave, R. H. (1970). Psychomotor levels. In R. J. Armstrong (Ed.), *Developing and writing behavioral objectives*. Tucson: Educational Innovators Press.

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives. The classification of educational goals; Handbook II: Affective domain*. New York: David McKay.

Mager, R. (1975). *Preparing instructional objectives* (2nd ed.). Belmont: Pitman Learning.

Moon, J. (2002). *The module and programme development handbook*. London: Routledge.

Simpson, E. J. (1966). The classification of educational objectives: Psychomotor domain. *Illinois Journal of Home Economics, 10*(4), 110–144.

Learning of Equivalence Classes

Karen M. Lionello-DeNolf
University of Massachusetts Medical School,
Shriver Center, Worcester, MA, USA

Synonyms

Sidman equivalence; Stimulus equivalence

Definition

Stimulus equivalence refers to a type of stimulus class in which the stimuli comprising the class are substitutable for (equivalent to) each other. For example, if a child says "dog" upon seeing a dog and then subsequently says "dog" upon seeing a picture of a dog, then the dog and the picture can be thought of as equivalent stimuli. This is an example of a symbolic process – one stimulus can refer to another. Stimulus equivalence classes can be distinguished from other types of stimulus classes (such as ▶ feature classes or ▶ functional classes) because members of the class do not necessarily share physical characteristics or serve identical behavioral functions (e.g., printed words, spoken words, and pictures). The presence of an equivalence class is inferred from an organism's behavior on specific tests that are typically conducted after training on the ▶ conditional discrimination training procedure matching-to-sample. In this procedure, a sample stimulus is presented and is followed by presentation of two or more comparison stimuli; the organism is required to make a choice from among the comparisons, and reinforcement (e.g., food items, tokens, etc.) occurs for choosing a particular comparison after a given sample. For example, a child may be presented with the spoken-word samples "apple" (A1) and "banana" (A2) and taught to choose an apple (B1) or a banana (B2), respectively, from among two or three comparison alternatives (AB matching). The child may also be presented with the apple (B1) and banana (B2) as samples and be taught to choose the written words APPLE (C1) or BANANA (C2), respectively (BC matching). After teaching, the child may have learned only the conditional relations that were directly taught, or s/he may have learned that the spoken words, written words, and objects were equivalent to each other. Equivalence class formation is inferred if the child can match, in the absence of reinforcement or other feedback, the stimuli in three specific ways that have not been directly taught. The first of these is reflexivity, or the ability to match each stimulus to itself (AA, BB, and CC matching). The second is symmetry, or the ability to match familiar stimuli when their roles as sample and comparison stimuli are reversed with respect to training (BA and CB matching). The third is transitivity, or the ability to match previously unpaired stimuli on the basis of a common association with a third stimulus: after training on AB and BC

matching, the organism can accurately perform AC and CA matching. Note also that the CA test is a combined test for symmetry and transitivity.

Theoretical Background

Psychologists have long been interested in organisms' ability at what can loosely be called concept formation, or the ability to group objects and events together, as evidenced by the volume of published research on perceptual ▶ categorization, non-similarity–based categorization, mediated generalization, ▶ paired associates learning, and relational learning. Interest in stimulus equivalence in particular originated with Sidman and his colleagues, who offered an operational definition based on mathematical set theory and on a decade-long program of research using the matching-to-sample procedure to teach developmentally disabled humans reading comprehension (Sidman 1994). This work was significant because it showed that training a small number of conditional discriminations could lead to a large number of relational performances that were not directly taught. For example, teaching just four conditional discriminations (A1-B1, A2-B2, B1-C1, and B2-C2) can potentially result in an additional 14 emergent (i.e., untrained) performances (reflexivity: A1-A1, A2-A2, B1-B1, B2-B2, C1-C1, C2-C2; symmetry: B1-A1, B2-A2, C1-B1, C2-B2; transitivity: A1-C1, A2-C2, C1-A1, C2-A2). In addition to increased teaching utility, the discovery of emergent equivalence was significant because it could not be explained by known learning principles, such as primary stimulus generalization and it illustrated how reinforcement contingencies could account for novel behavior and guide behavior in new environments. Thus, equivalence class formation may underlie complex human behaviors such as language and thought.

Regarding its origin, Sidman (1994) asserted that equivalence class formation results from naturally occurring reinforcement contingencies in the environment that create the prerequisite conditions for the defining behavioral properties. Species will have a varying potential to form equivalence relations and additional factors, such as testing conditions, context, and history, will determine whether and how this potential is realized. Sidman's view also holds that all aspects of the reinforcement contingency (antecendent-behavior-consequence) should participate in the equivalence class. That is, in addition to the stimuli used as samples and comparisons in the matching task, the class-specific defined reinforcers and responses also may become part of the equivalence class. For example, imagine that during training, a child is taught A1-B1 and B1-C1 discriminations, and is given a raisin for each correct response. Further, the child is taught A2-B2 and B2-C2 discriminations and is given a potato chip for each correct response. Training should yield two equivalence classes: one containing A1, B1, C1 and raisin, and the other containing A2, B2, C2 and chip. Studies that have explicitly tested whether class-specific reinforcers become members of an equivalence class have largely been positive. Although Sidman makes a similar argument for the inclusion of class-specific defined responses, evidence has been more difficult to obtain, and so this remains a topic under investigation.

Horne and Lowe's (1996) Naming Hypothesis asserts that equivalence is a direct result of verbal ability, and so only organisms with language ability will show evidence for stimulus equivalence. According to this hypothesis, equivalence relations in general, and symmetry in particular, are directly taught as children learn to speak. It is humans' ability to assign names to objects and coverly repeat those names that allows the relation "same" to form between stimuli. Without the ability to name, and without the ability to use the name as a mediator, an organism cannot form an equivalence relation. This hypothesis predicts that organisms without language ability (i.e., non-human animals or humans with atypical development) should not show evidence for equivalence. Early studies supported this hypothesis in that children who initially failed tests for equivalence passed them once they were taught to name the stimuli and in that nonhumans did not seem to pass tests for equivalence. However, more recent studies have shown evidence for equivalence both in humans lacking in language ability and in some nonhumans (see discussion below).

Relational Frame Theory (RFT; Hayes et al. 2001) asserts that as a result of humans' history of verbal behavior, they are given explicit training on relational responding to arbitrary objects across a variety of contexts. In other words, humans initially learn equivalence relations because symmetrical, transitive, and reflexive responses are reinforced as they learn language. At some point, this training results in the emergence of a generalized ability to respond in accordance with equivalence when novel stimuli or contexts

are encountered, provided the appropriate contextual cue (e.g., same as) is present. This theory is broader than Sidman's or the Naming Hypothesis because it encompasses a variety of ways in which stimuli can be related in addition to equivalence, such as opposite, larger than, smaller than, a part of, etc. Although RFT does not equate equivalence with verbal behavior, it emphasizes the consequences of extensive language training. Moreover, it also suggests that direct training on multiple exemplars of reflexivity, symmetry, and transitivity in the matching-to-sample context may also result in stimulus equivalence when novel stimulus sets are used, even in the absence of verbal capability of the organism. There is mixed evidence for this, however, in that some studies have shown that multiple-exemplar training facilitates equivalence class formation and others have shown limited or no effects.

Important Scientific Research and Open Questions

Equivalence class formation has been studied under a variety of conditions and, as a result, there is a substantial literature and all of the findings cannot be covered here. It has been documented using a range of stimuli, including auditory, visual, taste, odor, and haptic. It has been found in human populations such as college students, the elderly, young children, and individuals with developmental and intellectual disabilities, and the individual properties of equivalence have been found in animal species. Membership of individual stimuli in a particular equivalence class can be brought under contextual control such that a single stimulus may participate in different classes at different times. For example, the stimulus "fish" can be a member of distinct equivalence classes depending on whether the context is "food" versus "pets." Once an equivalence class has been formed, it can be expanded by simply teaching organisms to match one member of the class to a novel stimulus. Finally, if a new stimulus function is acquired by one member of the class, that function can also transfer to other members of the class without direct training.

Certain variables can influence the likelihood of equivalence class formation (Green and Saunders 1998). Teaching human participants to assign common names to the stimuli during baseline training can facilitate class formation, as can the type of instructions given to participants (e.g., participants are less likely to

pass tests for equivalence if minimal instructions are given, such as the experimenter saying "touch" while pointing to stimuli, than if they are given more specific instructions, such as "choose the comparison that goes with each sample"). There has been extensive analysis of the structure of equivalence classes (Fields and Verhave 1987), and several variables can influence the formation of equivalence classes. One is the way in which stimuli are combined in baseline training. Training can be conducted in a *linear series* (i.e., A-B and then B-C matching), by matching a common comparison to two or more samples (*many-to-one* [MTO] or comparison as node; A-B and C-B matching), or by matching two or more comparisons to a common sample (*one-to-many* [OTM] or sample as node, A-B and A-C matching). While the linear series is the least effective training sequence, the MTO and OTM sequences are similarly effective with humans with two exceptions: the elderly and individuals with developmental disabilities show more positive outcomes after MTO training. Another variable is the number of stimulus *nodes* in the class; a *node* is a stimulus that is related to at least two other stimuli. For example, in the OTM training design described above, the A stimuli are nodes and the B and C stimuli are singles. Positive equivalence outcomes decrease as the number of nodes increases. Finally, the order in which the test relations are presented also can influence the outcome. Positive outcomes are more likely if tests for symmetry are given directly after each baseline relation is learned, and the tests for transitivity are given once the tests for symmetry have been passed (simple-to-complex protocol) than if all the baseline relations are learned prior to testing the transitive and then symmetric relations (complex-to-simple protocol).

Because documenting equivalence class formation in preverbal and nonverbal humans and in nonhuman animals is one way of differentiating between the proposed origins of equivalence class formation, the role of language in equivalence class formation has generated much theoretical debate and research. Early work with humans seemed to indicate that verbal ability was necessary for equivalence class formation because (1) equivalence begins to appear in children as they become language-capable, (2) children without verbal skills did not seem to pass tests for equivalence, (3) children with some language skills who initially failed the tests passed them after being taught to give the stimuli

common names, and (4) nonhuman animals did not seem to pass the tests. However, many researchers question the conclusion that equivalence class formation is limited to language-capable organisms. First, verbal participants do not often provide common names for stimuli during testing, even when prompted to do so. Moreover, recent work has indicated that nonverbal children with developmental disabilities can pass equivalence tests in some circumstances, and evidence for all three properties of equivalence has been found in two California sea lions. There have also been positive reports of reflexivity and transitivity in species such as chimpanzees, monkeys, dolphins, rats, and pigeons. Evidence for symmetry in nonhumans has been more difficult to obtain and less than half the subjects tested for it have shown positive outcomes (see Lionello-DeNolf 2009, for a review). When symmetry is found, it is usually under conditions in which procedural variables are tightly controlled (such as where stimuli appear on the response apparatus). The variability observed in both the nonverbal human and the animal populations suggests that the training procedures typically employed do not yet account for all the variables that influence equivalence class formation. Current research is focusing on further identifying procedural variables that influence a positive outcome.

There are several open questions, and stimulus equivalence remains a vibrant research area. One current question is whether equivalence classes form in preparations other than matching-to-sample, such as in ▶ simple discriminations or in stimulus–stimulus pairings (as in Pavlovian conditioning). Another area is whether electrophysiological evidence (e.g., event-related potentials) corresponds with behavioral data. Finally, research is continuing to focus on translating what is known about equivalence class formation to natural environments in order to develop applications for teaching skill building and complex material (such as calculus) and to develop behavioral assays in areas such as phobias, prejudices, perspective taking, and false memories.

Cross-References

▶ Abstract Concept Learning in Animals
▶ Categorical Learning
▶ Concept Formation
▶ Operant Behavior
▶ Relational Learning

References

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior, 48*, 317–332.

Green, G., & Saunders, R. R. (1998). Stimulus equivalence. In K. A. Lattal & M. Perone (Eds.), *Handbook of research methods in human operant behavior* (pp. 229–262). New York: Plenum.

Hayes, S. C., Barnes-Homes, D., & Roche, B. (2001). Relational frame theory: A précis. In S. C. Hayes, D. Barnes-Homes, & B. Roche (Eds.), *Relational frame theory: A post-skinnerian account of human language and cognition* (pp. 141–154). New York: Kluwer/Plenum.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*, 185–242.

Lionello-DeNolf, K. M. (2009). The search for symmetry: 25 years in review. *Learning & Behavior, 37*, 188–203. PMCID: PMC19380896.

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston: Authors Cooperative, Inc.

Learning of Habits

▶ Habit Learning in Animals

Learning of Obedience to Authority

Norbert M. Seel
Department of Education, University of Freiburg, Freiburg, Germany

Synonyms

Shock studies; The Milgram experiment

Definition

Stanley Milgram's experiments on obedience to authority – sometimes referred to as the "shock" studies – centered on the question of the conditions under which people will carry out or refuse to obey commands from an authority. The studies were inspired by Milgram's interest in the pathologies of the Holocaust, and their conducting and results "shocked the world" (Blass 2004).

Theoretical Background

The starting point of Milgram's work on obedience to authority was his interest in the pathologies of the Holocaust. His central assumption was that obedience is a psychological mechanism which relates actions of individuals to certain, political purposes of others in positions of authority. Obedience of the kind aimed at in the military and other hierarchical organizations is so deeply ingrained that people tend to obey other people whom they believe are in positions of authority. The strength of this belief can even cause people to violate their own morals and ethics (Milgram 1974). This is, of course, much easier when people's moral standards are at a low level, as in the case of the murderers in concentration camps. More basically, Milgram wondered how and why it came about that ordinary Germany citizens were able to willingly carry out a genocide and massive killing program. He assumed that any behavior – no matter how evil – can become "normal" when it is seen as being legitimatized as obedience to authority.

The Study

In the original study, Milgram (1963) recruited 40 psychologically normal adult males between the ages of 20 and 50 through newspaper announcements and mail solicitations in New Haven. In order to increase the importance and legitimacy of the experiment, he conducted it at Yale University, and the participants were told they would be participating in a study on the effects of punishment on learning (Milgram 1974). The experiment was not a group experiment but rather was realized individually with each subject. More specifically, in each trial of the experiment each "true" subject was assigned the role of a "teacher," whereas a confederate of the experimenter had to play the role of a "learner." The third participant was the "experimenter," who was played by a high school biology professor. These participants met each other in a room and the subjects drew slips of paper from a hat to determine who would be the teacher or learner in the experiment. Of course, this random drawing was faked and the true participant was always the teacher. The teacher and learner were taken to another room, where the "teacher" could observe the learner being strapped down to a chair connected to a large shock generator in the adjacent room, where the "teacher" had to carry out the learning task. The generator had 30

switches labeled with voltage levels ranging from 15 to 450 V. The switches were also labeled in groups with verbal designations such as slight shock, moderate shock, danger, and XXX (Milgram 1963). The learning task involved the learner memorizing various word pairs. The teacher would read the list of pairs and then test the learner's memory of them. As instructed by the experimenter, the teacher had to administer a shock for each incorrect response, and more importantly to increase the shock generator by one level each time, announcing the level of shock before turning the switch (Milgram 1963). Each "teacher" was given a sample shock of 45 V prior to beginning the test in order to convince the subject of the authenticity of the generator. Although no shock was ever actually administered, the situation appeared realistic. Midway through the experiment, the confederate, who could be heard but not seen, screamed and begged for the experiment to be broken off. If the subject refused to administer shocks, the experimenter would urge him on with statements like "It is absolutely essential that you continue" and "You have no choice. You must go on."

The Expected Result

How many psychologically normal adult males would administer a 450 V shock resulting in cardiac arrest to another person? – Milgram asked this question to others, and the average estimate was no more than one in a hundred people, a group of psychiatrists even guessing one in a thousand. Furthermore, most people estimated that they themselves would break off at about 135 V before it could become dangerous for the learner. Almost none of those asked said that they would obey instructions up to 450 V.

The Observable Result

In contrast to the expectations of those asked, Milgram found that 27 out of 40 (i.e., 65%) of the men went to 450 V – and would have killed the learner. Maybe Milgram was himself astonished at this result, because he conducted an equally remarkable and elaborate series of follow-up studies in which he investigated how the subjects' obedience was affected by such factors as the proximity of the experimenter, the proximity of the victim, their own sex, and the presence of peers. Evidently, the obedience varied from one condition to another but remained in almost every case

astonishingly high – and would in most cases have ended with the learner's death.

Thus, Milgram concluded (as in a television interview in 1979) that "if a system of death camps were set up in the United States of the sort we had seen in Nazi Germany, one would be able to find sufficient personnel for those camps in any medium-sized American town." Fortunately, in the United States this pessimistic prediction has never become true, but unfortunately it has been verified in several places around the word – for example in Cambodia, China, Serbia, and Croatia, where evil politicians had no problems finding a sufficient number of people who obeyed the authorities and killed scores of other people with a feeling of doing what was necessary and right.

Important Scientific Research and Open Questions

The obedience experiments had a profound impact on academic social psychology and beyond. Indeed, as Stanley Milgram's first biographer Blass (2004) states, the studies literally shocked the world. They changed our general understanding of the Holocaust and other genocides in the course of history because they coincide in large part with Hannah Arendt's (1968) *Eichmann in Jerusalem: A Report on the Banality of Evil*, based on her observations of the Eichmann trial in Jerusalem in 1968. Like Eichmann, who contrary to many other SS officers can hardly be demonized as a pathologist, the ordinary people in Milgram's experiments were submitted to authority and were easily trained to become agents in a terrible destructive process (see also Bradley 2003).

Milgram's obedience experiments also changed academic social psychology, which was centering on "the trait/situation controversy" at the time and was questioning whether a person's behavior is affected more strongly by personality or by situation. Milgram's experiments demonstrate the "power of the situation" in learning obedience to authority – which is now seen as being somewhat independent of personality traits, though personality can unfold its power as a moderator variable with strengthening or weakening effects on learning obedience.

However, Milgram's obedience experiments also influenced academic social psychology with regard to the question of the ethics of experimentation with humans and other animals. Finally, the experiments also had significant effects on Milgram's career: Several years after completing the obedience experiments, which were already considered the most influential experiments ever conducted in social psychology, Milgram was turned down for tenure at Harvard. He lost his job and accepted an offer from the City University of New York – at that time a "second tier" university – where he spent the rest of his life.

Despite all ethical arguments against the obedience experiments, it has been replicated many times in the past decades – always with similar results (see for instance: Burger 2009; Blass and Schmitt 2001; Cassell 2005). The numerous examples of replications in broadcasting, for example, show that ethical constraints cannot stop the entertainment industry.

Cross-References

▶ Milgram, Stanley
▶ Social Construction of Learning

References

Arendt, H. (1968). *Eichmann in Jerusalem: A report on the banality of evil* (rev. ed.). New York: Viking.

Baumrind, D. (1964). Some thoughts on ethics of research: After reading Milgram's "behavioral study of obedience". *The American Psychologist, 19*, 421–423.

Blass, T. (2004). *The man who shocked the world: The life and legacy of Stanley milgram*. New York: Basic Books.

Blass, T., & Schmitt, C. (2001). The nature of perceived authority in the milgram paradigm: Two replications. *Current Psychology, 20*(2), 115–121.

Bradley, J. (2003). *Flyboys. A true story of courage*. Boston: Little & Brown.

Burger, J. M. (2009). Replicating Milgram: Would people still obey today? *The American Psychologist, 64*, 1–11.

Cassell, E. J. (2005). Consent or obedience? Power and authority in medicine. *The New England Journal of Medicine, 352*, 328–339.

Milgram, S. (1963). Behavioral study of obedience. *Journal of Abnormal and Social Psychology, 67*, 371–378.

Milgram, S. (1965). Some conditions of obedience and disobedience to authority. *Human Relations, 18*, 56–76.

Milgram, S. (1974). *Obedience to authority: An experimental view*. New York: Harper and Row.

Internet Sources

http://www.youtube.com/watch?v=88YJTg1nETk
http://www.youtube.com/watch?v=BcvSNg0HZwk
http://www.youtube.com/watch?v=IzTuz0mNlwU&feature=related

Learning of Predictions

▶ Anticipatory Learning

Learning Organization

JOHN BURGOYNE
Institute Department of Management Learning and
Leadership, Lancaster University Management School,
Lancaster University, Lancaster, Lancashire, UK

Synonyms

Dynamically capable organization; Learning company

Definition

"An organization that dynamically changes itself, its
members and its context in a mutually beneficial way
that enhances the long term viability of the whole
system and all its parts." This definition is based on
Pedler et al. (1996)

Theoretical Background

Nineteen ninety was a landmark year for the Learning
Organization, marked principally by the publications
of Peter Senge's "Fifth Discipline," (Senge 1990) and to
a lesser extent our (Pedler et al. 1991) book: "The
Learning Company."

Pedler, Burgoyne, and Boydell called it "Learning
Company" partly to differentiate it, certainly not to
identify primarily with the private sector, but mainly
to reclaim the terms "Company" for its original mean-
ing of people being together.

There are earlier uses of the term and the idea. It
gets a brief mention in Peters and Watermans' "In
Search of Excellence" (1982). Arguably it is implicit in
the total quality management idea which now goes
back 60 years, and there are various other references
to it in academic writing.

However, 1990 marks the moment when the idea
took off in a significant way, both in practice and in
theory. Interestingly it was in that order. The practi-
tioner literature took off around this time, followed by
the academic literature (we have suggested that we call
these two "learning organization" and "organizational
learning," an idea first put forward in the introduction
to a book this author edited with Mark Easterby-Smith
and Luish Arujo in 1999).

In the middle and late 1990s knowledge manage-
ment took over from learning organization as possibly
the leading idea in business transformation. This

author has argued that when organizations learn to
learn in the verb sense of the word learning they
produce learning in the noun sense, i.e., knowledge,
and if this is to be used as an organizational asset then
this has to be managed. This is perhaps too neat, but
there is a core of truth in it.

Again development of practice preceded develop-
ment of theory, but when the academics got round to
studying it Harry Scarsborough of Warwick Business
School pointed out that the learning organization,
despite being about organizations as a whole, and prob-
ably because of the "learning" word, was largely taken up
in the HR function, and knowledge management, prob-
ably because of a confusion between knowledge and
information, was largely taken up in the IT function.

Interestingly people who thought about knowledge
management soon concluded that one had to think
about "knowing" at the same time (and about what
we mean by knowledge anyway), thus reversing the
journey from learning as verb to learning as noun.

In 1999, the author had the honor of delivering the
Alec Roger Memorial Lecture in the Department of
Organisational and Occupational College at Birkbeck
College, London. He did it on the learning organization
10 years on. This is being written 20 years on.

The main argument was published at the time in
People Management (Burgoyne 1999). In it, the author
listed about ten criticisms of the learning organization
idea. Arguably, the two most important of these were
naivety about power and the moral and the lack of
obvious concern for the ethical aspect or organization
and organizational learning. The former observed that
early formulations of the learning organization
assumed a willingness of an open, collaborative, sharing
approach to organization, its work and rewards, which
has to some extent been dealt with both in theory and
practice since. The second related to crises like Enron
and the subsequent developments of concern for cor-
porate social responsibility and corporate governance.

With the benefit of hindsight, the author should
have added sustainability in the ecological sense.
Interestingly, the subtitle for our book "The Learning
Company" was "A strategy for sustainable growth". The
authors were deliberately playing on the double
meaning of the sustainability word, the long term
economic and the environmental sense. The environ-
mental bit does get a brief look in the book, but it is far
from highlighted. Today this meaning is much more

prominent, and the issue of where the two priorities work together or are in conflict is of great interest.

Returning to the knowledge management move, it is also noticeable that learning organization has been reinvented here under the heading of "dynamic capability," based much more in the language and theory of economics and corporate strategy, probably benefiting from not using the "learning" word. It is about having systems and procedures for innovation.

Taking the argument forward, it can be argued that the knowledge management move has lead to the creation of more knowledge workers, and that knowledge workers, unlike other kinds, need leading rather than managing. This can best be explained in terms of Marxist theory. Manual workers need access to the means of production (the machine on the factory floor) in order to add value to something and take a share of this as a wage. The machine is under managerial control so the managers have a relatively easy time managing the workers. However, with knowledge work, "mentofacture" as we call it (making with the mind rather than the hand). With knowledge work, the ownership of the means of production is returned to the worker, and walks out of the organizational door with the worker, not that he or she needs to go in through it in the first place, they can work from home or as an outsourced subcontractor. All they need is a back bedroom, a computer, and a phone line, so setup costs are small. In fact, you can do it from Starbucks if you want to. So to align the efforts of a knowledge worker with corporate purpose needs leadership rather than management, in both the transactional and transformational senses.

Leadership has preoccupied us for most of the new millennium so far, and may be reaching its end as a major preoccupation.

What comes next is an interesting question.

Keith Grint argues that there is a pendulum swing back and forward between scientific management and human relations. Learning organization was human relations, knowledge management was scientific management, and leadership is human relations, so it works so far.

In the health service, there has been a pulling back from leadership development toward things like Six Sigma, which is more scientific, more local in effect, quicker to implement, and easier to evaluate.

What else?

The most likely is: Virtual, Scientific, Lean, Spiritual, Sustainable, Networking Leadership.

Virtual because, as an extension of knowledge work, more and more work is becoming virtual, at three levels: for the individual more time at the workstation, which can be anywhere; for the organization more work that is virtually mediated, virtual teams, etc.; and for the organization externally more interactions that are virtual, Amazon, eBay, etc., and not just with customers, with employees, and suppliers too.

Scientific is the swing mentioned above, Lean is the likely response to the current financial situation, both in the public and private sector, the need to do the same with less.

Spiritual is in response to what I see as the next step in the agriculture-manufacture-mentoculture progression, to what this author calls "spiroculture," or, if that is to whacky for my audience, "identity culture." In either case it is about meaningfulness, not only for customers but for employees and other stakeholders too. This is why organizations market their brands internally to employees as well as externally to customers. This may call for a new form of charismatic leadership.

Then sustainability in both the economic and environmental sense. I remain optimistic on the grounds that in the spiroculture world, the rich as well as the poor can walk lightly on the earth.

Finally networking, in the network theory not just social networking sense, because, and this is a main current interest with my Learning Company coauthors and others. Increasingly leading is thought of as something that happens in networks as parts of complex adaptive systems is where it is at.

The author might be tempted to add "cross cultural" and something like "inter-faith" to the overlong title. This because terrorism, for which read the tension between Islam and the liberal, free market, democratic, semi Christian western tradition, is the other big game in town as well as the ecological environment. It is interesting to note that the Leadership Trust at Ross on Wye is finding that the title "Worldly Leadership" is proving a great attractor.

If there is a progression from learning organization to knowledge management to leadership, then an important question is what comes next. Perhaps it is scientific leadership?

This author is fairly sure that he has not got it right yet though. I suspect it is something more radical, with

a shorter title and without the word "leadership" in it at all, and the points above are just fingers in the direction of what it might be.

Important Scientific Research and Open Questions

A lot of these are to do with the acceptability and use of the idea. Because of the learning word it is seen much as part of Human Resources, and a "soft" issue. Possibly calling it "dynamic capability" is helping. Network theory and theories of chaos, complexity, and complex adaptive systems have yet to be fully exploited to develop this idea and its application.

Cross-References
► Absorptive Capacity and Organizational Learning
► Acquiring Organizational Learning Norms
► Action Learning (and Organizational Development)
► Barriers to Organizational Learning
► DICK Continuum in Organizational Learning Framework
► Organizational Change and Learning
► Professional Learning and Development
► Technological Learning in Organizations

References

Burgoyne, J. G. (1999). Alec Roger Memorial Lecture, The learning company ten years on. Department of Organizational Psychology, Birkbeck College, London University, 3 June 1999.

Pedler, M., Burgoyne, J. G., & Boydell, T. (1991). *The learning company.* Maidenhead: McGraw-Hill.

Pedler, M., Burgoyne, J. G., & Boydell, T. (1996). *The learning company.* Maidenhead: McGraw-Hill.

Peters, T. J., & Waterman, R. H. (1982). *In search of excellence.* New York: Harper and Row.

Senge, P. (1990). *The fifth discipline: The art & practice of the learning organization.* New York: Doubleday Currency.

Further Reading

Easterby-Smith, M., Burgoyne, J., & Arujo, L. (Eds.). (1999). *Organizational learning and the learning organization: Developments in theory and practice.* London: Sage.

Learning Outcomes

► Learning Criteria, Learning Outcomes, and Assessment Criteria
► Outcomes of Learning
► Problem Typology

Learning Persistent

► Learning Retention

Learning Perspectives

► Learning Metaphors

Learning Platform

► Learning Management System

Learning Potential Tests

► Dynamic Testing and Assessment

Learning Preferences

► Adaptation to Learning Styles
► Kolb's Learning Styles
► Learning Styles
► Social Interaction Learning Styles

Learning Processes

► Approaches to Learning and Studying

Learning Protocols

► Inductive Learning Spatial Attention

Learning Pyramid

► Multimodal Learning Through Media

Learning Rejection

► Learning Resistance

Learning Resistance

KNUD ILLERIS
Department of Learning, The Danish University School of Education, Aarhus University, Copenhagen NV, Denmark

Synonyms

Learning blockage; Learning rejection; Non-learning

Definition

The expression *learning resistance* has a double meaning. The immediate psychological understanding of the concept refers to situations in which one or more individuals directly or indirectly, consciously or unconsciously reject any engagement in a learning possibility. But there is also a sociological and political understanding referring to learning resistance as part of a general opposition to societal conditions by oppressed populations, segments, or classes. This understanding also involves the development of alternative strategies and learning possibilities.

Theoretical Background

It is striking that the psychological understanding and influence of learning resistance has only recently been launched as a topic of relevance to learning theory. The concept was introduced in 2002 by the Danish learning researcher Knud Illeris in his book "The Three Dimensions of Learning" and later elaborated in more detail in the more comprehensive "How We Learn" (Illeris 2002, 2007).

Illeris emphasizes the fact that it takes quite a strong mobilization of mental energy to resist learning activities, at least in cases which are defined as learning situations and in which the participants are expected and encouraged to learn what is taught or in other ways presented. However, this strong mobilization at the same time implies that there is a considerable potential and readiness for alternative learning. When an individual, consciously or unconsciously, refuses to learn what he or she is supposed to learn there is usually an important personal reason for this, and the individual will therefore usually also be strongly motivated to find, elaborate, and acquire some alternative knowledge and understanding which can substitute for and make better personal meaning than what has been presented. When adults are asked to think over in which situations they have learned something which has really been of personal importance to them, far more than half of the answers will usually refer to situations of learning resistance. Therefore, teachers and others should not react to learning resistance just by rejection or indifference but rather try to find an opportunity to help the individuals concerned to clarify the reasons for the strong reaction. Learning resistance should not be met by rejection but by help to understand and qualify what is at stake.

The sociological and political approach to learning resistance seems to have been investigated much more and has played a central role in many more or less alternative educational initiatives and movements in the second half of the twentieth century.

Most important has, no doubt, been the role of learning resistance and alternative learning in the theory and movement of alternative schooling of illiterate peasants in the developing countries as introduced by Brazilian Paulo Freire and described in his books "Pedagogy of the Oppressed" and "Cultural Action for Freedom" (Freire 1970, 1971). The fundamental issue was to combine the schooling and alphabetization of such oppressed people with their common uncovering of how and why they are oppressed and what to do to change this situation.

In the USA, the ideas of Paulo Freire have been taken up by Henry Giroux as a background for an extensive work on alternative schooling, mainly on the elementary school level, and Giroux has also been the author of the most important theoretical work on the concept and theory of resistance in relation to learning and education.

As one of many examples from Europe, the work of German Oskar Negt can be mentioned as including both theoretical and practical efforts in the same line and comprising both adult education of workers and an alternative primary school (the Glocksee School Project). However, Negt's theoretical work has been centered on the concept of *exemplary learning* (learning by working with subjectively relevant and societally representative examples), and resistance has only been taken up indirectly (Negt 1971, 1997).

Important Scientific Research and Open Questions

As already stated, research on learning resistance as a psychological concept has been very limited. Activities in relation to the sociological and political ideas of learning resistance have flourished in the 1960s, 1970s, and 1980s, but since the 1990s they seem to have more or less vanished. However, precisely the same strict, top directed, bureaucratic, and controlling neoliberal educational policy which lies behind this development obviously creates increasing learning resistance at a basic level and therefore also causes an increasing need for research and other measures which can deal with and counter this tendency.

Cross-References

▶ Inhibition and Learning
▶ Learning Defense
▶ Resistance to Learning and the Evolution of Cooperation

References

Freire, P. (1970). *Pedagogy of the oppressed.* New York: Seabury.
Freire, P. (1971). *Cultural action for freedom.* Cambridge, MA: Harvard Educational Review.
Giroux, H. A. (1981). *Ideology, culture, and the process of schooling.* Philadelphia: Temple University Press.
Giroux, H. A. (2001 [1983]). *Theory and resistance in education: Toward a pedagogy for the opposition.* Westport: Bergin & Garvey.
Illeris, K. (2002). *The three dimensions of learning: Contemporary learning theory in the tension field between the cognitive, the emotional and the social.* Leicester: NIACE (Malabar: Krieger).
Illeris, K. (2007). *How we learn: Learning and non-learning in school and beyond.* London: Routledge.
Negt, O. (1971 [1968]). *Soziologische Phantasie und exemplarisches Lernen.* Frankfurt a.M: Europäische Verlagsanstalt (*Sociological imagination and exemplary learning*).
Negt, O. (1997). *Kindheit und Schule in einer Welt der Umbrüche.* Göttingen: Steidl (*Childhood and school in a changing world*).

Learning Resources

▶ Mental Models and Lifelong Learning

Learning Retention

Judy Tzu Huang
National Open University, New Taipei City, Taiwan

Synonyms

Dropout; Learning motivation; Learning persistent

Definition

Learning retention is a psychological mechanism that makes the learning experience a success.

Theoretical Background

Learning retention, when referring to the strength that supports an individual to continue in his/her learning cycle, is related to both individual and context factors. The magnitude that drives individual retaining in learning activity is usually contributed by the interaction effects of individual and context variables. In learning retention research, individual factors might include a variety of characteristics, such as personal demographic background, motivation, ability, and sense of control. Context factors might include aspects of teaching, interpersonal interactions, learning support, and physical environments. Learning retention, when considering in a progressive way, could be explained as a psychological mechanism that makes the learning experience a success.

Woodley and Parlett tried to picture how adult learners persist or drop out in their learning process. They offered a theory of "pull" and "push" which explains that adult learners would face two kinds of power that strongly influences their learning. The power of "pull" would have a negative magnitude that pulls the learner away from learning, such as difficulties in study, high tuition fee, dissatisfaction toward teachers, family burden, etc. The power of "push" would provide learners a positive motivation to continue learning, such as a promise of positive future,

a sense of growth, and family support. When the magnitude of "push" is greater than "pull," the learner would be more likely to continue. But when the magnitude of "push" is smaller than "pull," the learner might experience a negative pressure that would possibly pull the individual away from learning (Chen and Chen 1988, Chen 1995).

Kember (1995) constructed the learning retention model conceptually similar to the theory of "pull" and "push." Kember constructed the "Student Progress Model" which introduced a dynamic path. Kember explained that learners would undergo two different types of learning path. One is from social integration to academic integration; another is from external attribution to academic incompatibility. Adult learners interacting with the learning environment would undergo one of the learning paths and finally come to face the result of learning (GPA). After weighting between the cost of continuing to learn and GPA, individual learners would make their own decision, to drop out or to retain.

Important Scientific Research and Open Questions

Huang (2005) constructed a learning retention model that described successful learning experience as a series of psychological challenges. It takes both internal (individual inner aspects) and external supports (learning environment) to accomplish learning. Especially for a long-term learning activity, persistence is the essential basis for success. Huang, concluding from the discussion based on the perspectives of teachers and adult learners, emphasized that individual and environmental factors are influential to learning retention either positively or negatively. For individual factors, learner's characteristics or personal perception and attribution are also included.

Huang emphasized that there exists a decision point that is critical for retention. It is the point when each learner will measure the possibility of success in the future based on the result of both sense of progress and academic achievement. The result of all these considerations would be to retain or drop out (Fig. 1).

According to Huang's learning retention model, considering the context-reliance learner who is more dependent upon interpersonal support, closer human contact and proper encouragement from teachers and peers would be essential to build up the sense of growth

Learning Retention. Fig. 1 Adult learning process and retention model (Huang 2005)

which is crucial to the positive measure of success. For a more self-regulated learner who prefers individualized learning, more offering of independent studies and subject explorations would probably be essential to build up the sense of growth which is an important source of satisfaction.

Understanding factors that influence the strength of learning retention does provide ideas to find a way to enhance positive power that would help individual learners to retain in learning, in other words, meeting the individual need to build up a sense of satisfaction would be a primary consideration to individualized learning support.

Cross-References

▶ Research of Learning Retention and Support
▶ Retention and Learning

References

Chen, R. (1995). Adult open & distance learning – A research on NOU learners, NOU.

Chen, S.-H., & Chen, R,-C. (1988). A research on NOU drop-out, NOU.

Huang, T. J. (2005) A research on learner retention and learning support, US-China education review Jan 2005, US-China Education Review(Journal), Inc.

Kember, D. (1995). *Open learning courses for adults: A model of student progress.* New Jersey: Educational Technology.

Learning Self-Image

▶ Learning Identity

Learning Set Formation and Conceptualization

ROGER K. THOMAS
Department of Psychology, The University of Georgia, Athens, GA, USA

Synonyms

Concurrent discrimination learning; Deuterolearning; Interproblem learning; Learning to learn; Object quality learning set; Reversal learning; Transfer of training

Definitions

Learning set formation (LSF), according to Harlow (1949) who originated the term, is defined as "...learning how to learn efficiently in the situations the animal frequently encounters" (p. 51). Optimal evidence for LSF is seen when animals learn successive discrimination problems progressively more quickly, often, in one trial. *Conceptualization*, as defined here, refers to a subject's ability to select correctly exemplars of a class concept using trial-unique discriminanda or responding correctly to their *first* presentations if discriminanda are presented for more than one trial; otherwise, the possibility cannot be discounted that a subject's performance was based on rote memorization.

Theoretical Background

One of Harlow's most widely used experimental procedures, object quality learning set, involves multiple problems where two objects (one associated with a food reward) are presented for some number of trials (n) with six being, perhaps, most common; then, two new objects are presented for n trials, etc. Because the animal has no basis to know which to choose on trial 1, its choice is due to chance. If the animal "wins" on trial 1 (chooses the object with the food reward) the optimal strategy is to "stay" with that object for the remaining trials with those objects; if it "loses" on trial 1, it should "shift" to the other object for the remaining trials to maximize its food rewards. Optimal results will reflect increasing success on trial 2 as a function of the number of problems, and such successful performances have been described as learning a "win-stay, lose shift" rule or strategy. However, as

discussed below, an animal might show LSF without having learned such a "rule."

Early findings comparing species on their rates of LSF seemed to confirm general impressions shared by many about the comparative intelligence of species. For example, chimpanzees attained 90–100% correct on trial 2 in about 200 problems, while rats achieved only about 55% correct on trial 2 in 1,000 problems. However, the discriminanda typically used were intended to be identified visually, namely, objects that varied in color, form, and size. This was an advantage for chimpanzees, which have human-like trichromatic color vision, compared to rats which are color blind and otherwise have poor vision. When odoriferous discriminanda were used with rats, their performances were comparable to those of chimpanzees (Bailey and Thomas 1998).

Harlow (1959) also wrote, "...all concepts such as triangularity, middle-sizedness, redness, number, and smoothness evolve only from LS formation" (p. 510), and immediately preceding this quotation, Harlow wrote, "...insightful learning through LS formation is a generalized principle ... [that] ... appears in ... oddity learning" (p. 510). If by "evolve only through LS formation" Harlow meant that multiple problems and trials with discriminanda that are exemplars of concepts may be needed to enable an animal to affirm trial-unique exemplars of the concept on a reliable basis, that part of the quotation seems reasonable. However, whether "insightful learning through LS formation is a generalized principle in oddity learning," raises significant questions.

Important Scientific Research and Open Questions

Thomas and colleagues (e.g., Bailey and Thomas 1998) investigated oddity concept learning by rats using odoriferous discriminanda which were repeated for five trials (position of the odd object was randomized). A typical oddity problem involves two clearly similar or identical discriminanda and one clearly different or odd discriminandum. In two separate investigations, they found a clear distinction between learning the oddity concept versus learning to choose the odd object via LSF. If one has acquired use of the oddity concept, first trial performances using oddity problems should be better than chance, because the odd object will be obvious on the first trial. In the most extensive study,

all four rats performed at chance on trial 1, but all showed increasing success on trial 2 (the four rats averaged 76% correct on trial 2 over 60 problems). Other nonhuman species such as monkeys and apes easily acquire the oddity concept. In any case, the research shows that conceptualization and LSF can be differentiated using oddity problems, which leaves open the question of how LSF relates to conceptualization.

One question, especially relevant to relative class concepts such as "oddity," is that it is reasonable to suggest that if an animal is presented discriminanda concurrently where some are identical and one is different (i.e., odd), the odd discriminandum should be immediately perceptible (this general argument is applicable also to "same" vs. "different," "more" vs. "fewer," "larger" vs. "smaller," etc.). What the animal is required to learn is that the odd object in any *new* exemplar is the object associated with reinforcement. That rats did not learn that reinforcement was associated with odd but did learn to use trial 1 information to perform well on trials 2-*n*, further confirms the argument that LSF without conceptualization has occurred.

To consider further the relationship between LSF and conceptualization, a conceptual framework is needed. Building from work by Gagné (1970) and Borne (1970), Thomas proposed an eight-level hierarchy of intellectual or cognitive abilities suitable for all species that included *all of the fundamental types of learning abilities.* Any learning task or product, no matter how complex, can be reduced to these fundamental learning or cognitive abilities; see Bailey et al. (2007) for references, examples, and additional explanations of each of the levels. The fundamental learning abilities (see schema below) ranged from the lowest level (Level 1) habituation and sensitization, complementary processes which appear to be within the capabilities of single-celled organisms, to the two highest levels which involve using class concepts in conjunctive, disjunctive, conditional (level 7), or biconditional (level 8) relationships. Nonhuman primates have been shown to have some degree of capability at level 7, but only humans have been shown to be capable at level 8. Generally (with possibly minor exceptions), that the abilities are hierarchical is due to lower levels being prerequisites for higher levels. Any animal's (including human's) general intellectual or cognitive capability depends on how many types of learning abilities from the hierarchy are within its capabilities. It is recognized

that most intellectual/cognitive tasks may involve an animal using several of its abilities concurrently, in series and in parallel.

A hierarchy of the fundamental types of learning upon which intelligence and most cognitive abilities are based
8. Using class concepts in biconditional relationships as defined by symbolic logic
7. Using class concepts in conjunctive, disjunctive, or conditional relationships as defined by symbolic logic
6. Using absolute and relative class concepts
5. Multiple discrimination learning: concurrent discrimination learning or learning set formation
4. Chaining units of stimulus-response learning
3. Stimulus-response learning (i.e., Instrumental or operant conditioning)
2. Signal learning (i.e., Pavlovian or classical conditioning)
1. Habituation and sensitization

Thomas and colleagues have also considered the question of where LSF fits within the hierarchy (Bailey et al. 2007). The schema shows that concept learning begins with class concept learning at level 6, and that LSF is deemed to be at level 5. Class concept learning is divided into absolute class concepts and relative class concepts. Identifying features of discriminanda that serve as exemplars of absolute class concepts are inherent in each discriminandum, such as, an exemplar of "flower," "chair," "triangularity," etc., but identifying features of discriminanda associated with relative class concepts require comparing discriminanda such as those used to manifest "oddity," "same" (a pair of clearly similar or identical objects) versus "different" (a pair of clearly different objects), "more" versus "fewer," etc. Evidence for conceptualization requires successful responses to exemplars of class concepts using *trial-unique* discriminanda or successful *first-trial* performances when discriminanda are presented more than once. LSF cannot involve conceptualization as defined here because first-trial successes can occur only by chance. Placing LSF formation at a prerequisite level for concept learning as was done here also appears to be consistent with Harlow's earlier assertion that "all concepts . . . evolve only from LS formation." In this regard it may be noted that Concurrent Discrimination Learning, which involves learning multiple

discrimination problems concurrently and presented in random order, is also at level 5 and that some students of LSF have considered Concurrent Discrimination Learning to be a type of LSF.

One interpretation for successful LSF might be that the subject relatively passively acquires an efficient strategy for rote learning and working memory that can be applied to each new pair of discriminanda. It is reasonable to conceptualize successful performances on trials 2-*n* in terms of concurrent rote learning of two simple associations. For example, by chance an animal might choose object A and receive food reinforcement and then simply associate A with reinforcement on trials 2-*n*, or, alternatively and following an initial nonreinforced choice of B, it might simply associate A with reinforcement on trials 2-*n*. The animal need never use mediational "rules" such as "avoid B" and "choose A" nor one such as "win-stay, lose-shift."

Nevertheless, some may consider it to be an open question whether to agree with Thomas and colleagues, and many who study concept learning in animals, regarding (a) what "conceptualization" means or (b) that the necessary evidence for conceptualization requires that the subject respond correctly to trial-unique or first trials with new exemplars of the concept. For example, one might argue that learning a strategy or "rule" such as that which humans might verbalize as "win-stay, lose shift" involves a kind of conceptualization. However, it must also be recognized that with animals it is unlikely that they learn anything akin to such verbalizations of a rule or strategy, not to overlook that it is unlikely that an experimenter could provide unequivocal evidence that they did. It might only involve a kind of passive learning, as described above, where, through extensive experience, they acquire a habit or response pattern that serves them well in acquiring rote-learning strategies to use when performing tasks such as object quality learning set.

Cross-References

▶ Abstract Concept Learning in Animals
▶ Analogical Reasoning in Animals
▶ Animal Learning and Intelligence
▶ Associative Learning
▶ Behavioral Capacity Limits
▶ Complex Learning
▶ Complex Problem Solving
▶ Concept Learning
▶ Conditional Reasoning
▶ Conditions of Learning
▶ Conditions of Learning – Robert M. Gagné
▶ Discrimination Learning Model
▶ Evolution of Learning
▶ Human Learning
▶ Laboratory Learning
▶ Learning About Learning
▶ Logical Reasoning and Learning
▶ Problem Solving
▶ Rote Memorization
▶ Rule Formation
▶ Working Memory

References

Bailey, A. M., & Thomas, R. K. (1998). An investigation of oddity concept learning by rats. *The Psychological Report, 48*, 333–344.

Bailey, A. M., McDaniel, W. F., & Thomas, R. K. (2007). Approaches to the study of higher cognitive functions related to creativity in nonhuman animals. *Methods, 42*, 3–14.

Borne, L. E., Jr. (1970). Knowing and using concepts. *Psychological Review, 77*, 546–556.

Gagné, R. M. (1970). *The conditions of learning*. New York: Holt, Rinehart and Winston.

Harlow, H. (1949). The formation of learning sets. *Psychological Review, 56*, 51–65.

Harlow, H. (1959). Learning set and error factor theory. In S. Koch (Ed.), *Psychology: A study of a science* (Vol. 2). New York: McGraw-Hill.

Learning Setting

▶ Learning Environment

Learning Skills

▶ Cognitive and Affective Learning Strategies

Learning Society

▶ Lifelong Learning

Learning Spatial Orientation

Susanna Pietropaolo, Wim E. Crusio
Centre de Neurosciences Intégratives et Cognitives
UMR5287, Université de Bordeaux and CNRS,
Talence, France

Synonyms

Goal-oriented behaviors; Place learning; Spatial memory

Definition

Spatial orientation refers to the ability of an individual to regulate his body orientation and/or posture in relation to the surrounding environment. Good spatial orientation relies on the effective perception, integration, and interpretation of visual, vestibular (mediated by organs of equilibrium located in the inner ear), and proprioceptive (collected by receptors located in the skin, muscles, tendons, and joints) sensory information. Learning spatial orientation is the ability to learn directions to reach a goal, such as the location of specific resources (access to food or partners for reproduction, for example) or ways to escape from danger. In general, all non-sessile animal species (with the possible exception of non-benthic aquatic animals) need to acquire information about the surrounding environment, such as the position of familiar and distinctive landmarks, and subsequently use this knowledge to navigate. Navigation can then be conducted either by using these landmarks and triangulate them with the direction of the goal, or by a landmark-independent compass, such as the earth's magnetic field or celestial cues. Depending on the characteristics of the particular species, spatial navigation can be realized over relatively short distances, such as within a home range, or across long distances, for example, to migrate to new home ranges (Gould 2004).

Theoretical Background

Much of the classical research on spatial learning has been conducted in nonhuman animals; this work has allowed uncovering the neurobiological mechanisms underlying learning spatial orientation. Recent advances in brain imaging have confirmed and extended our knowledge of the neurobiology of spatial memory in humans.

There have been two main conflicting hypotheses about how spatial learning occurs. The first proposed that animals acquire knowledge of the layout of the environment and form a cognitive map (Tolman 1948); whereas the second suggested that this type of learning, like others, is based on the formation of stimulus–response (S–R) habits (Hull 1943). Subsequent research has demonstrated that animals are able to solve spatial tasks using both map-based and S–R navigational strategies and that these strategies may be acquired in parallel (White and McDonald 2002), since lesion studies have shown that they are mediated by distinct brain systems (O'Keefe and Nadel 1978; White and McDonald 2002). External sensory cues are used differently depending on the strategy. The map-based, or locale, strategy seems to favor distal over proximal landmarks, whereas the S–R (or taxon) strategies preferentially use proximal cues, when they are available. This hypothesis of multiple parallel memory systems has highlighted the major importance of three neural structures: the hippocampus, the matrix compartment of the dorsal striatum (caudate-putamen), and the amygdala. Although these systems process information independently, they can interact by either simultaneous parallel influence on behavioral output or by directly influencing each other, and these interactions can lead to similar (cooperative interactions) or to different (competitive interactions) behaviors.

Important Scientific Research and Open Questions

The most important advance in the study of spatial learning was undoubtedly the discovery in 1971 of the existence of specific cells in the rat hippocampus whose firing encodes the location of the animal, each cell only firing when the animal is within a certain portion of the environment, its place field (O'Keefe and Dostrovsky 1971). Cells with similar response patterns have later also been found in primates, including humans. The presence of these cells has been a strong argument against the S–R hypothesis of spatial learning, since the firing patterns of these cells could not be described in terms of response to a single stimulus. Indeed, the discovery of place cells played a critical role in the development of the influential cognitive map theory (O'Keefe and Nadel 1978). However, a gap remained

between place and cells and the theoretical requirements of a functional system for spatial orientation, stimulating the search for additional neuronal populations (reviewed in Andersen et al. 2007). "Head direction cells" were described from the mammillary bodies, anterior thalamic nuclei, and dorsal presubiculum. These cells fire when the animal's head points toward a specific direction, independently of its current location. A third type of cells, known as grid cells, occurs in the dorsomedial entorhinal cortex where they fire in a set of locations laying out a hexagonal grid on the specific environment in which an animal finds itself. The ways in which the activities of these cells are modulated and integrated are highly complex and remain largely unknown. For example, in open environments the firing rates of place cells are not influenced by the animal's orientation, whereas in environments in which movement direction is limited, such as in mazes, firing is strongly modulated by the rat's direction. Furthermore, it has been hypothesized that a set of orientation-dependent cells called "view field" units may become associated with a set of goal units, encoding the direction to the goal relative to the current heading direction. "Spatial view cells" that fire as a function of where the animal is looking rather than where it is, have been identified in the macaque hippocampus. The presence of location-independent view cells has also been observed in humans, where they were found to constitute about 15% of the neurons of the parahippocampal gyrus.

Another crucial advance in the study of spatial learning was the development of a simple and widely applicable testing procedure for laboratory rodents, the water navigation test. In its basic form, animals are trained to find a hidden platform in order to escape from a circular pool of opaque water. Since there are no local cues indicating the position of the platform, learning is supposed to rely only on distal information. Lesions of several areas of the hippocampal formation impair or abolish learning of the water maze task. This impairment disappears when the platform is made visible, thus suggesting that the observed deficit is spatial in nature. This task has also been used extensively to investigate in more details the hippocampal control of spatial navigation, showing that small portions of intact dorsal, but not ventral hippocampus are sufficient to solve the spatial task, thus suggesting the existence of a functional differentiation along the long

axis of the hippocampus. The water navigation task has become hugely popular in behavioral neuroscience, being widely used also in laboratory mice. Mice are increasingly employed to investigate the neurobiology of spatial learning thanks to the availability of numerous lines carrying targeted, sometimes even inducible, gene deletions. Mouse and rat studies in this field have evolved impressively in recent years, complementing classical lesion methods with reversible pharmacological interventions, monitoring of the expression of early genes, and single-unit recordings. Furthermore, functional studies of spatial learning have become possible also in humans by combining imaging techniques with virtual reality, e.g., assessing navigation in imaginary towns.

Despite the advances in our knowledge of spatial learning, there are several points that remain elusive. The main one probably concerns the role of the hippocampus in controlling the various aspects of learning spatial maps (Andersen et al. 2007). As already described, the general role of the hippocampal formation in spatial cognition was first demonstrated by lesion studies in laboratory rats. Further evidence was provided by neuroethological research on other rodent species. For example, polygamous male meadow voles having a home range five times larger than females show a corresponding difference in hippocampal volume and in spatial learning, while these differences are absent in closely related monogamous prairie voles. Nonetheless, both rodent and human studies (the latter based on patients with complete ablations of the hippocampal formation) have suggested that, strictly speaking, the hippocampal formation is actually necessary only to acquire new spatial information, but not to store it, a function that may rather be covered by neocortical areas. It is also not clear whether the hippocampal areas are mainly associated with the process of learning the location of a goal ("knowing where"), rather than with designing the strategy to reach it ("getting there"), the latter ability being disrupted by fimbria-fornix lesions. Finally, there are forms of learning spatial maps that have clearly a mixed control. Homing behavior, i.e., the special form of spatial learning allowing an animal to come back to its home base, is one intriguing example: studies conducted on pigeons have demonstrated that some components of the navigation of these animals are hippocampus dependent, while others are not. This evidence has suggested the existence of multiple

mapping systems in the brain, prompting the elaboration of new complex theoretical and computational models that are still under discussion.

Cross-References

References

Andersen, P., Morris, R. G., Amaral, D., Bliss, T., & O'Keefe, J. (Eds.). (2007). *The hippocampus book.* New York: Oxford University Press.

Gould, J. L. (2004). Animal navigation. *Current Biology, 14*(6), R221–R224.

Hull, C. L. (1943). *Principles of behavior: An introduction to behavior theory.* New York: Appleton-Century.

O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map.* Oxford: Clarendon.

O'Keefe, J., & Dostrovsky, J. (1971). The hippocampus as a spatial map. Preliminary evidence from unit activity in the freely-moving rat. *Brain Research, 34*(1), 171–175.

Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review, 55*(4), 189–208.

White, N. M., & McDonald, R. J. (2002). Multiple parallel memory systems in the brain of the rat. *Neurobiology of Learning and Memory, 77*(2), 125–184.

Learning Strategies

Ali Simsek
Institute of Communication Sciences,
Anadolu University, Eskisehir, Turkey

Synonyms

Cognitive strategies; Generative learning; Learning to learn; Metacognitive skills; Self-regulation of learning; Study habits

Definition

Learning strategies can be defined as individual approaches that learners employ to accomplish academic tasks or improve their social skills. In this sense, learning strategy is a preferred choice rather than an inherent personal trait. It may be deliberately selected based upon the learner's individual assessment of the situation, and changed if it does not work.

A learning strategy is different and should not be confused with learning style. In general, learning strategy involves situational choices of learners toward accomplishing a task. Learning style, on the other hand, is a distinguishing individual difference of learners related to the way of perceiving, processing, and interpreting learning stimuli.

There are a number of words used interchangeably in relation to the concept of learning strategies such as cognitive strategies, study habits, learning to learn, self-regulation, and metacognitive skills. Among them, the most frequently used concept is "cognitive strategies." It should be noted, however, that learning strategies do not only have cognitive dimensions but also affective and even psychomotor dimensions.

Theoretical Background

Learners employ more than one strategy in the learning process depending upon conditions of the situation. The reason is simple: Each strategy is effective for different learning tasks. The choice of learning strategy also interacts with personal characteristics of the learner. A particular strategy may be effective for some learners, while it does not bring about success for others. Therefore, the learner has to evaluate all aspects of the instructional situation and employ the most appropriate strategy (Gu 2005).

The choice of learning strategy is highly contextual; that is, there are many strategies in the personal pool of strategies for each learner, and the learner employs certain strategies that he/she thinks appropriate for a situation. Of course, this process requires strong metacognitive skills that will help learners make the best judgment about his/her own capabilities.

Whatever the conditions, learning requires strategic thinking and acting. Various instructional approaches, types of content, and individual differences of learners interact with each other in the learning process. It is not always easy to be aware of this interaction and achieve the learning task by using a combination of appropriate strategies. Considering that the main responsibility for learning lies on shoulders of the learner, it becomes important for learners to find out what kinds of

learning strategies are available, how to select appropriate ones, and evaluate consequences of using them (Tait and Entwistle 1996).

There are a number of classifications of learning strategies in the literature. Among them macro–micro; general–special; primary–secondary; dependent–independent; external–internal; separated–embedded; and multipurpose–single purpose strategies are particularly common (Simsek 2006).

Weinstein and Mayer (1986) classified learning strategies in eight major categories such as strategies of basic rehearsal, complex rehearsal, basic elaboration, complex elaboration, basic organization, complex organization, metacognition, and motivation. This is probably the best known and the most accepted classification in the literature. However, it is possible to reduce the number of categories into five, by merging the basic and complex subgroups of the first three groups of strategies. The rationale for reducing the number of categories from eight to five is that it is either difficult or confusing to differentiate basic and complex categories in practice. Furthermore, complex strategies often include or involve activities that are parts of basic strategies.

The five major categories of learning strategies as discussed here are rehearsal, elaboration, organization, metacognition, and motivation. It can be thought that there is a hierarchy of sophistication among these groups of strategies, particularly for the first three categories.

Rehearsal strategies are mainly based on identifying and repeating important components of the content. Learner activities in this category may include but not limited to oral reading, underlining, marking, repeating, note-taking, using mnemonics, highlighting, memorizing, etc. These strategies are particularly useful for rote learning.

Elaboration strategies require successful comprehension of the available content and extending it by adding new components to enhance the given content. Learning activities in this category may involve paraphrasing, summarizing, using metaphors, generating questions, comparisons, finding similarities/differences, and adding new information. Strategies in this category are particularly effective for learning and developing intellectual skills.

Organization strategies involve that the learner analyzes the given content from a critical perspective and comes up with a better and easier structure for learning it. Grouping, restructuring, categorization, finding examples, converting into a different symbol system, translation, using diagrams, etc. are common learning activities related to these strategies. Most of the activities in this category have been developed for learning tasks involving list-learning.

Metacognition strategies are about developing self-awareness of one's own strengths and weaknesses that affect learning. Developing these strategies take time and are based on accumulation of personal experiences. Therefore, younger learners may benefit little from these strategies, while more mature learners find them particularly beneficial.

Motivation strategies usually involve affective components of learning. Learners feel either ready to learn a particular task because it is necessary or they find it challenging and unnecessary to learn. Of course, they evaluate their prior experiences, present motives, and prospective ideals before using or thinking about these strategies.

When using learning strategies or perceiving and processing information into memory, four basic processes are in operation. These are: (1) *selection* (learner's directing his/her attention to some information and sending them to working memory); (2) *acquisition* (transferring some of this information into long-term memory from the short-term memory); (3) *construction* (actively organizing links among various information pieces and producing new and consistent patterns); and (4) *integration* (learner's surveying prior knowledge in the long-term memory, sending this information to working memory, and forming external connections between new information and prior knowledge). It is important to note that these four basic processes bring about different components and functions during each learning strategy. Furthermore, these four basic processes determine the nature of learning strategies when trying to accomplish learning goals. For example, selection and acquisition are dominant during rehearsal strategies, while construction and integration are dominant during elaboration and organization strategies.

Important Scientific Research and Open Questions

Research shows that learners have a number of gains when they start thinking strategically about learning tasks and employ functional strategies in order to

accomplish their learning goals. These are common results of many research studies conducted under various educational settings over the years. Specific findings that are related to certain independent variables can also be found in the literature of education and psychology. In general, learners who employ effective strategies:

(a) Rely on their minds
(b) See more than one way of doing something
(c) Understand their mistakes and try to correct them
(d) Evaluate their own products and behaviors
(e) Enhance their memories
(f) Increase learning levels
(g) Improve self-esteem
(h) Feel that they are powerful
(i) Develop the sense of responsibility
(j) Increase the ratio of completing a task and doing it correctly
(k) Develop personal study habits
(l) Learn how to try or show efforts
(m) Concentrate on and engage in learning tasks

One may wonder which strategies should be used more in order to maximize the above gains. The answer is not simple because research shows that learners employ a wide variety of strategies depending upon expected learning outcomes and domains of knowledge. Research also demonstrates that high-achieving learners select and employ effective strategies more frequently than low-achieving learners (Cho and Ahn 2003). It means that proper use of learning strategies is highly contextual and it requires powerful metacognitive skills. In this sense, there is no "ideal strategy" that works for all kinds of learning tasks.

Although the use of learning strategies contributes to achievement of learners, there are certain situations where learners do not prefer to use them or use them very rarely. Garner (1990) identifies such situations as: (1) when learners are not informed about their ongoing performance; (2) when they can complete learning tasks with primitive routines without any creative efforts; (3) when knowledge base that lead to selecting and employing proper strategies is not sufficient; (4) when goals do not require or support the use of strategies; and (5) when the use of strategies is considered a waste of time due to minimum transfer of strategic activity to tasks or events.

There is considerable amount of research on learning strategies. However, each study has investigated the impact of a particular strategy on a certain dependent variable. This makes it difficult to combine all research findings and reach certain generalizations. Generally speaking, as the complexity of learning tasks increases, the sophistication level of learning strategies increases. In other words, cognitive load required by a learning strategy is directly related to the acquisition of learning tasks. For example, a complicated learning task cannot be completed with the use of a simple strategy.

In order to take advantage of learning strategies, there are both macro and microlevel measures that should be taken in educational settings. First, learners should be trained about identifying, selecting, and employing effective strategies. Secondly, both instructional designers and classroom teachers should be sensitive to learning strategies of individual learners. Third, learners should be encouraged to share their effective learning strategies with each other. Fourth, learners should be given appropriate opportunities to monitor their development as users of learning strategies. Finally, more research should be conducted to find out possible interactions among learner characteristics, instructional treatments, and ways of assessment.

Cross-References

► Abilities to Learn: Cognitive Abilities
► Analogy-Based Learning
► Approaches to Learning and Studying
► Cognitive and Affective Learning Strategies
► Collaborative Learning Strategies
► Elaboration Strategies
► Elaboration Strategies and Human Resources Development
► Generative Learning
► Learning About Learning
► Learning Styles
► Metacognition and Learning
► Metalearning
► Mnemonic Learning
► Self-regulated Learning
► Study Strategies

References

Cho, S., & Ahn, D. (2003). Strategy acquisition and maintenance of gifted and non-gifted young children. *Council for Exceptional Children, 69*(4), 497–505.

Garner, W. (1990). When children and adults do not use learning strategies: Toward a theory and settings. *Review of Educational Research, 60*(4), 517–529.

Gu, P. Y. (2005). *Learning strategies: Prototypical core and dimensions of variation* (Working paper No. 10). Nanyang Technological University National Institute of Education Centre for Research in Pedagogy and Practice, China.

Simsek, A. (2006). Bilissel stratejilerin öğretimi [Teaching cognitive strategies]. In A. Simsek (Ed.), *Icerik turlerine dayali ogretim* (pp. 181–208). Ankara: Nobel.

Tait, H., & Entwistle, N. J. (1996). Identifying students at risk through ineffective study strategies. *Higher Education, 31*, 97–116.

Weinstein, C. E., & Mayer, R. E. (1986). The teaching of learning strategies. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (pp. 315–327). New York: Macmillan.

Learning Style

Learning Styles

ALICE Y. KOLB, DAVID A. KOLB
Organization Behavior Department, Weatherhead School of Management, Case Western Reserve University, Cleveland, OH, USA

Synonyms

Learning approaches; Learning preferences; Learning strategies

Definition

The concept of learning style is used to describe individual differences in the way people learn. Individual learners do not use exactly the same process of learning. The physiological processes and life experiences that shape learning allow for the emergence of unique individual adaptive processes that tend to emphasize some adaptive orientation over others. There are many learning style typologies and assessment tools based on a great variety of individual differences that are thought to influence how individuals learn.

Theoretical Background

The term learning style first appeared in the research literature in the early 1970s as an evolution of psychological research on individual differences. Since then a number of frameworks that classify and discuss various learning style models and measures have been developed. In 1987, Lynn Curry developed a three-layer typology of these measures resembling the shape of an onion. The first layer of the onion represents learning style as measured by an individual's personality types. The second layer centers around information-processing styles of learning; the third layer deals with learner's instructional preferences based on interaction with the educational teaching environment.

In the personality-related styles Curry lists: the Myers-Briggs Type Indicator (which suggests that the individual's way of learning is influenced by learner's personality type); the Witkin Embedded Figure Test (which measures a learner's cognitive style in terms of field dependence and field independence); and Kagan's Matching Familiar Figure Test (which determines individual's impulsivity and reflectivity in a given situation).

Information-processing learning styles include: the Hunt Paragraph Completion Method (which measures a learner's conceptual complexity, interpersonal maturity, and self-other maturity) and Shmeck, Ribick, and Ramanaiah's Inventory of Learning Processes which identifies two types of learners in terms of how they process information – elaborative information processors and shallow information processors. The Kolb Learning Style Inventory is based on experiential learning theory, which describes learning as the holistic engagement of affective, perceptual, cognitive, and behavioral processes. The Learning Style Inventory consists of 12 sentences that describe learning preferences. Each sentence has four endings to be rank ordered and the responses are organized into two dichotomous dimensions: concrete experience versus abstract conceptualization and reflective observation versus active experimentation. Individuals take in experience either through concrete experience or abstract conceptualization and transform experience through active experimentation or reflective observation. Nine learning style types are identified as a learner's preference to take in and transform experiences: experiencing, diverging, reflecting, assimilating, thinking, converging, acting, accommodating, and balancing.

The instructional environment learning style measures include the Canfield and Laffety Learning Styles Inventory (which identifies learner's instructional preferences based on conditions of learning, content of learning, mode of learning, and expectation of

learning) and the Dunn, Dunn, and Price Learning Style Inventory (which measures environmental conditions under which students prefer to learn including the environmental, physical, emotional, sociological, and psychological elements). Hill's Cognitive Style Interest Inventory measures the learning environment congruent with students' learning styles and the Grasha and Riechmann Student Learning Styles Scales identifies students' learning behaviors in college classrooms along three bipolar dimensions: independent-dependent, avoidant-participant, and collaborative-competitive.

Important Scientific Research and Open Questions

The proliferation of diverse conceptualization and instrumentation of learning styles have posed challenges for researchers and theorists to achieve a coherent and generally accepted definitions of learning styles (Hickcox 1995). In the learning style literature, a plethora of terms are used interchangeably to define learning styles without careful consideration about the theoretical assumptions as to what constitutes learning. As a result, for the most part, the wide range of learning style instruments used to gather individuals' learning style information are only tangentially related to a theory of learning. Some learning style research is based on brain-based theories relating the pattern of neural activities to specific learning types, while others have relied upon psychological theories to put forth the concept of personality traits as dominant factors that define learning styles. In parallel to the research on learning style, the cognitive theories proposed the concept of cognitive style centered around the typology of intellectual competencies to explain certain human behaviors. According to Hickcox (1995, p. 27), there are differences in approach to learning style research between North American and European researchers in general. North American researchers have taken a more deductive approach to learning style research based on psychological theories with a focus on psychometrics. The European counterparts have approached the learning style research inductively relying on observations of the learning behavior of small groups of individuals. Hickcox further notes that North American researchers have focused on individuals' learning strategies that are relatively easy to change, while the main focus of European researchers has been on learners' relatively unchanging psychological characteristics (Hickcox 1995, p. 27).

Cross-References

► Adaptation to Learning Styles
► Adult Learning Styles
► Cross-cultural Learning Styles
► Jungian Learning Styles
► Kolb's Learning Styles
► Multiple Intelligences and Learning Styles
► Personality and Learning
► Social Interaction Learning Styles
► Styles of Learning and Thinking

References

Bedford, T. (2006). Learning styles: A review of the English language literature. In R. Sims & S. Sims (Eds.), *Learning styles and learning: A key to meeting the accountability demands in education.* Hauppauge: Nova.

Curry, L. (1987). *Integrating concepts of cognitive or learning style: A review with attention to psychometric standards.* Ottawa: Canadian College of Health Service Executives.

Hickcox, L. K. (1995). Learning styles: A survey of adult learning style inventory models. In R. J. Sims & S. J. Sims (Eds.), *The importance of learning styles* (pp. 25–47). London: Greenwood Press.

Hickcox, L. (2006). A review of the inventories – 1960s-2000s and the question of their actual uses inside and outside of the classroom. In R. Sims & S. Sims (Eds.), *Learning styles and learning: A key to meeting the accountability demands in education.* Hauppauge: Nova.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs: Prentice Hall.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 106–119.

Learning Support

► Research of Learning Support and Retention

Learning Tasks

SABINE RICHTER
University of Freiburg, Freiburg, Germany

Synonyms

Instructional task(s)

Definition

Learning tasks play an important role in instructional settings. They may be characterized as an interface between the learners and the information offered in the learning environment. They serve to activate and control learning processes in order to facilitate successful learning. They stimulate reactions referring to learning material, thus prompting the learners to engage intensively in the subject matter. Ideally, the learners receive feedback on how well they performed on a learning task and guidance on how to acquire the relevant information. While there is general agreement on the significant role of learning tasks, there is as yet little knowledge on how to design them appropriately.

Theoretical Background

In the context of programmed instruction, a behaviorist instructional technology, learning tasks have been systematically constructed on a large scale. Based on the assumption of Skinner (1954) that all behavior is determined by the consequences it produces, learning researchers developed programmed courses designed to adapt to this naturally occurring learning process.

The development of programmed courses involves a lot of effort (see Lysaught and Williams 1963): One has to account for the students' learning conditions and analyze the subject matter to be taught in great detail. Distinct definitions of the desired behavioral outcomes of instructions are imperative. The individual steps of the program are learning tasks, which have to be sequenced in a logical manner and should be solvable for the learners with as few mistakes as possible. The learners have to respond actively, and they then receive immediate feedback on whether their answer was correct or not. This is how the learning program continuously reinforces the desired behavior and increases the likelihood of its occurrence.

The formal structure of learning tasks consists of the following components (Fig. 1):

An information component presents the subject matter to be learned. Then a stimulus is presented, to which the learner is supposed to respond actively. After providing an answer, the learner receives feedback on its quality.

Learning programs in the tradition of Skinner are organized in a linear form. Typical forms of learning tasks are cloze texts, in which the learners have to fill in missing information. Later on, branched programs were developed. These programs consider characteristic mistakes in the student's learning process and integrate them into the learning tasks from the outset. Typical forms of learning tasks in these programs are multiple choice questions which prompt the learner to choose between several alternatives.

Working with programmed courses can enable successful learning. The technology can be applied to a lot of subject areas and learning objectives which can be broken up into smaller pieces and sequenced in a linear form. The technology is limited to learning objectives which can be made observable in terms of behavior. Programmed instruction is the technology which has been engaged most intensively in the development of learning tasks.

In the context of cognitive learning, however, the limitation to observable learning objectives is overcome. Learning tasks are conceptualized in a broader way and embedded in comprehensive frameworks. Bloom's theory of school learning, for example, names three major interdependent variables which can explain differences in the learning progress of students and are grouped around learning tasks (cf. Bloom 1976).

The first variable is student characteristics, namely, their *cognitive entry behaviors* (e.g., prior learning, reading comprehension) and *affective entry characteristics* (e.g., attitude toward school and subject matter). These entry behaviors and characteristics are prerequisites for mastering individual learning tasks. The next variable is the *quality of instruction*, which means the extent to which the students *participate* in the learning process and the degree to which the *cues* (information on what to learn and how to learn) and the *reinforcements* used in instruction are adapted to the needs of the students. Formative testing serves as *feedback* for

Learning Tasks. Fig. 1 Formal structure of learning tasks in programmed instruction

Learning Tasks. Fig. 2 Major variables in Bloom's theory of school learning

the learners. If their performance is not sufficient to go on to the next learning unit, *corrective* procedures (additional cues and practice) must be implemented. These procedures consist of further learning tasks or sequences of learning tasks.

The main assumption of the theory of school learning is that differences in student characteristics and the quality of instruction determine the third major variable, the *learning outcomes* (level and type of achievement, rate of learning, and affective outcomes). Learning tasks are the reference point and the binding link between the three major variables of the theory (see Fig. 2).

Thus, from a cognitive point of view, learning tasks are conceptualized in a comprehensive way which takes into account both the interdependence and the interaction between multiple elements that influence learning and instruction. Bransford (1979) describes a tetrahedral framework which emphasizes especially the interaction between the involved factors. These factors are:

1. "The nature of the materials to be learned.
2. The characteristics of the learner – his or her current knowledge, skills, attitudes.
3. The learning activities, or the kinds of things that learners do when presented with material – do they, for example, attend to the information, rehearse the information?
4. The criterial tasks, or the kinds of test tasks used to evaluate the degree of learning – for example, we may ask people to remember a previously defined concept, to demonstrate that they can use that concept to solve a new problem, and so forth" (Bransford 1979, p. 7).

Every factor of the tetrahedron represents an entire cluster of variables influencing learning, remembering, and understanding. Interactions can be found between two, three, or all the four factors of the model. Accordingly, in designing learning tasks one has to pay attention to all of the factors and the interactions between them. It is evident that this extensive perspective does not allow immediate derivation of design principles.

Regarding learning tasks in the discipline of instructional design, it is also necessary to mention task analysis methods (see Jonassen et al. 1999). The function of task analysis methods is to define the goals and objectives of learning. They describe what a person who has already achieved the desired goal does or knows. Task analysis methods characterize the knowledge to be acquired and form the basis for the selection and the design of activities for supporting learning, or in other words: learning tasks.

Traditional methods of task analysis break down the overall task into discrete parts, shedding light on the conditions preceding a performance and sequencing the steps necessary to carry out the task. Task analysis methods focus on observable processes and behavior. But when one wants to analyze tasks that "involve problem solving and decision making and are not algorithmic," it is necessary to use another form of task analysis, cognitive task analysis (Means 1993, p. 98). A cognitive task analysis examines the relation between the elements of knowledge within a complex cognitive task and describes the progression and concurrence of mental processes. The goal is to represent human expertise and to provide a better understanding of human performance on cognitive tasks. The results of cognitive task analysis methods are not yet likely to be represented in a way that could be used to derive direct prescriptions for the design of learning tasks. Overall, however, even if task analysis methods, whether traditional or cognitive, do not produce learning tasks directly, their results can certainly provide important information for the selection, construction, or sequencing of learning tasks.

Important Scientific Research and Open Questions

Despite their significant role, the question of how to design learning tasks has received little attention in educational research. In the context of the cognitive load theory, a design model for complex learning has

Learning Tasks. Fig. 3 Design of learning tasks using SEGLER

been presented to allow educators to cope better with authentic learning tasks, the 4C/ID model (van Merriënboer et al. 2003). The instructional design model proposes a set of different types of learning tasks that is meant to optimize cognitive load during learning: There are worked examples which present both the problem and the solution to the learner. Completion tasks are meant to be better suited for activating the learner since they present the problem and only a partial solution. Goal-free tasks address general and unspecific targets. Reverse tasks present a solution and require the learner to find the initial problem. Finally, conventional tasks present a problem the learner has to find the solution to himself. In this way, the 4C/ID model helps educators to decide which types of learning tasks to use in specific instructional situations.

A broader approach for designing learning tasks is a technology for formulating and designing learning tasks presented by Richter (2009). This author conceptualizes the design of learning tasks as a complex decision-making process which has to take into account

several factors, namely, the learning material and its psychological and physical structure, the characteristics of the learners, the intended learning outcome, and the learning activities necessary for reaching this outcome (cf. Bransford 1979). These interacting factors are analyzed by means of decision theory and subsequently integrated into a model which accounts for the manifold interactions between them. This forms the basis for the design model SEGLER, which provides a systematic guide to the process of developing instructional tasks.

SEGLER consists of the following steps (See Fig. 3).

The design of learning tasks using SEGLER starts with the structuring of the subject matter area for which learning tasks are to be developed. The result of this first step is a concept map, which is then transformed into a map of possible learning outcomes. For this purpose, the concept map is analyzed and different types of learning outcomes are developed and highlighted in the graph. SEGLER provides a step-by-step checklist for analyzing the concept

map. Knowledge types in SEGLER are domain-specific knowledge (declarative or procedural), strategic knowledge (heuristics, control strategies, learning strategies), situative knowledge (communication and problem solving in groups), and transfer (defined by its scope, content, and context). As it is possible to develop an immense number of learning outcomes, the designer of the learning tasks has to select the ones for which learning tasks should be designed.

After selecting the intended learning outcomes, the designer allocates learning activities to each of them. Learning activities in SEGLER are defined as analyzing or synthesizing processes. On a macro level, these processes change the level of complexity or abstraction of concepts. On a micro level, analyzing and synthesizing processes are described in terms of verbs specifying what the learners should do in order to reach the intended outcomes. Examples of analyzing processes are *differentiating, comparing*, or *concretizing. Synthesizing* processes, on the other hand, can be specified by verbs such as to *generalize, categorize*, or *abstract*. The result of this step is a table listing the learning outcomes and the corresponding learning activities.

Next, the content of the table is compared with the underlying material (text- or schoolbooks). The semantic range between the learning material and the intended learning outcomes has to be determined. *Semantic range* refers to research on text comprehension and has two possible values, *low* or *high*: Low semantic range means the information needed for achieving the intended learning outcome is enclosed directly in the learning material. High semantic range means that learners have to go beyond the information provided in the learning material and integrate the new information into their prior knowledge in order to explain or predict concepts, processes, or results and thus achieve the intended outcome.

Once the semantic range has been determined, the preliminary conceptual work is complete and it is possible to derive actual variations of learning tasks. Detailed checklists guide the designer through this process, providing concrete suggestions on types of learning tasks according to the semantic range. The designer writes down initial blueprints of the learning tasks. Next, the designer has to decide on how explicitly the learning tasks should guide the learners through the learning process. Different extents of guidance can be implemented through variations in the information

and the stimulus and response component of tasks. This step of SEGLER leads to the generation of a wealth of new drafts of learning tasks. The last two steps of SEGLER are the integration of motivational strategies and cognitive style dimensions into the design of the task. Again, detailed checklists including central questions and adequate design propositions are provided. In a final step, the developed learning tasks are revised in order to improve their comprehensibility and ensure their appropriate representation.

SEGLER is a prescriptive instructional design model that guides the designer systematically through the process of developing learning tasks. The provided checklists are precise and specific decision-making aids – using them leads to the design of manifold learning tasks.

Cross-References
▶ Bloom's Model of School Learning
▶ Cognitive Load Theory
▶ Cognitive Tasks and Learning
▶ Interactive Learning Tasks
▶ Task Sequencing and Learning

References
Bloom, B. S. (1976). *Human characteristics and school learning*. New York: McGraw-Hill.

Bransford, J. D. (1979). *Human cognition*. Belmont: Wadsworth.

Jonassen, D. H., Tessmer, M., & Hannum, W. H. (1999). *Task analysis methods for instructional design*. Mahwah: Erlbaum.

Lysaught, J. P., & Williams, C. M. (1963). *A guide to programmed instruction*. New York: Wiley.

Means, B. (1993). Cognitive task analysis as a basis for instructional design. In M. Rabinowitz (Ed.), *Cognitive science foundations of instruction* (pp. 97–118). Hillsdale: Erlbaum.

Richter, S. (2009). Gestaltung von Lernaufgaben unter entscheidungstheoretischer Perspektive: Entwicklung des Designmodells SEGLER. Freiburg: Albert-Ludwigs-Universität. http://www.freidok.uni-freiburg.de/volltexte/7081/pdf/SEGLER_richter_2009.pdf. Accessed 12 Apr 2010.

Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review, XXIV*(2), 86–97.

van Merriënboer, J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist, 38*(1), 5–13.

Learning Taxonomy

▶ Problem Typology

Learning Technology

JAN ELEN, GERALDINE CLAREBOUT
Department of Educational Sciences, Center for
Instructional Psychology and Technology, Katholieke
Universiteit Leuven, Leuven, Belgium

Synonyms

Educational technology; Instructional technology

Definition

Learning technology refers to a field of study and ample
practices of mainly two different types: technology for
learning and technology of learning. Technology for
learning pertains to the use of technology during (the
support of) learning processes. It is also often called
"educational technology" or "instructional technol-
ogy." In line with the more general meaning of "tech-
nology" as the application of scientific insights to solve
practical problems, "technology of learning" relates to
the question on how scientific findings with respect to
(supporting) learning can actually be used to support
learning processes. Instructional design and develop-
ment is another label under which the second meaning
of educational technology can be situated.

Theoretical Background

Technology of learning aims at providing (probabilis-
tic) guidelines on the design of learning environments
to support goal-direct learning (Reigeluth 1999). It
does so by considering theories of learning and instruc-
tion. Parallel to changes in such theories, i.e., parallel to
changes in our thinking about how learning occurs and
how that learning can be supported, the guidelines do
differ. Based on a behavioral analysis of learning and
more specifically based on recognition of the impor-
tance of immediate, frequent, and positive feedback,
Skinner (1958) has been a strong advocate of
programmed instruction which some will call the first
systematic technology of learning. Much more inspired
by (gradually evolving) cognitive views on both learn-
ing and instruction, Gagné has proposed hierarchical
sequencing and the systematic use of nine instructional
events. With new insights showing their relevance,
Gagné has gradually adapted his guidelines and, for
instance, has gradually paid more attention to

metacognitive and motivational variables (Aronson
1983). Confronted with the problems created by ana-
lytical views on learning and inspired by more recent
insights with respect to learning and instruction (e.g.,
cognitive load theory), van Merriënboer (1997) has
proposed his 4 C/ID-model which is continuously
adapted and reshaped in order to accommodate new
scientific findings.

Technology for learning relates to the use of tech-
nological devices in (supporting) learning. In addition
to theories about learning and instruction, it is clear
that evolutions with respect to those technological
devices do play an important role as well. When it
comes to how technological devices may contribute to
(supporting) learning, instructional design and devel-
opment ("technology of learning") on the one hand and
the attributes of the technological devices on the other
play an important role. With each new technological
device, a discussion about its potential for (supporting)
learning emerges. This has been the case for classical
instructional media; such as radio and television (see
Reiser 2001) but is also the case for more recent devices
such as portable computers and mobile phones.

From a socio-constructivist perspective, the use of
technology in learning also attracts a lot of attention. It
is argued that the nature of the tool or device that
people use during learning and/or problem-solving
affects the core of these processes. Säljö et al. (2006),
for instance, asked people to solve a numerical task
without any tool, with pen and paper, or with
a calculator. It was clear from the results that prob-
lem-solving processes differed in both quantity (e.g.,
time to solve the problem) and quality (nature of
cognitive processes engaged in).

Of a different nature is the issue of teachers' use of
these technological devices. Numerous studies have
shown that despite the potential of technological
devices, teachers often do not or inadequately use
these devices. The "technology-acceptance-model"
which was originally proposed by Davis (1989) is
repeatedly used to explain that phenomenon. It
specifies that the use of technology is dependent on
perceived usefulness and perceived ease of use.

Important Scientific Research and Open Questions

Two major issues remain prevalent for learning tech-
nology. For technology of learning it is wondered

whether a "technology" can be realized or whether the elaboration of guidelines on how to support learning is mainly an art (Clark and Estes 1998). Immediately related to this issue is the possible impact of learning theories on such guidelines and about the nature of the research that might be informative with respect to the elaboration of guidelines (e.g., Fox 2006).

For technology for learning the question about the importance of the technological device as such has been a recurrent point of discussion. Essential is the relationship between media and method in this debate (Clark 1994; Kozma 1994). Whereas some argue that media are mere delivery instruments which (provided they can adequately deliver the method) do not affect learning, others argue that media and method cannot be easily disentangled and hence that a similar "method" delivered by two different media will be perceived and experienced by the learner as different methods and hence may result in different types of learning processes engaged in.

Cross-References

► Actor Network Theory and Learning
► Media Effects on Learning

References

Aronson, D. T. (1983). Contributions of Gagné and Briggs to a prescriptive model of instruction. In C. M. Reigeluth (Ed.), *Instructional design theories and models* (pp. 75–98). New York: Routledge.

Clark, R. E., & Estes, F. (1998). Technology or Craft: what are we doing? *Educational Technology, 38*(5), 5–11.

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development, 42*(2), 21–29.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Fox, E. J. (2006). Constructing a pragmatic science of learning and instruction with functional contextualism. *Educational Technology Research and Development, 54*(1), 5–36.

Kozma, R. B. (1994). Will media influence leaving? Reframing the debate. *Educational Technology Research and Development, 42*(2), 7–19.

Reigeluth, C. M. (1999). What is instructional design theory and how is it evolving? In C. M. Reigeluth (Ed.), *Instructional design theories and models* (Vol. II, pp. 5–29). New York: Routledge.

Reiser, R. A. (2001). A history of instructional design and technology: Part I: A history of instructional media. *Educational Technology Research and Development, 49*(1), 53–64.

Säljö, R., Eklund, A., & Mäkitalo, A. (2006). Reasoning with mental tools and physical artefacts in everyday problem solving. In L. Verschaffel, F. Dochy, M. Boekaerts, & S. Vosniadou

(Eds.), *Instructional psychology: Past, present, and future trends* (pp. 73–90). Amsterdam: Elsevier.

Skinner, B. F. (1958). Teaching machines. *Science, 128*, 969–977.

van Merriënboer, J. J. G. (1997). *Training complex cognitive skills: A four-component instructional design model for technical training*. Englewood Cliffs: Educational Technology.

Learning Tests

► Dynamic Testing and Assessment
► Measurement of Change in Learning

Learning the Affective Value of Others

Eliza Bliss-Moreau
Department of Psychiatry and Behavioral Sciences, California National Primate Research Center, University of California, Davis, Davis, CA, USA

Synonyms

Social affective learning

Definition

Learning the ► affective value of others is the process by which we learn that people we encounter throughout our social lives are good or bad, rewarding or threatening, exciting or dull. In other words, such learning imbues people in our social environments with *affective properties*. Learning the affective value of others is one form of ► affective learning, and more specifically one form of *social affective learning*.

Theoretical Background

In order to effectively navigate the social environment, people must know who is friend and who is foe; who has the potential to help them and who has the potential to hurt them; with whom allegiances should be formed and who should be avoided all together. People, though, are not innately good or bad. Instead, we must learn such affective information about them.

Learning the affective value of others is one form of *affective learning*. Affective learning is the process by

which stimuli (e.g., people or objects) acquire affective value. A stimulus is said to have *affective value* when it is capable of generating an affective response in an individual. In this way, the affective value of a stimulus *is* the affective response it generates in the observer. Affective value is characterized by some degree of hedonicity (or valence; ranging from goodness to badness) and some degree of arousal (or physiological activity; ranging from activated to deactivated).

There is a long history of studying affective learning in humans and nonhuman animals. For example, in the early 20th century, Pavlov (1927) demonstrated that dogs learned to associate the sound of a bell with the positive experience of eating food. Prior to learning, the bell was neutral. During learning, the bell became associated with the food and thus with the dog's positive response (salivation) to the food. After learning, the bell had affective value insofar as the sound of the bell caused the dog's positive response even when there was no food present. In all forms of affective learning, a neutral stimulus (generally called a conditioned stimulus, because it requires "conditioning" or learning to cause an affective response) is paired with a stimulus of known affective value (generally called an unconditioned stimulus because the learner's response to it is "unconditional" and does not require learning). Over time and many pairings, the conditioned stimulus acquires the ability to generate an affective response in the learner akin to that of the unconditioned stimulus and in that vein is said to have acquired affective value.

Affective learning is thought to occur via two processing modes – associative processing mode and rule-based processing mode (for a discussion of the two processing modes, see Sloman 1996). Via associative processing mode, stimuli are paired in time or space, such as in the example of Pavlov's dog discussed above. Learning occurs by experiencing the two stimuli in proximity; the relationship of the stimuli is never explicitly stated. There are a number of "types" of affective *associative learning* that have been identified in the literature, including (but not exclusive to) *classical conditioning*, *"fear" conditioning*, and *evaluative conditioning*. In contrast, via rule-based processing mode, the potential value of a stimulus is specified using explicit symbolic communication (i.e., language, or other culturally relevant symbols; e.g., a red octagon

with white writing signals "stop"). Such affective learning can occur for any stimulus in the environment. When the stimuli are social, then the learning is said to be *social affective learning*. Learning the affective value of others is one form of social affective learning that occurs when the conditioned stimuli are other people.

People can learn the value of other people via associative processing mode. For example, when pictures of novel people (indicated by face pictures) are paired with an electric shock (e.g., Öhman and Dimberg 1978) that provoke a robust physiological response, learners begin to respond to those faces with a physiological response, even when the electric shock is not presented. People can also learn the value of other people via rule-based processing mode. For example, when learners are instructed that novel people (indicated by face pictures) performed good or bad social behaviors (e.g., good behaviors such as "celebrated a friend's birthday"; bad behaviors such as "hit a small child"), they later judged those people as being good or bad (Bliss-Moreau et al. 2008).

Important Scientific Research and Open Questions

A good deal of research on the mechanisms, properties, and global rules of affective learning occurred during the last half of the twentieth century. For example, seminal work by Rescorla and colleagues (e.g., Rescorla and Wagner 1972) modeled the properties of affective learning, focusing on what aspects of stimuli contributed to the magnitude and speed of learning. Key questions about the nature of affective learning still remain, however. One such question currently being debated in the literature is whether affective learning occurs automatically or is necessarily conscious and, or, effortful (e.g., Mitchell et al. 2009). Stated differently: under what conditions does *unconscious learning* occur? Another open question is whether the principles of affective learning that have been unearthed in experimentation and modeling conducted with nonsocial stimuli (and/or nonhuman animals) apply to social affective learning as well.

There are also open questions about the neurobiology of social affective learning. It is widely recognized that the amygdala is critically involved in affective learning. One of the classic findings demonstrating the amygdala's central role in affective learning is that

animals with damage to the amygdala cannot form new associations between conditioned and unconditioned stimuli. Other brain areas that are involved in computing affective value and representing organisms' affective states, such as orbitofrontal cortex, have also been implicated in affective learning. While there is a growing breadth of research using functional neuroimaging during social affective learning, the extent to which unique brain regions are recruited for social affective learning specifically is largely unknown.

Cross-References

References

Bliss-Moreau, E., Barrett, L. F., & Wright, C. I. (2008). Individual differences in learning the affective value of others under minimal conditions. *Emotion, 8*, 479–493.

Mitchell, C. J., De Houwer, J., & Lovibond, P. F. (2009). The propositional nature of human associative learning. *Brain and Behavioral Sciences, 32*, 183–246.

Öhman, A., & Dimberg, U. (1978). Facial expressions as conditioned stimuli for electrodermal responses: A case of "preparedness"? *Journal of Personality and Social Psychology, 36*, 1251–1258.

Pavlov, I. P. (1927). *Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex.* Oxford: Oxford University Press.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning: II. Current research and theory* (pp. 64–99). New York: Appleton.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin, 119*, 3–22.

Learning Theory

Learning Through Artifacts in Engineering Education

JONTE BERNHARD
Engineering Education Research Group, ITN, Linköping University, Norrköping, Sweden

Synonyms

Artifacts; Tool mediation

Definition

The word *artifact* (usually spelled *artefact* in the UK) comes from the Latin words *arte*, which means "by skill," and *factum*, "something made," which is neuter of past participle of *facere*, "make." In general, an artifact is something created by humans for a practical purpose. Artifact could either be used as a general term used to connotate symbolic, psychological, and physical tools used by humans in artifact-mediated action, for example in engineering education or in engineering practice, or used in a more narrow sense to only denote physical artifacts. Studying *Learning through artifacts in engineering education* is the study of the role of artifacts in influencing human experience in engineering education and the study of learning to use artifacts as tools for experiencing.

Theoretical Background

In human artifact-mediated experience of our world, experience is not seen as a direct experience *human – world*, but as an experience shaped by the use of physical and symbolic tools, i.e., artifacts. The concept of mediation and mediating tools could be represented diagrammatically as: *Human – mediating tools (artifacts) – world*.

Artifact-mediated experience is central in engineering through the use of different technologies (artifacts) for the collection and processing of physical data, for example, for the control and monitoring of production, or from experiments or monitoring of the environment.

Questions about the role of technology (artifacts) in everyday human experience include:

– How do technological artifacts affect the existence of humans and their relationship with the world?

– How do artifacts produce and transform human knowledge?
– How is human knowledge incorporated into artifacts?
– What are the actions of artifacts?

The structure of an artifact as well as learning to use an artifact changes the structure of human interaction with the world and hence is closely related to learning. Questions related to human use of tools (artifacts) are central in different kinds of praxis philosophies and in theories focusing on human practice.

In the sociocultural theory and in cultural–historical activity theory, which is rooted in the thinking of Lev Vygotsky (1896–1934) and Aleksey Leontiev (1903–1979), tools and mediation are key concepts. The central thesis is that the structure and development of human psychological processes are co-constituted by the interaction with tools. These are historically developed and could be of different types such as *psychological tools*, *material tools*, language is also a tool. Using tools makes it possible to act in more powerful and functional ways and enhances and alters human development. These tools (artifacts) are *simultaneously material* and *ideal/conceptual*. In these views, we can see the learner as an individual in society, learning and thinking through artifacts (Cole and Derry 2005). Marx Wartofsky (1928–1997) expressed the codevelopment of artifacts and human thinking in his *historical epistemology* and in his view cognitive artifacts, such as representations, are not what we perceive but means by which we perceive real objects, and hence the development of perception is closely coupled to the historical development of artifacts.

In European phenomenology and in U.S. pragmatism that was appearing simultaneously, the analysis of human experience played a central role. The focus in pragmatism is on practice and not on representation. Human use of tools and the role of tools for human experience play an important role in John Dewey's (1859–1952) pragmatism and in his philosophies of education and of technology. Phenomenology understands thinking as being-in-the-world and points to the unity of mind and the lifeworld through humans' use of tools. In phenomenology, perception is seen as active, situated, intentional (i.e., is always the perception of "something") and embodied. In the phenomenological tradition, Martin Heidegger (1889–1976) provides an early example of a contextual tool analysis. Heidegger recognized that all modern science is technologically embodied in its apparatus and argued for the ontological priority of technology over science. Maurice Merleau-Ponty (1908–1961) further developed the idea of embodied perception and incorporated uses of some artifacts in his analysis.

The philosopher of technology Don Ihde has extended and synthesized ideas from phenomenology and pragmatism into a post-phenomenology. According to Ihde, all science in its production of knowledge is technologically embodied and perception is co-determined by technology, but technology on the other hand uses the theories of science. Hence the term techno-science is often used to denote present days' symbiotic relationship between science and technology. Ihde developed the following schematic distinctions regarding mediated intentional relationships between humans and their world:

Embodiment: (Human ⇔ Artifacts) ⇔ World
Hermeneutic: Human ⇔ (Artifacts ⇔ World)
Alterity: Human ⇔ Artifacts (⇔ World)

In alterity relationships humans do not relate to the world through a technology, or to a world-technology complex, but to a technology itself as, for example, is the case with simulations. In embodiment relationships, we are often unaware of the technology, it works as an extension of the body. We see the world through a microscope or the physician listens to the patients' hearth or lungs through a stethoscope. In hermeneutic relationships, some kind of interpretation is involved, hence the term hermeneutic. The world is read through a technology usually producing some kind of *inscription*, often of a visual kind. In both embodiment and hermeneutic relationships, experience is transformed by the mediating technology. In techno-science, instruments do not merely "mirror reality" but mutually constitute the reality investigated. The technology actively shapes the relationship between humans and their lifeworld by placing certain aspects in the foreground (and others in the background) and also by making certain aspects of reality visible that otherwise would be invisible. Neglecting the role of instruments (i.e., technological artifacts) in science leads either to naïve realism or naïve idealism.

A further parallel strand can be found in the tradition of science studies and in philosophy of scientific

experimentation. Ian Hacking was an early critic of the lack of discussion about experiments, technology, or the use of knowledge to alter the world in the philosophy of science. Later criticism of the neglect of the technological dimension of science was repeated and detailed studies of the role of technologies and instrumentation in the development of techno-science started to appear (e.g., Radder 2003). Theoretical perspectives in the philosophy of science that saw observation as something unproblematic and hence believed that instruments and experimental devices per se had no cognitive value were criticized. Furthermore, in the philosophy–physics of Niels Bohr (1885–1962), it is claimed that it is impossible physically, especially in quantum physics, to distinguish sharply between phenomena themselves and their conscious perception, i.e., technology and world should be seen as a complex. In Ihde's hermeneutic relations described above, technology world is perceptually seen as a complex, but in Bohr's view, technology-world should in many cases also even physically be seen as constituting a complex. Agencies of observation (the technology) and the object studied (some aspect of the world) cannot meaningfully be separated. According to Bohr, only concepts that are defined by their specific embodiment in a material arrangement that produces a reading that can be read by a human are meaningful (Barad 2007).

Important Scientific Research and Open Questions

Engineering education research is a relatively new field of research but the role of laboratories for student learning has been investigated in science and in physics education research. However, with a few exceptions, the role of instrumental technologies for student learning in laboratories is rarely studied and their role is either neglected or taken for granted. A consequence of this is that emphasis in research is placed mainly on instructions, concepts, and ideas, or on organization of labs.

Research focusing the role of physical artifacts for learning is instead investigating what could be called *material hermeneutics* (Ihde 2009) or *material-discursive practices* (Barad 2007). The answer to the question "What change in conceptual change?" is different from the ones suggested by other theoretical approaches: The world experienced, the world seen, the world lived by the learner is that change

(Marton and Pang 2008). Learning is seen as developing students' ways of seeing or experiencing the world.

Existing research studies in the field of engineering education (e.g., Bernhard 2010) suggest that the role of technologies (artifacts) for student learning is dependent upon the fact that the technology used places some aspects of reality in the foreground, others in the background, and makes certain aspects visible that would otherwise be invisible. Different technologies have different affordances for discernment and hence the possibilities for learning different objects of learning are dependent upon the technologies available or made available to students. Sensors attached to a computer-based data acquisition system can collect, process, and display physical data and experimental results in real time. In, for example, a lab in kinematics, a motion sensor could bring velocity associated with a motion to the fore, i.e., it enters in the focal awareness of students. Other features of the situation, physical as well as nonphysical, are not highlighted, i.e., some discernment has already occurred. Combined with suitable designed instructions, this has been shown to be beneficial for student learning. Using an oscilloscope in electronics or electric circuit theory instead makes voltages visible and brings them to the fore. Findings from existing research show that student' interactions with artifacts and the aspects of the world to be learned are complex. Briefly existing research suggest that the situation in successful labs could be described as a situation involving embodiment as well as hermeneutics; there human-artifact complexes and world-artifact complexes could be seen as overlapping: (Human ⇔ {Artifacts) ⇔ World}. There is, however, ample evidence in research that, in most cases, it is very difficult for students to make connections between artifacts and the world, and the situation could be seen as the ultimate alterity relationship: Human ⇔ Artifacts. It has been demonstrated that technologies are neither deterministic tools causing predetermined learning nor neutral tools.

Although research making detailed investigations of students' material-discursive practices in different fields of engineering education starts to appear, extension of this to more fields in techno-science is needed. Furthermore, the relationship between the development of concepts as expression of materiality and the development of experimental technologies in techno-science need to be explored. Connections between

theoretical approaches that see concepts as tools for inquiry or expression of materiality and those that investigate concepts and learning in relation to mental processes have a similar need to be explored and developed.

Cross-References

► Activity Theories of Learning
► Actor Network Theory and Learning
► Affordances
► Cognitive Artifacts, Technology, and Physics Learning
► Models and Modeling in Science Learning
► Phenomenography
► Sociocultural Research on Learning
► Vygotsky's Philosophy of Learning

References

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning.* Durham: Duke University Press.

Bernhard, J. (2010). Insightful learning in the laboratory: Some experiences from ten years of designing and using conceptual labs. *European Journal of Engineering Education, 35*(3), 271–287.

Cole, M., & Derry, J. (2005). We have met technology and it is us. In R. J. Sternberg & D. D. Preiss (Eds.), *Intelligence and technology: The impact of tools on the nature and development of human abilities.* Mahwah: Lawrence Erlbaum.

Ihde, D. (2009). *Postphenomenology and technoscience: The Peking University lectures.* Albany: State University of New York Press.

Marton, F., & Pang, M. F. (2008). The idea of phenomenography and the pedagogy of conceptual change. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 533–559). New York: Routledge.

Radder, H. (Ed.). (2003). *The philosophy of scientific experimentation.* Pittsburgh: University of Pittsburgh Press.

Learning Through Creating

► Learning by Design

Learning Through Perception and Animals

► Animal Perceptual Learning

Learning Through Practice

► Authenticity in Learning Activities and Settings
► Workplace Learning

Learning Through Social Media

MARCIA CONNER
Staunton, VA, USA

Synonyms

Collaboration; Social learning; Social network learning

Definition

Social media is a set of Internet-based technologies designed to be used by three or more people. It is rarer than it sounds. Most interaction supported by technology is narrowcast (one to one), often with a telephone call or an e-mail message; niche-cast (one to small groups), for instance using e-mail distribution lists or small-circulation newsletters; or broadcast (one to many), as in large-scale online magazines or a radio show.

Learning through social media is what it sounds like – learning with and from others using social media. Learning socially has been around for a long time and naturally occurs at conferences, in groups, and among old friends in a café as easily as it does in classroom exercises or among colleagues online who have never met in person. We experience it when we go down the hall to ask a question and when we post that same question on Twitter anticipating that someone will respond.

While social media is technology used to engage three or more people and learning socially is participating with others to make sense of new ideas, what is new is how powerfully they work together. Social tools leave a digital audit trail, documenting our learning journey – often an unfolding story – and leaving a path for others to follow.

Tools are now available to facilitate learning socially that is unconstrained by geographic differences (spatial boundaries) or time-zone differences (temporal boundaries) among team members.

Theoretical Background

Learning through social media reframes social media from a marketing strategy to a strategy that encourages knowledge transfer and connects people in a way consistent with how we naturally interact. It is not a delivery system analogous to classroom training, mobile learning, or e-learning. Instead it is a powerful approach to sharing and discovering a whole array of options – some of which we may not even know we need – leading to more informed decision making and a more intimate, expansive, and dynamic understanding of the culture and context in which we work.

Learning through social media provides people at every level, in every nook of the organization, and every corner of the globe, a way to reclaim their natural capacity to learn nonstop. Social learning can help the pilot fly more safely, the saleswoman be more persuasive, and the doctor keep up to date.

For a long time, many people have known learning could transform the workplace. They longed for tools to catch up with that potential. Only recently have changes in corporate culture and technology allowed this eventuality to unfold.

At its most basic level, learning through social media can result in people becoming more informed, gaining a wider perspective, and being able to make better decisions by engaging with others. It acknowledges that learning happens with and through other people, as a matter of participating in a community, not just by acquiring knowledge.

Social Media Tools

Learning happens using social media tools and through extended access and conversations with all our connections – in our workplaces, our communities, and online. It happens when we keep the conversation going on a blog rich with comments, through coaching and mentoring, or even during a workout at the gym.

Learning is augmented by commercial tools, such as Facebook, Twitter, YouTube, blogs, and wikis, and with enterprise applications and suites of applications including Socialtext, Socialcast, Newsgator, and Lotus Connections. With some custom development, learning also can grow on enterprise social platforms such as IBM WebSphere Portal Server, Microsoft Sharepoint, SAP Netweaver Portal and Collaboration, and Oracle's Beehive.

Do not conclude this is all new, though. Social software has been around for almost 50 years, dating back to the Plato bulletin board system. Networks such as Compuserve, Usenet, discussion boards, and The Well were around before the founder of Facebook was even born. Only technology enthusiasts used those systems, though, because of clunky interfaces that did not readily surface or socialize the best ideas.

Learning through social media is enabled by easy-to-use, socially focused, and commercially available "Web 2.0" tools and "Enterprise 2.0" software that move services, assets, smarts, and guidance closer to where they are needed – to people seeking answers, solving problems, overcoming uncertainty, and improving how they work. They facilitate collaboration and inform choices on a wide stage, fostering learning from a vast, intellectually diverse set of people.

These new social tools augment training, knowledge management, and communications practices used today.

They can introduce new variables that can fundamentally change getting up to speed, provide a venue to share spontaneously developed resources as easily as finely polished documents, and draw in departments that previously had not considered themselves responsible for employee development at all.

Social tools are powerful building blocks that can transform the way we enable learning and development in organizations. They foster a new culture of sharing, one in which content is contributed and distributed with few restrictions or costs.

Most of what we learn at work and elsewhere comes from engaging in networks where people cocreate, collaborate, and share knowledge, fully participating and actively engaging, driving, and guiding their learning through whatever topics will help them improve. Training often gives people solutions to problems already solved. Collaboration addresses challenges no one has overcome before.

Learning through social media makes that immediate, enabling people to easily interact with those with whom they share a workplace, a passion, a curiosity, a skill, or a need.

Social Learning Theory

A "social learning theory" was first put forward in 1954, standing on the shoulders of John Dewey and drawing on the budding fields of sociology, behavior modification, and psychology applied to understanding and changing conduct. 4 Ideas from social learning

theory informed the thinking of later learning theorists, including Albert Bandura who wrote in 1977, "Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do. Fortunately, most human behavior is learned observationally through modeling."

The early focus of social learning theory was learning socially appropriate behavior by imitating others, which is only a small aspect of how social learning is used in practice today. Given the recent explosion of means for people to learn socially and the vast array of topics that can be learned from others, it is unfortunate what was called social learning had such a limited scope. Recognizing this, there will be times we shorten "the new social learning" to "social learning" here and in our work elsewhere to describe the broader issues and opportunity now available. Social learning is modeling, observation, and so much more.

Social Constructivism

Social constructivism is the theory of knowledge that seems to best describe how people learn together, whether in person or through social media. When you engage with people, you build your own insight into what is being discussed. Someone else's understanding complements yours, and together you start to weave an informed interpretation. You tinker until you can move on.

Swiss psychologist Jean Piaget laid the groundwork for this approach by challenging the behaviorist notion popular in the 1950s that people were passive recipients of external stimuli that shaped how they behaved. 6 Instead, Piaget conducted many experiments to demonstrate that people are active participants in their learning. They interpret what is around them based on their unique current understanding of the world, and then they continually modify their understanding as they encounter new information. Piaget's discoveries eventually led to the concept and practice of discovery learning for children and the use of role-play and simulation for adults. Active participation is the key in both cases.

This set the stage for Peter Berger's and Thomas Luckman's social construction of reality, which led to the prominence of social constructivism. 7 We are social creatures. If we play an active role in creating our views of reality, then the groups we participate in

also contribute. Our reality is shaped by our social interactions. These exchanges provide context – socially scaffolding what you have already learned with what another person has learned and so on. This generates a virtuous spiral, socially generated and built and more powerful than any one participant could create individually.

In a world of rapid change, we each need to garner as much useful information as possible, sort through it in a way that meets our unique circumstances, calibrate it with what we already know, and recirculate it with others who share our goals.

Learning through social media leverages online communities, media sharing, microsharing, content collaboration, and immersive environments to introduce people to ideas in quick bursts, when it suits their workflow, without a big learning curve, and in a way that more closely mirrors how groups interact in person.

Social constructivism has become timely because work has for so long focused on what is known. To triumph today, we must now understand new information and complex concepts – what has not been known before and is often more complicated than one person can figure out alone.

The twenty-first century mind is a collective mind where we access what we know in our friends' and colleagues' brains. Together we can be smarter and can address ever more challenging problems. What we store in our heads may not be as important as all that we can tap in our networks. Together we are better.

Important Scientific Research and Open Questions

Harnessing social media to facilitate learning in the organization has only just begun. It takes intention to create an organizational culture where learning is part of the fabric, core values, and infrastructure. People can learn by bumping into the obstacles we encounter in our work. Sure, people can and will learn when they must. However, the cultural shift that occurs when social learning is designed into the work process is life changing. It does not just add new tasks to your workload. It literally changes the way the whole company learns, works, and succeeds.

Once you move away from the push of information to the pull of learning, you liberate creative powers in

your people to succeed in this rapidly changing environment. Once you make it easy for people to inquire and announce activities and projects and you create an environment where people are not afraid to fail, you allow them to ask the really hard questions. And you begin to get answers you never could have found otherwise.

Learning through social media is not just about being social. It is not just a matter of having the right tools. It is about making learning a priority and using the tools of social media to facilitate a culture where we get better at getting better. It is no longer about just being a better competitor. It is now about being a stronger contributor and a savvier learner.

Cross-References

Further Reading

American Society for Training & Development. (2010). *The rise of social media: Enhancing collaboration and productivity across generations, research report.* Alexandria, VA: ASTD Press.

Bingham, T., & Conner, M. (2010). *The new social learning: A guide to transforming organizations through social media.* Alexandria, VA: ASTD.

Bozarth, J. (2010). *Social media for trainers.* San Francisco: Jossey-Bass.

Learning Through the Breach: Language Socialization

Lanita Jacobs
Department of Anthropology, University of Southern California, Los Angeles, CA, USA

Synonyms

Bracketing; Breaches; Breaks in frames

Definition

To err is human but to breach is to err in befuddling yet ultimately insightful ways; herein lies the essence of the breach. Sociologist Harold Garfinkel, the father of ethnomethodology (EM) and one of our foremost teachers in this regard, notes that *breaches* violate expectations governing social behavior and, in doing so, reveal tacit rules underlying how to behave. Similarly, Erving Goffman, one of Garfinkel's contemporaries, notes that *breaks in frames* can violate implicit interactional scripts governing everyday encounters, such as when someone enters McDonalds and attempts to order a Whopper or a pizza. When breaches occur, they force interlocutors to stop and consider, just for a moment, whether the breach was intentional (e.g., perhaps a joke/gaff) or unintentional so that they reconstitute a sense of normalcy. In this *bracketing* process, they are reflecting on questions of accountability and normalcy in relation to local assumptions about what is "right" or "wrong" behavior, talk, etc. This process of reconstituting a sense of social order is *intersubjective* and can entail *revoicings* and *keyings* that seek clarification or elaboration, or entreaties to other interlocutors or bystanders to check whether something wrong did, indeed, occur (Goffman 1974, 1981). In such ways, breaches expose how folks engage in the creation of local social order, on the spot, out of the materials at hand in recognizable ways (Garfinkel 2002, p. 18).

Theoretical Background

Garfinkel's notion of the breach was a significant component of the EM paradigm of American sociology during the 1930s and 1940s. Garfinkel's students actually staged breaching experiments in the 1950s and 1960s at UCLA to reveal the taken-for-granted assumptions people rely upon to negotiate social order. Recent breaching experiments by students at American universities have yielded similar insights (see O'Brien 2010). For example, one college student who accompanied her boyfriend to a party took the host's idiom, "Make yourself at home," quite literally; she took a shower while the party was underway, much to her boyfriend's chagrin! Other students shopped from other folk's grocery shopping carts or volunteered to pay more than the posted price for an item. These students learned that when confronted with a breach, observers and participants may first try to ignore it or

check with others that something happened that was not expected. In this way, breaches reveal just how fragile and interaction (and meaningful) cultural realities can be (O'Brien 2010).

Garfinkel's systematic study of moments of breakdown as a window into the production of social order led many to view EM as a methodology versus a multifaceted sociological approach. Scholars have since sought to redress this and other misreads by highlighting Garfinkel's early theoretical influences (e.g., Edmund Husserl, Alfred Schütz) and various contemporaries (e.g., Erving Goffman, Ludwig Wittgenstein, C. Wright Mills, Harvey Sacks) with whom he shared a fascination for the nature of intersubjectivity and the social constitution of knowledge. Other scholars document Garfinkel's allegiance but nuanced departure from theorists such as Durkheim, Weber, and his research advisor, Talcott Parsons (Heritage 1984; Hilbert 1992; Garfinkel 2002). Amidst this important work, *breaches* remain one of Garfinkel's most resonant and time-transcendent offerings. Breaches continue to generate cross-disciplinary interest because they offer a most vivid window into how local actors construct social order in everyday talk and interaction. Language socialization scholars have taken note.

Important Scientific Research and Open Questions

Language socialization scholars examine how people – whether they be children or other novices – are socialized *through* and *to* proper language befitting their particular roles and speech contexts (Schieffelin and Ochs 1986; Garrett and Baquedano-López 2002). Like Garfinkel, language socialization scholars often mine micro-level contexts, including everyday conversations, family dinner time narratives, classrooms, beauty salons, etc., for insights into how people are socialized *through* the use of language, as well as how they are socialized *to* use language. In language socialization contexts, breaches – disagreements in interpretations of language, instruction, arguments, and so on – may expose implicit cultural expectations and assumptions underlying a social practice (Schieffelin 1990). Research in this vein show that breaches can be witting or unwitting, deliberate/staged, or accidental. They can entail verbal or non-verbal (i.e., gestural) mistakes that violate implicit expectations about how such talk is supposed to go.

Language socialization scholars excavate conversational breaches for spoken language and paralinguistic cues – tone, prosody, body language, stance, gestures (e.g., eye rolls) – that serve to mark what went wrong, or was supposed to happen in interaction. They are curious about how the exchange also manages to reveal aspects of the presumed social order, speaker roles, or situational conventions. In this way, they oblige the interpretive agenda of EM, which considers how the organization of social interactions is anticipated and managed by participants in everyday encounters. Language socialization scholars' strong ethnographic orientation and roots in sociolinguistics, psycholinguistics, and developmental psychology, also takes them into analytical terrains not originally afforded by an EM paradigm; for language socialization scholars, the locus for insight into taken-for-granted assumptions – or the *"just-thisness"* of social encounters (Garfinkel 1967) – includes culture and individuals, and not just the dynamics of the scene or exchange itself. Their scope is similarly broad, encompassing not just the socialization of children into culturally competent members, but also socialization of newcomers into specific communities of practice, socialization across the life-span, bilingual and multilingual socialization, literacy socialization, and narrative as a means of language socialization.

Breaches are also illuminative insofar as they lay bear the fact that conversation is an interactional achievement. Speakers share specific assumptions about the proper conversational roles, turn-taking, and the like. When these assumptions are violated, such as when a speaker laughs after a sad story or talks while someone else is talking, it can be read as a breach of social norms and cause people to feel angry or hurt. Breaches can also incur loss of social face and mark people as troublesome or unpredictability. This is why what happens after the breach is as significant, if not more so (at times) than the actual breach itself – though the nature of the breach (e.g., whether it is witting or unwitting, intentional vs. unintentional) is also instructive.

For example, Jacobs-Huey's (2007) 18-month study of an African American cosmetology school in South Carolina examined a series of breaches committed wittingly and unwittingly by students, clients, teachers, and the author, herself. One of the most obvious breaches she observed occurred when a client picked up a stylist's curler and applied the finishing touches to her own hair, much to the astonishment of her stylist

and other women in the salon. Additionally, Jacobs-Huey committed her own set of breaches while serving as a receptionist from time to time. One day, she conveyed a client's request for the cost of a wash-and-set to an instructor and received a reply more akin to a reprimand: "Do you mean *shampoo*? Because you wash dogs, not hair!" Each of these breach episodes compelled candid dialogue during the moment of the breach (and long after) about what went wrong or was supposed to happen. These evaluations underscored the importance of speaker intentionality and accountability and, most importantly, served to clarify what was at stake for African American stylists, their predominantly Black female clientele, and cosmetology students when mistakes were made at the level of language and representation.

Similarly, work in elementary school classrooms by Baquedano-López et al. (2005) demonstrate that discontinuities or disruptions in classrooms can constitute breaches that render visible the components of expected forms of participation that underlie social interaction (3). Their analysis of classroom breaches is multi-faceted and reveals that breaches do not merely instigate attempts to resolve the breach, but can also incite further conflicts. In fact, the identification of the breach can itself constitute a breach of a different sort – one that warrants a response of its own. Breaches, they ultimately demonstrate, constitute *teachable moments* that, in their violation and resolution, serve to: reveal (and constantly reshape) specific *participation frameworks*, index particular identities, shore up specific authoritative stances – with bearings upon power relations and the production of knowledge.

Any consideration of the breach as it pertains to language socialization must also consider the place of Conversational Analysis (CA), a field of language study developed by one of Garfinkel's colleagues and collaborators, Harvey Sacks. Sacks' pioneering work with Emanuel Schegloff and Gail Jefferson (1974) displays an abiding interest in what verbal or non-verbal mistakes can teach us about the social organization of talk through its focus on *repair* – moments wherein interlocutors signal confusion, request clarifications, etc.; and moments in spoken discourse that belie shared expectations (e.g., pregnant pauses that are a bit too pregnant). Garfinkel (2002) laments that scholars often miss the linkages between CA and EM given CA's highly technical methodology and systematic portrayal of

dialogue (see also Heritage 1984). Garfinkel adds that while this systematicity has helped CA avoid the stigma typically associated with EM, they both are concerned with revealing members' *competencies* or methods for creating social order through the detailed study of social practices, including naturally-occurring conversations.

Breaches beckon even greater attention by language socialization scholars. The concept of the breach is not yet a key term in linguistic anthropology textbooks, nor is it featured in the indices of the field's most canonical tomes. Future research might also examine the potentialities of the breach; that is, might there be extra-situational conditions or contextual issues at play which prime the pump for breaches and/or preclude specific types of breaches? Another question language scholars might consider is when is something a breach vs. merely a mistake in language learning contexts? Might there ever be occasions or genres (e.g., humor) wherein breaches get ratified as "right" or acceptable? Moreover, *who* gets to deem something a breach and what might this teach us about the constitution of speaker authority and "the right to speak"? What verbal or nonverbal strategies are employed to evaluate a breach episode? How are linguistic ideologies implicated in the execution and evaluation of breach episodes? How might breach episodes speak quite literally to the politics of representation, as well as questions of accountability and intentionality; what, further, is at stake, implicitly and explicitly, in the evaluation of breach episodes?

Cross-References

▶ Language Acquisition and Development
▶ Socialization-Related Learning

References

Baquedano-López, P., Solís, J. L., & Kattan, S. (2005). Adaptation: The language of classroom learning. *Linguistics and Education, 16*, 1–26.

Garfinkel, H. (1967). *Studies in ethnomethodology*. Englewood Cliffs, NJ: Prentice Hall.

Garfinkel, H. (2002). *Ethnomethodology's program: Working out Durkheim's aphorism* (Introduction by A.W. Rawls (Ed.)). New York: Rowman & Littlefield.

Garrett, P. B., & Baquedano-López, P. (2002). Language socialization: Reproduction and continuity, transformation and change. *Annual Review of Anthropology, 31*, 339–361.

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. Cambridge, MA: Harvard University Press.

Goffman, E. (1981). *Forms of talk*. Philadelphia, PA: University of Pennsylvania Press.

Heritage, J. (1984). *Garfinkel and ethnomethodology.* Cambridge, UK: Polity Press.

Hilbert, R. A. (1992). *The classical roots of ethnomethodology: Durkheim, Weber, and Garfinkel.* Chapel Hill, NC: The University of North Carolina Press.

Jacobs-Huey, L. (2007). Learning through the breach: Language socialization among African American cosmetologists. *Ethnography, 8*(2), 171–203.

O'Brien, J. (2010). Building and breaching reality. In J. O'Brien (Ed.), *The production of reality: Essays and readings in social psychology* (5th ed., pp. 338–358). Newbury Park: Pine Forge Press.

Sacks, H., Schlegloff, E. A., & Jefferson, G. (1974). The simplest systematics for the organization of turn-taking for conversation. *Language, 50*(4, Pt 1), 696–735.

Schieffelin, B. (1990). *The give and take of everyday life: Language socialization of Kaluli children.* Cambridge: Cambridge University Press.

Schieffelin, B., & Ochs, E. (Eds.). (1986). *Language socialization across cultures.* Cambridge: Cambridge University Press.

Learning Through Working

Learning to Avoid Aversive Outcomes

Learning to Construct and Integrate

Learning to Learn

Mariel F. Miller, Allyson F. Hadwin
Department of Educational Psychology and Leadership Studies, University of Victoria, Victoria, BC, Canada

Synonyms

Lifelong learning; Self-regulated learning; Study skills

Definition

Learning to learn is a lifelong process in which individuals deliberately plan, monitor, and adapt their learning. When students learn to learn, they treat learning activities as objects of inquiry. They interpret tasks, set task-specific goals, experiment with strategies, monitor successes and failures, and implement changes to improve shortcomings. As today's knowledge economy is characterized by increasingly rapid change and shifting demands, learning to learn is a critical aspect of success in the workplace as well as academic contexts.

Theoretical Background

Contemporary perspectives conceptualize learning to learn as self-regulated learning. Theories of self-regulated learning contend that students learn to learn by deliberately planning, monitoring, and regulating their cognitive, behavioral, and motivational processes toward completion of an academic task. There are numerous models of self-regulated learning (e.g., Weinstein et al. 2000; Winne and Hadwin 1998; Zimmerman 1989) with diverse theoretical foundations. While models differently conceptualize mechanisms by which students self-regulate their learning, many share a number of common assumptions:

- *Task Contexts.* Whenever learners regulate learning, they do so within the context of a task. Given the large amount of variability among tasks, students must tailor their approaches to the nuances and requirements of individual tasks.

- *Agency.* The notion that learners are inherently agentic is central to theories of self-regulated learning. In other words, learners purposefully strive to exercise choice in learning to achieve goals.

- *Goals.* Self-regulating individuals set goals for learning. Goals define the standards against which learners judge the adequacy of their learning processes and products.

- *Motivation.* Motivation is a key influence on task engagement, strategy use, and goals. As students self-regulate, new motivational beliefs also emerge that carry forward to influence future learning. Finally, students can regulate their own motivation in a task.

- *Cognitive Engagement.* Self-regulated learning requires that students acquire declarative, procedural,

and conditional knowledge about strategies for learning and remembering. Further, they must experiment with and adapt strategies in response to standards defined by goals for a given learning task.

- *Metacognition.* Successful learners are meta-cognitive. They build metacognitive knowledge about tasks and strategies, continuously monitor and evaluate learning in every learning episode, and adapt or fine-tune learning in response to monitoring.

Important Scientific Research and Open Questions

Key Processes in Learning to Learn

Research indicates students must engage a number of key processes when learning to learn. These processes are fundamentally grounded in self-regulated learning, cognitive theories, and assumptions described above.

Task Perceptions. Learners encounter a broad array of academic tasks throughout their academic careers. Theories of self-regulated learning posit that accurate task perceptions are critical for learning to learn because they provide the information upon which students base their task goals and standards. Without the skills necessary to decode the subtleties of academic tasks, learners may overlook errors in standards, experiment with ineffective strategies and solutions, and fail to uncover ways learning can be improved.

Constructing accurate task perceptions is challenging. This process requires students to interpret multiple sources of information, including (a) explicit task features overtly communicated in task descriptions such as task criteria, (b) implicit information framed by task context and purpose that students must extrapolate from explicit task descriptions, and (c) socio-contextual task features such as the larger disciplinary contexts and values framing the task.

Findings indicate task perceptions contribute to performance. However, learners often misinterpret common academic tasks especially when they are complex and ambiguous. In particular, students struggle to accurately interpret the implicit task information underlying task instructions. Finally, learners often fail to detect and address deficiencies in their task perceptions, and misattribute difficulties to factors such as time management or poor planning. Little research has examined

strategies for task perception, and few study skills text-books devote attention to this topic. Thus, future research is required to investigate effective methods for constructing accurate perceptions of the multiple levels of task information.

Goal Setting. Goals provide the task-specific standards learners utilize to monitor and evaluate learning strengths and weaknesses. Goals are fundamental components of learning to learn because they inform students' judgments about discrepancies between desired and actual performance. Without goals, learners cannot effectively recognize instances where adaptations are necessary for improving learning.

Research indicates goals facilitating learning to learn are characterized by a number of key properties. For instance, effective goals identify and target (a) one specific task or studying instance, (b) a short-term time frame in which to achieve the goal, (c) a standard against which to evaluate goal progress and attainment, and (d) cognitive, behavioral or motivational processes required to achieve the goal. Thus, the goal of "get my readings done" may be less effective than "on Friday between 9 a.m. and 11 a.m., I will review the cardio-vascular system in Chapter 3 by making flashcards of key physiological components until I am able to recite them in my own words." Since the latter goal integrates each of these key processes, it supports learning to learn by providing more immediate feedback about progress and enabling active self-monitoring and adapting. Currently, research is often limited to goals assigned to students by external sources. Thus, questions remain regarding how students' self-assigned goals influence learning to learn within and across tasks.

Strategy Experimentation. Learning to learn involves more than applying simple skills or tactics. Students who effectively learn to learn possess a repertoire of strategies including knowledge about when, how, and why strategies work. Second, they apply strategies in consideration of three factors: (a) external task features, (b) internal characteristics such as prior knowledge and perceived challenge, and (c) the appropriateness of the strategy relative to other approaches for achieving task goals.

Research identifies a wide range of strategies students use for regulating their behavior, motivation, and cognition in their learning. Strategies for behavior include modifying the environment, managing time and priorities, and strategies for active and passive

procrastination. For instance, in order to reduce distractions, a student might modify the environment by closing the door. Strategies for motivation include methods of increasing, decreasing, or maintaining factors such as self-efficacy, task value, interest, and academic emotions like test anxiety. Common motivational strategies identified by students include positive self-talk and self-consequencing.

Finally, empirical research identifies five general categories of cognitive processing strategies. Strategies for activating prior knowledge, such as K-W-L, help students integrate new information with what they already know. Strategies for searching and selecting, such as highlighting, help learners prepare for deeper processing by distinguishing important ideas from less relevant information. Strategies for organizing and structuring, such as concept mapping, help students mentally organize information into coherent representations and assemble connections among concepts. Strategies for generative processing and elaboration, such as predictive questioning, help students establish long-term memory and transfer knowledge to new problems and situations by extending knowledge beyond what is provided and making connections between existing knowledge and new information. Strategies for repetition and rehearsal, such as reciting information, help students to improve remembering and recall by affording repeated exposure to information.

Contemporary research demonstrates that self-regulated strategy use results in higher knowledge acquisition; however, further research is required to investigate the effectiveness of a wider range of strategies in authentic learning situations. In particular, little research has examined the effectiveness of strategies for regulating motivation and affect. Finally, further research is required to systematically examine strategies in relation to other key processes in learning to learn, such as task perceptions and task goals.

Monitoring and Adapting. An essential process in learning to learn is metacognition. Successful students build metacognitive knowledge about their own thinking, the task, and strategies for completing the task. In order to learn to learn, students must continuously metacognitively monitor learning within and across tasks by comparing actual progress to desired outcomes and standards for cognition, motivation, and behavior. When metacognitive monitoring reveals a discrepancy between desired and achieved standards, students may exercise metacognitive control to reduce the discrepancy by adapting or changing aspects of their learning such as their standards and/or strategies utilized.

Research indicates the success of enacting metacognitive control to adapt learning depends, in part, on the accuracy of metacognitive monitoring. These findings highlight the importance of creating accurate task perceptions, and effective goals as students use this information as the foundation for monitoring and evaluating progress. Furthermore, while monitoring ability develops slowly, findings suggest it can be improved with training and practice.

Facilitating Learning to Learn

A number of interventions have been developed to help students learn to learn. Effective interventions are often framed by theoretical models of learning, provide opportunities for students to practice strategies in authentic task contexts, and support metacognitive monitoring and adapting of learning. Due to space limitations, we highlight three examples.

Self-regulated strategy development (*SRSD*) (cf. Harris et al. 2003) supports development of strategy knowledge, monitoring and regulating of strategy use, and development of self-efficacy and positive beliefs in six flexibly sequenced stages: (1) development and activation of background knowledge, (2) development of knowledge about strategies including procedures for implementation, (3) modeling the strategy and illustrating metacognitive thinking through self-talk, (4) development of memory aids for strategy memorization, (5) use of external supports, such as guiding and prompting, for strategy implementation, and (6) independent performance of the strategy. Research demonstrates the effectiveness of SRSD in both large and small groups and in number of domains such as writing, reading, and mathematics.

Strategic Content Approach (*SCL*) (cf. Butler 1998) provides students with a framework for strategically approaching and engaging in new tasks by targeting self-regulatory processes. The program involves four steps providing students with opportunities to develop and individualize strategies. In step 1, students analyze task demands and criteria. In step 2, students select, adapt, or invent strategies based on criteria established in step 1. In step 3, students are prompted to monitor

strategy use. In step 4, students are supported in evaluating and adapting strategies for future use.

Self-regulation Empowerment Program (*SREP*) (cf. Cleary and Zimmerman 2004) facilitates independent learning using a preliminary diagnostic to identify motivational and strategic weaknesses followed by a three-step process targeting these weaknesses: (1) the empowerment step supports students in making connections between strategy use and successes and failures in order to develop perceptions of control over learning. (2) the study/learning strategy step facilitates development of a strategy repertoire through modeling, coaching, and guided practice, (3) the final step facilitates engagement in a cyclical feedback loop of self-regulated learning involving forethought (setting goals and making plans), recording performance, evaluating goal attainment, and reflecting on strategy effectiveness and ways in which strategies can be improved.

Contemporary Issues and Future Directions

Knowledge about how students learn to learn continues to evolve. In the final section of this article, we illustrate two contemporary issues that are the focus of emerging research.

Social context in learning to learn. Learning to learn has traditionally been defined as an individual process influenced by the social context. Emergent perspectives posit, however, that learning to learn can also occur through co-regulation and socially shared regulation. In co-regulation, social supports provided by others, such as peers or teachers, facilitate and scaffold individuals in learning to learn by sharing some of the self-regulatory burdens. In socially shared regulation, groups learn to learn in group tasks by regulating their collective activity. In other words, not only must individuals learn to learn, but groups must engage in a parallel process in which they regulate shared learning through co-constructing shared task perceptions, goals and standards, and engage in shared monitoring and evaluation of progress. Future research in this area is required to explore research designs, methodologies, and analytical techniques for examining co- and shared-regulation.

Technology and learning to learn. In recent years, technology has become an invaluable asset for supporting and researching learning to learn. For instance, learning to learn instruction is increasingly designed and implemented in computer and web-based environments. In addition, technological tools provide new methods for guiding and tutoring learning such as computer-based scaffolding. Finally, technology enables researchers to harness new types of data, such as computer trace data. While these data supplement traditional methods of investigating learning to learn such as self-report questionnaires, further research is required to examine new methodologies and analytical techniques in order to use this data to its full potential.

Cross-References

▶ Active Learning
▶ Cognitive and Affective Learning Strategies
▶ Computer-Supported Collaborative Learning
▶ Deutero-learning
▶ Learning Set Formation and Conceptualization
▶ Learning Skills
▶ Learning Strategies
▶ Metacognition and Learning
▶ Meta-learning
▶ Methodologies of Learning Research (Overview)
▶ Scaffolding Cognitive Self-Regulation
▶ Self-Regulation and Motivation Strategies
▶ Strategic Learning
▶ Study Strategies

References

Butler, D. L. (1998). The strategic content learning approach to promoting self-regulated learning. In B. J. Zimmerman & D. Schunk (Eds.), *Developing self-regulated learning: From teaching to self-reflective practice* (pp. 160–183). New York: Guildford.

Cleary, T. J., & Zimmerman, B. J. (2004). Self-regulation empowerment program: A school- based program to enhance self-regulated and self-motivated cycles of student learning. *Psychology in the Schools, 41*, 537–550.

Harris, K. R., Graham, S., & Mason, L. H. (2003). Self-regulated strategy development in the classroom: Part of a balanced approach to writing instruction for students with disabilities. *Focus on Exceptional Children, 35*, 1–16.

Weinstein, C. E., Husman, J., & Dierking, D. R. (2000). Self-regulation interventions with a focus on learning strategies. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 727–747). San Diego: Academic.

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated engagement in learning. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Mahwah: Lawrence Erlbaum.

Zimmerman, B. J. (1989). A social-cognitive view of self-regulated learning. *Journal of Educational Psychology, 81*, 329–339.

Learning to Sing Like a Bird: Computational Developmental Mimicry

MICHAEL H. COEN
Departments of Biostatistics and Medical Informatics; Computer Sciences; and Zoology, University of Wisconsin-Madison School of Medicine and Public Health, 6785 Medical Sciences Center (MSC), Madison, WI, USA

Synonyms

Artificial intelligence; Biologically inspired computing; Developmental learning; Sensorimotor learning

Definition

How do animals learn their behaviors? Examining this question admits a wide variety of possible explanations. These range from innate "programmed" reflexes acquired through phylogenetic evolution within a specific ecological niche to *tabula rasa* (i.e., "blank slate") models that place few a priori constraints on the learning process itself. Of course, we know that animals are indeed constrained in *what* they can learn. This is why a human child acquires language while her pet puppy does not; the child is genetically disposed to make language learning possible, in most cases unavoidable, whereas a puppy has no such capacity. Nonetheless, what neural and cognitive mechanisms enable animals to acquire their learned behaviors remains very much an open question. The clearest area for examining this problem is perhaps in *mimicry,* an essential form of behavioral learning where one animal acquires the ability to imitate some aspect of a conspecific's activity, constrained by the capabilities and dynamics of its own sensory and motor systems. Evidence supports that animals subsequently learn while observing the effects of their own motor activities in attempting to duplicate previously observed behaviors (e.g., Deregnaucourt et al. 2005).

The ubiquity and robustness of learning through imitation in the animal kingdom has led to a renewed interest in studying biological models for creating intelligent machines. In contrast with many engineered systems, animals are robust and capable learners even when faced with problems that are computationally challenging, for example, they are over *distribution free* or *non-parametric* data. By studying how biological systems manage to overcome these issues, biologically inspired computing aims to duplicate these capabilities artificially.

Theoretical Background

The study of birdsong acquisition is among the most examined problems in sensorimotor learning; here, external behavior displays such as singing are readily observable and sufficiently simple that they can be approached directly. One may contrast this with the study of human acquisition of language, which appears to require elucidation of extremely complex rules governing its obtainment. Taking birdsong as a model for exploring sensorimotor learning, Marler (1997) outlines three models of song development. These range from fully unconstrained, instructive tutoring to the assumption of innate neural templates for acquiring highly constrained, conspecific song patterns. He argues for an intermediate approach, incorporating song memorization into a phylogenetically evolved framework that has been selected to facilitate rapid learning within an individual species. This fits the hypothesis espoused by Berwick (1985) that "natural learning systems are designed to be easily learnable." Namely, we expect biological systems have evolved to learn the things they need to know, without the less flexible (and presumably, selectively disadvantageous assumption) that this knowledge is entirely genetically encoded.

From both cognitive science and computer science perspectives, we would say the selection of necessary *features* – namely, the data extracted from an animal's inputs – is largely predetermined, but these features are sufficiently flexible to enable a wide range of learned phenomena. Similarly, motor systems are constrained by factors such as anatomical considerations, minimization of energy expenditure, stability of outputs, etc. Thus, they are not given free reign, but instead possess the features that are necessary for each given species. For example, it is believed that the presence of the lateral thyrohyoid ligament in the vocal anatomy of hominoids enables vowel production, necessary for human speech. Capabilities such as this enable people to generate any phoneme used in human language, but not vocalizations, for example, found in dolphin songs.

There is therefore a clear tradeoff between specificity and generality. A system, biological or

computational, must possess sufficient specificity to enable required learning in a reasonable timeframe; however, it should not artificially constrain the nearly limitless sets of things the system could discern upon exposure. Elucidating these features and innate capabilities, from both sensory and motor perspectives, provides basic insight into what a system may learn and how it might approach doing so.

Important Scientific Research and Open Questions

It is generally accepted that human languages are composed of discrete generative vocal units called *phonemes*, the number of which varies with dialects of each given language. For example, it would not be surprising to discover that a native English speaker can vocalize approximately 40 phonemes – the primitive sounds combined to generate English utterances. Understanding phonetic structures and their relation to one another occupies the fields of phonology and phonotactics, among other areas. It provides basic insight into the structure and constraints of human language. We can view protolinguistic behavior such as babbling as part of an infant's ongoing effort to internalize the phonemes of her native language. Thus, understanding phonetic development is one window into early linguistic development.

We may ask whether other animals also possess some type of discrete, generative vocal units. In other words, should we view animals as capable of producing arbitrary sounds, such as a music synthesizer might, or are they instead limited to some set of primitive sounds out of which their utterances are somehow constructed? Although many animal vocalizations appear complex – and indeed, many are even hypersonic, meaning they are outside of the human auditory range – what characteristics do they share in common with human communication? In asking this question, our goal is not simply to describe animal "song." More importantly, we are interested in how it might be learned. Assuming it is composed of discrete units combined in well-defined patterns proposes a theory of learning for animal communication. An open and increasingly important question is how widespread vocal learning is in the animal world. Once thought to be in the exclusive purview of very few species, even African elephants (*Loxodonta africana*) have now been demonstrated to be capable of learning new sounds during social communication.

A number of early attempts were made to find discrete generative vocal units to other species. Species examined include zebra finches (*Taeniopygia guttata*), white handed gibbons (*Hylobates lar*), and free-tailed bats (*Tadarida brasiliensis*), among many others. However, the majority of these analyses were done by hand and involved grouping similar *visual* shapes displayed on spectrograms of recorded audio into common "phonemes." While extremely useful as first steps, these analyses ignored clear internal differences within the derived phonetic groupings. Further analysis required a combination of machine learning and signal processing. Among the earliest works formalizing this methodology was that of Tchernichovski et al. (2001), who elucidated a set of acoustic features believed to be biologically relevant in zebra finch audition. These features were examined over song constituent called "syllables," namely, parts of the song separated by period of silence. However, the "syllables" had clear internal structure that was left unexamined, suggesting that a simple temporal-based grouping was insufficiently revealing.

This work was elaborated upon by Coen (2006, 2007), who deconstructed the traditional unit of "syllable" ubiquitous in the birdsong and animal literature, as shown in Fig. 1. By computationally segmenting the syllables, more basic vocal constituents were identified. These were proposed to represent the avian analog of phonetic structure given their: (1) repeated use, as demonstrated through clustering; (2) appearance in stereotypical patterns; and (3) differential rates of acquisition – namely, pieces of "syllables" were acquired at different rates and some of these pieces appeared easier to acquire than others. This analysis enabled the development of the first computational framework that could both acquire these bird "phonemes" and subsequently learn to generate them with an articulatory synthesizer designed to simulate bird vocalizations. By first acquiring the finite repertoire of primitive vocalization units, it proved straightforward to fit them to the song of a zebra finch using a hidden Markov model. Thus, what is known as a divide-and-conquer mechanism proved successful for the task.

An increasingly studied question is whether this type of approach generalizes to other species. We may also ask if it can be used to characterize the complexity of a species' vocalizations. For example, one can easily imagine looking for the existence of morphology

Learning to Sing Like a Bird: Computational Developmental Mimicry. Fig. 1 Breaking a birdsong down into constituent phonemes. On the *top*, the song is displayed divided into seven syllables, namely, song sections separated by brief periods of silence. In the *middle*, a single syllable is expanded to reveal its interior structure. On the *bottom*, this syllable is segmented into seven primitive vocalizations, illustrating an avian analog to phonemes. The *blue lines* indicate segment boundaries, which are derived from the peaks of the song's smoothed log power

(word-like constructs) and even syntax (recursive structure), which has long been assumed to be the exclusive crown-jewel of human language. Clearly, computational techniques have much to offer in understanding the structure and acquisition of communication in animals. Simultaneously, studying how animals learn appears to provide significant benefits in improving computational learning methods (e.g., Coen 2006). In addition, formally studying the relationship between communication in animals and

language in humans provides a solid foundation for exploring the evolution of communication and possible universal mechanisms shared by multiple species.

Cross-References

References

Berwick, R. C. (1985). Learning from positive-only examples. The subset principle and three case studies. In R. S. Michalski, J. G. Carbonell, & T. M. Mitchell (Eds.), *Machine learning: An artificial intelligence approach.* Los Altos: Morgan Kaufmann.

Coen, M. H. (2006). *Multimodal dynamics: Self-supervised learning in perceptual and motor systems.* Ph.D. Dissertation, Massachusetts Institute of Technology.

Coen, M. H. (2007). Learning to sing like a bird: An architecture for self-supervised sensorimotor learning. *Proceedings of the Twenty Second AAAI Conference on Artificial Intelligence (AAAI-07),* Vancouver.

Deregnaucourt, S., Mitra, P. P., Feher, O., Pytte, C., & Tchernichovski, O. (2005). How sleep affects the developmental learning of bird song. *Nature, 433*(7027), 710–716.

Marler, P. (1997). Three models of song learning: Evidence from behavior. *Journal of Neurobiology, 33,* 501–516.

Tchernichovski, O., Mitra, P. P., Lints, T., & Nottebohm, F. (2001). Dynamics of the vocal imitation process: How a zebra finch learns its song. *Science, 291*(5513), 2564–2569.

Learning to Think

Learning to Write

Carlo Magno
Counseling and Educational Psychology Department, De La Salle University, Manila, Philippines

Synonyms

Composition writing; Technical writing; Writing proficiency

Definition

Learning to write is a process where preverbal ideas (thoughts) are transformed into a written form. Such written forms produced vary from words to sentences to higher forms of discourse such as essays, reports, researches, reviews, poems, stories, dialogues, etc. These written forms that are generated, formed, and activated from thoughts are then organized into meaningful information. The organized information is then transformed into a verbal message that comes in a written form. The ability to speak and read is prerequisite in writing. Individuals follow a system of grammatical rules, punctuations, capitalizations, and style when composing written discourse such as in the formulation of sentences and paragraphs. Proficiency in the production of written discourse improves as the individual develops and gain experience.

Theoretical Background

The domain of "learning to write" is explained vastly in a developmental and cognitive perspective. In a developmental perspective, learning to write contributes in an individual's literacy level. Children start to show evidence of ability to write by age 5–6 years. At this stage, children have already developed content knowledge and plot structure. At the later elementary and high school levels, individuals begin to provide details and support to their main ideas. By the adult stage, individuals gain the ability to articulate their knowledge of text structure. This articulation involves their awareness of specific strategies in writing in the planning, execution, evaluation, and finalization stage. The effective use of such strategies contributes to a coherent composition.

Individuals' development of syntactical formation is explained by Chomsky's generative grammar theory. The theory posits that individuals have a natural ability in generating and understanding unlimited combinations of words and sentences. This theory explains that individuals can create sentences and paragraphs in vast amounts given the different rules of one's language. These rules may involve word order and morphological markings (Tomasello 2008).

The ability to write is explained as a cognitive process where individuals use and operate on different processes to produce coherent compositions. When content knowledge is added in the writing task, the individual uses simultaneous operations to integrate

content into the process of writing, which requires declarative and procedural knowledge. The writing task generally involves generating the idea, organizing the ideas, structuring and organizing sentences, forming paragraphs with coherent meaning, and organizing the entire composition. The idea-generation phase is activated through interaction with one's readings, conversation and brainstorming with others, and other factors that stimulates the individual to think of content knowledge to write about. These ideas are then organized by representing the ideas into sentence and paragraph structures that basically forms a discourse. The composition is further organized through feedback and assessment by oneself or with the assistance from others. The composition is shaped by creating an introduction, the body of the text, and conclusion.

The writing stage and the cognition involved in writing is explained in the composition process framework by Bartlett (2007). The framework explains the writer who initially thinks about purpose of writing by considering personal and social influences. The writer then goes through an interactive process in the preparation to write by gathering information and potential response from the audience. In the actual composition process, the individual attempts to write successively until a written text is produced. This stage can be facilitated through instruction.

The process of writing involves complex tasks, allowing the individual to enhance their skills. Writing skills further develops through maturation where individuals become aware and create techniques to facilitate their writing. Learning theories describe expert writers use metacognition and self-regulation strategies when engaging in a writing task that allows them to gain desirable consequences in the outcome of their composition. The social cognitive theory explains that individuals arrive at better writing compositions when they are self-regulated in the process of writing. The theory involves the influence of the environment and specific behaviors that contributes to the individual's ability to write. When a well-structured environment is created, it facilitates a mood for writing. The autonomy of an individual to engage in writing makes the individual acquire a belief that one is capable of writing. Specific self-regulated strategies that facilitates better writing include ways of remembering important words to use in writing, setting goals for ones composition,

evaluating the results of writing, seeking others help by brainstorming, and organizing thoughts (Magno 2009).

When writing a composition, expert type of learners usually plan, create drafts, and revise their drafts. Planning involves what the writer wants to write about, the position and theme of the composition, the support that will be provided for the main themes, organization and tone of the paper. The draft is written as the initial formulation of the composition. The writer thinks about what the reader needs to know first, how the body of the composition will be structured, and how to end the composition. The revision may come in the form of revising one's own work or asking others to provide feedback or revise. In the revision process, the writer goes through the entire manuscript from beginning to end and edit certain parts that need to be improved. The elements revised are usually grammar, content, further elaboration, and organization.

Important Scientific Research and Open Questions

The research findings that involve learning to write are focused on determining factors that contribute to writing and specific instruction that facilitates writing.

The factors that influence writing involve two set of variables: Linguistic devices and psycholinguistic factors. Linguistic devices include the use of mechanics, parts of speech, punctuations, number of words, grammar, spelling, vocabulary, etc. in writing. On the other hand, psycholinguistic devices involve learning strategies, metacognition, self-regulation, self-efficacy, motivation, attitude, etc., which help individuals arrive at a better composition. Studies on linguistic devices break the composition into its lexical and syntactical parts. Writing proficiency is attained depending on the amount of text characteristics (e.g., Number of words, word per sentence, character per word, number of sentences, sentences per paragraph, number of unique words, lexical density, number of paragraphs, readability, strength index, descriptive index, etc.), lexical features (e.g., Conjuncts, exclusives, additives, particularizers, hedges, intensifiers, demonstratives, etc.), grammatical features (e.g., Noun, nominalizations, verbs, modals, adjectives, adverb, prepositions, pronouns, articles), and clause feature (e.g. Coordinates, subordinates, infinitives, adverb, relatives, passives, etc.). Writing proficiency is attained

with less error. Such error categories include errors in noun endings, articles, subject-verb agreement, verb tense, unnecessary shift in verb tense, verb form, word choice, preposition errors, pronoun–antecedent agreement, pronoun shift, subject omitted, capitalization, apostrophe, hyphenation, spelling, fragments, run-on sentences, comma, redundancy, word order, contraction, missing word, and unnecessary word. The psycholinguistic factors also contribute to writing proficiency when effectively used. People differ in their use of learning strategies according to some personal as well as environmental characteristics when writing. Among the personal characteristics that influence individuals' writing is the use of learning strategies such as motivation as well as cognitive and metacognitive abilities. Environmental factors include the level of exposure that an individual has, contextual, and cultural variables.

The issue that arises in the contribution of linguistic devices and psycholinguistic factors is about the importance of each predictor or which factor contributes to better writing. These factors are studied separately depending on the orientation of the researcher. Linguistics focuses exclusively on the use of linguistic devices to predict written proficiency (McNamara et al. 2010). On the other hand, psycholinguistics and learning theorists focus on building models where the outcome is writing proficiency. The challenge for future researchers is to assess the strength of contribution accounted for by the linguistic devices and psycholinguistic devices (Magno 2008).

Another aspect of studies on learning to write is focused on how it is facilitated through instruction. The line of studies in facilitation to writing ends on proper and better ways of teaching students to write. Such instruction suggests building a relationship between teachers and students, teaching students strategies for effective writing, providing constructive feedback and assessment to improve student compositions (Thais and Zawacki 2006). Building a relationship between the teacher and student describes the connection that the teacher needs to make with the student as a writer. The connection is made in order for the student to allow the teacher become his/her mentor and guide in the writing process. This aspect is within the classroom management domain. The second aspect is teaching the student to gain awareness and construct ways to achieve better writing. This aspect focuses on

teaching students the psycholinguistic factors involved in writing. The assumption here is that students who are aware and control their writing process are able to write better. The last line of research in facilitating writing is through assessment. The assessment process is built within the instruction and assessment results are utilized to make students write better. Examples of assessment techniques are communicating the criteria with the use of rubrics, providing feedback after writing, and allowing students to revise their work based on feedback.

The questions stemming from instructions on writing involve the appropriateness of such techniques in different contexts. Constructivist approaches in the facilitation of writing may not work well in other cultures where teachers' authority is expected. The effectiveness of instruction in writing also depends on how well teachers carry out the procedure.

Cross-References

► Beliefs about Language Learning
► Complex Skill Acquisition
► Discourse
► Discourse and the Production of Knowledge
► Knowledge and Learning in Natural Language
► Language (Discourse) Comprehension and Understanding
► Language Acquisition and Development
► Language Learning and Socialization
► Learning to Write in a Second Language
► Linguistic Factors of Learning
► Literacy and Learning
► Meaning Development in Child Language: A Constructivist Approach
► Metacognitive Strategies
► Mnemotechnics in Second-Language Learning
► Psycholinguistics and Learning
► Self-Regulation and Motivation Strategies
► Vocabulary Learning in a Second Language

References

Bartlett, E. J. (2007). *Learning to write: Some cognitive and linguistic components*. Washington, DC: Center for Applied Linguistics.

Magno, C. (2008). Reading strategy, amount of writing, metacognition, metamemory, and apprehension as predictors of English written proficiency. *Asian EFL Journal: Professional Teaching Article, 29*, 16–48.

Magno, C. (2009). Self-regulation and approaches to learning in English composition writing. *TESOL Journal, 1*, 1–16.

McNamara, D. S., Crossley, S. A., & McCarthy, P. M. (2010). Linguistic features of writing quality. *Written Communication, 27*(1), 57–86.

Thais, C., & Zawacki, T. M. (2006). *Engaged writers and dynamic disciplines: Research on the academic writing life.* Portsmounth: Boynton/Cook.

Tomasello, M. (2008). *Origins of human communication.* Cambridge, MA: MIT Press.

Learning to Write in a Second Language

ELI HINKEL
Department of Anthropology, Seattle University, Seattle, WA, USA

Synonyms

Additive language; Nonnative language; Written prose; Written text and discourse (units of connected speech and writing)

Definition

Writing in a second language refers to expressing or communicating ideas in a written form in a language other than one's first (native) language. A second language is learned after a native language that is typically learned in childhood and used throughout one's lifetime as the dominant language.

Theoretical Background

Learning to write in a second language is a process foundationally and substantively distinct from learning to write in a first language. In addition to learning new global discourse (units of connected speech and writing) constructions, how ideas are arranged, and how cohesion and coherence are established, second language writers must develop sufficient language proficiency in the second language to enable them to convey their ideas in writing. Over the last half century, the broad-based objective of research on second language writing has been to develop effective pedagogical models. Many of these models have attempted to create strategies, tactics, various techniques, and curricula for teaching second language writers discourse organization skills, with a secondary focus on the quality of written text.

In the 1950s and 1960s, early studies began with the examination of rhetoric and discourse and idea structuring in various languages. In light of the fact that the study of the flow of ideas in writing represents one of the foundational philosophical endeavors in the Western literary tradition, early analyses of discourse and the linguistic properties of text largely adhered to classical Aristotelian and Greco-Roman rhetorical theory, such as the canonical elements of discourse and stylistics. These examinations established conclusively that discourse and ideational paradigms differ greatly in and across languages and cultures (e.g., Hinds 1976).

Investigations carried out in the 1960s and 1970s sought to develop new knowledge based on empirical data, with the overarching objective of providing theoretical and practical approaches to teaching second language writing and teacher education. In the 1980s and 1990s, studies of second language writing and discourse achieved a great deal of prominence and began to proliferate dramatically as an outcome of an exponential growth of immigration and the numbers of nonnative learners enrolled worldwide at various levels of education.

At present, three broad domains of applied linguistics research can be identified in the analysis of written discourse and text with immediate or theoretical goals of curricular development. In the first domain of second language writing research, numerous studies have focused on the organization of ideas and the flow of information in discourse, as well as linguistic properties of second language text, such as, for example, sentence construction or uses of lexical (vocabulary) and grammar features (e.g., Hinds 1987). Comparative investigations that undertake analyses of similar genres and types of written prose in native and nonnative writing have long been considered essential in pedagogical and curricular models for teaching and learning to write in a second language (e.g., Hinkel 2002).

In general terms, an ever-expanding body of work has shed light on a wide range of properties of discourse and text produced in a second language, as well as systematic variability in second language writing. Since the 1990s, much has been learned about the structuring of ideas in written prose and the smaller, the essential components of discourse, also called discourse moves (Swales 1990).

The second domain of research in writing in general and second language writing in particular has been

closely associated with the rapid development of technology that has enabled a computerized analysis of written and spoken text. Corpus analyses represent examinations of large – a million words or more – written and spoken collections of language, as it is used in real life. The widespread computerized analyses of first and second language corpora have radically altered how written and spoken text can be studied and how its systematic regularities (or exceptional occurrences of language) can be analyzed.

An inevitable point of dissention arises whenever multiple discourse paradigms or perspectives on discourse construction are at play. In the late 1980s and 1990s, in the third domain of studies, some researchers highlighted the connections between discourse, language, and power in society. Critical discourse analysts have emphasized the need to address the issues of power and inequality in discourse and language pedagogy, which is invariably entailed in virtually all types of schooling.

Taken together, these investigations in the language and discourse features of second language prose have identified important and significant differences in the features of writing in first and second languages in similar genres. Research on how discourse is organized and language is used in second language writing has led to a greater understanding of many issues that confound second language writing and its teaching and learning.

Important Scientific Research and Open Questions

Research in effective pedagogical models in second language writing has not even come close to the body of established knowledge about the properties of second language written discourse and text. As Leki et al. (2008, pp. 72–73) point out, "indeed, one would be hard pressed to identify foundational concepts that have aspired to provide a single, guiding basis on which to organize writing curricula comprehensively. . . . [L]ittle research and few models of L2 writing have tried to relate curriculum content directly with L2 students' writing achievements." The evolution of curricular and instructional approaches to teaching second language writing has been traditionally determined by factors that are not necessarily related to the teaching of writing as a discipline. While an enormous body of work has been published on the uses of language and ideational organization in the written prose of second language learners, as well as their social and cultural backgrounds and identities, only a handful of research undertakings have set out to examine what second language writers have to be able to do and how they need to be taught. For instance, in many cases, second language writing is not usually taught as a separate skill, but in conjunction with other types of language instruction, such as that in reading or grammar, or even instruction in school subjects, such as literature or social studies.

Generally speaking, a handful of methods for developing curricula and teaching second language writing, including academic second language writing, have emerged in the last half century. These have diverged to varying extents depending on the prevailing fashions and contemporary views on the effectiveness of a particular writing instruction, political trends in academic writing instruction, composition teaching, language learning, second language learning, and cognitive development.

In the 1970s, 1980s, and 1990s, much in the methods and techniques for teaching second language writing was derived from pedagogy in first language composition. In later years, second language writing instruction has striven to move away from composition studies at least to some extent. Techniques prevalent in the teaching of second language writing have sought to address an extensive array of issues that have traditionally represented major and minor foci of instruction modified to meet the needs of second language learners specifically. These techniques encompass generating ideas and producing second language text, organizing ideas in keeping with second language discourse conventions, planning and outlining, paragraph and text development, drafting, revising at the discourse and sentence levels, considerations of audience, lexical choice, precision, and vocabulary changes, dictionary uses, spelling, punctuation, editing, and error correction, as well as using computers for writing, grammar practice, and vocabulary development.

Currently, two approaches to second language curricula and pedagogy seem to be most commonly adopted. These schools of thought on second language writing pedagogy predominate in different world regions and are distinct in regard to how second language writing should be taught and what types of instruction best serves the needs of second language

learners. For instance, content-based (also called theme-based) language and writing instruction is commonly found in US-based curricula, while genre-based (also called text-based) teaching of second language writing predominates in the UK, Australia, and New Zealand. It is important to note, however, that neither of the two approaches is focused specifically on second language writing, but rather each entails integrated instruction in writing together with other language skills.

Content-based instruction and curricula play an important role in the teaching of second language writing to school-age learners and academically bound students in preparatory pre-university programs. In content-based teaching, second language reading, writing, and the attendant linguistic skills are integrated with that in a subject matter, such as, say, history or geography, with auxiliary grammar and vocabulary instruction. In content-based curricula, second language reading and writing occupy a prominent place. For example, combined with instruction in the subject matter and language uses in thematically cohesive readings, the teaching of second language writing can address issues of discourse and information flow, as well as the uses of grammar constructions and contextualized vocabulary. Critics, however contend that in many situations where second languages are taught worldwide, the implementation of content-based instruction may be simply inappropriate and impractical. For example, when instruction in subject areas, such as science or math, is carried out in a second language, teachers often find it difficult to maintain expertise in both language and the content.

In the UK and Australia, in particular, genre-based approaches have predominated among methodological directions in second language writing instruction and curricular designs. Like content-based instruction, genre-based teaching also represents an integrated approach to teaching second language writing together with reading and supplementary foci on the linguistic features of writing. The genre-based approach and teaching techniques draw on the foundations of systemic functional linguistics and genre theory. These analytical approaches have informed the teaching of second language writing mostly for academic and specialized purposes, such as, say, university assignments or technical prose from email messages to doctoral dissertations. Genre-based pedagogy seeks to equip language learners to analyze written discourse while reading and to produce school writing that adheres to the sociocultural norms of a particular academic (or professional) genre. Many experts in the teaching and learning of a second language have commented, however, that genres and their linguistic features may be subjective, culture-bound, vaguely defined, or even irrelevant to diverse types of second language learners (e.g., Widdowson 2003).

To date, research findings have established that second language writers need intensive and extensive instruction in practically all aspects of constructing discourse and reasonably fluent and accurate text. Research has also demonstrated that, in many cases, crucial factors that confound second language writing and text have to do with shortfalls of writers' language proficiencies and restricted linguistic repertoire that significantly undermine second language writers' ability to produce reasonable quality texts (Hinkel 2002). Based on the results of these studies, many researchers of second language learning in general, and second language writing in particular, have pointed out that even school-age learners or highly educated adults need years of language training to attain the levels of proficiency requisite for effective writing.

New research and the development of pedagogical theory and validated classroom practice are urgently needed. In the end, the overarching objective of empirically grounded and principled pedagogical models is to provide second language writers with the necessary skills for communicating effectively in a broad range of contexts.

Cross-References

▶ Learning to Write
▶ Second Language Learning

References

Hinds, J. (1976). *Aspects of Japanese discourse structure*. Tokyo: Kaitakusha.

Hinds, J. (1987). Reader versus writer responsibility: A new typology. In U. Connor & R. B. Kaplan (Eds.), *Writing across languages: Analysis of L2 text* (pp. 141–152). Reading: Addison-Wesley.

Hinkel, E. (2002). *Second language writers' text: Linguistic and rhetorical features*. Mahwah: Lawrence Erlbaum.

Leki, I., Cumming, A., & Silva, T. (2008). *A synthesis of research on second language writing in english*. New York: Routledge.

Swales, J. (1990). *Genre analysis*. Cambridge: Cambridge University Press.

Widdowson, H. (2003). *Defining issues in english language teaching*. Oxford: Oxford University Press.

Learning Transfer

Learning Transgenics

Learning Under Stress

Learning Under the Migrant Condition

Learning via Linear Operators

SANDOR SZEDMAK
Institute für Informatik, Leopold Franzens University of Innsbruck, Innsbruck, Austria

Synonyms

General, and generalized, linear models; Kernel methods; Linear functions; Linear maps; Linear regression; Multivariate regression; Pursuit regression; Ridge regression; Structural learning

Definition

The linear operator-based learning connects two linear vector spaces by approximating the possible functional relationship by a linear mapping between these sets.

Theoretical Background

Learning via linear operators covers a collection of machine learning and statistical methods which are based on a linear mapping between two sets. The linear mapping is generally called linear operator if these sets are linear vector spaces (Halmos 1974). In the machine learning literature, the domain of the linear mapping is called as input set and the range is referred as output set. The input might also be referred as independent or explanatory variable, and the output as dependent or respond variable. The learning task is then to find a linear operator mapping the input space into the output space if only a sample of input and output pairs of observations is known, (Hastie et al. 2009; Cristianini and Shawe-Taylor 2000). The learning task realized via linear operators can be interpreted as an extension of the case where the outputs are only real numbers, generally called as univariate problems, and the extension can be referred as multivariate, or vector-valued learning tasks.

The selection of the most appropriate linear operator is based on some rules given in advance and depends on the concrete learning method. These rules are generally called loss functions which can measure the discrepancy between the images of the inputs with respect to the linear operator learnt and the corresponding outputs (Hastie et al. 2009; Cristianini and Shawe-Taylor 2000). The discrepancy can be expressed by a certain metric, e.g., Euclidean distance, between the images of the inputs and the outputs or a certain function of these distances, e.g., square Euclidean distance, most generally known as least square error. The methods of multivariate linear regression, general linear model are good examples for applying the squared Euclidean loss function (Hastie et al. 2009). Alternative loss functions can be built upon the absolute deviation, and in the maximum margin framework, e.g., Structural learning, inner product-based loss functions can be applied (Bakir et al. 2007).

The linear operator-based learning can be extended to estimate functional relations when the supposed to be most accurate mapping between the input and output spaces is probably nonlinear. This can be carried out by applying nonlinear mappings on the input or (and) on the output spaces into linear vector spaces. The target space of this kind of mapping is generally called as feature space. Then a linear operator is looked for which maps the feature space of the inputs into the corresponding space of the outputs, and in this way the nonlinear relationship between the original input and output spaces can be discovered. In the statistical literature, the nonlinear mappings connecting

the inputs and outputs are generally called as link functions (Hastie et al. 2009). The kernel-based learning methods can model the nonlinear relations via kernel functions without direct references to the underlying nonlinearity. These kernel functions represent inner products between the feature vectors provided by the nonlinear mappings (Cristianini and Shawe-Taylor 2000). The pursuit regression, generalized linear model, and kernel ridge regression are good examples working on nonlinear spaces (Hastie et al. 2009). The application of the feature space representation paves the way for applications of linear operator-based learning methods on objects with special structure, e.g., on graphs or strings which can describe images, text documents, or even chemical molecules (Shawe-Taylor and Cristianini 2004; Bakir et al. 2007).

The linear operator-based learning frequently applies so-called regularization methods, which reduces the range of the possible choices of these operators (Tychonoff and Arsenin 1977). The reason for the regularization is to increase the generalization performance, the estimation accuracy of the linear mapping derived in the learning problem toward the cases of potential input and output items which were unseen in the learning procedure. Probably, the most well-known method implementing this kind of approach is the ridge regression. Learning methods developed for structural learning problems are also good examples to the application of the regularization (Shawe-Taylor and Cristianini 2004; Bakir et al. 2007).

Important Scientific Research and Open Questions

One of the most important question addresses the so-called pre-image or inverse problem. If the output items have a special structure, e.g., they are graphs, and own characteristic feature vector representation, then the linear operator-based learning can provide only an estimation of the feature representation of the optimal output item but not the item itself. To reconstruct the underlying structure of the optimal output item if the feature mapping is not an invertible function turns to be a hard problem and it can be generally solved only for special, and mostly simple, cases (Bakir et al. 2007). A demonstrative and important example can be that when the target of the learning task is to predict the biochemical effect of a new drug. Assuming that there exist good descriptive feature representations for the

known biochemical reactions and also for the drugs, then the effects might be predictable and can be recovered at a sufficient accuracy.

Cross-References

▶ Learning Algorithms
▶ Model-Based Learning
▶ Supervised Learning

References

Bakir, G. H., Hofman, T., Smola, A. J., Schölkopf, B., Taskar, B., & Vishwanathan, S. V. N. (Eds.). (2007). *Predicting structured data*. Cambridge: MIT Press.

Cristianini, N., & Shawe-Taylor, J. (2000). *An introduction to support vector machines and other kernel-based learning methods*. Cambridge: Cambridge University Press.

Halmos, P. R. (1974). *Finite-dimensional vector spaces*. New York: Springer.

Hastie, T., Tibshirani, R., & Friedman, J. H. (2009). *The elements of statistical learning* (Series in statistics 2nd ed.). New York: Springer.

Shawe-Taylor, J., & Cristianini, N. (2004). *Kernel methods for pattern analysis*. Cambridge: Cambridge University Press.

Tychonoff, A. N., & Arsenin, V. Y. (1977). *Solution of ill-posed problems*. Washington, DC: Winston.

Learning with Representations

▶ Representational Learning

Learning with a Teacher

▶ Supervised Learning

Learning with and from Blogs

Francesc Balagué
Universitat de Barcelona, Barcelona, Spain

Synonyms

Blended learning; e-learning; Netlearning; Social learning

Definition

A blog (short for Web + log) is a Web site where entries are made and displayed in reverse chronological order. Most blogs provide commentary or news on a particular subject, such as food, politics, or local news; some act as more personal online diaries. A typical blog combines text, images, links to other blogs, Web pages, and other media related to its topic. The ability for readers to leave comments in an interactive format is an important part of most early blogs.

Although weblogs are a resource mainly for communication, the way that they organize information, allowing for interaction and sharing of knowledge, makes them an ideal educational tool. Students can individually express and reflect about their thoughts and experiences, while sharing these with colleagues and receiving teacher's feedback. Blogs can be used for simple and specific educational activities, as well as for long-lasting and complex ones. The environment also allows teachers to monitor students' work.

Learning with and from blogs goes further than just publishing online the work done in class. It also implies other aspects, from communicative, to expressive, to social that will highly enrich the learning process.

Theoretical Background

This section examines some of the theoretical research that supports the use of blogs in education and presents guidelines for the adoption of this technology in the classroom.

Main Implication of the Use of Blogs in Education

The technological facilities currently offered by the blog tool simplify many administrative and design tasks that were required before to set up a Web site, letting users to focus on the content rather than on the underlying code or webpage design. This ease of use represents a big advance for the adoption of this kind of technology in educational areas. Blogs are one of the most popular tools in the Web 2.0 environment. They are multimedia; students can use videos, images, music, etc. to express their ideas, thoughts and questions, or to illustrate the learning process. This combination of media widens the ability to reflect about the learning process, promoting creativity and other skills (Conole et al. 2006).

In this technological context, the old role of teachers is no longer suitable. New functions are needed, in which the teacher guides students in the discovery, organization, and management of the ever-growing information available to them. The use of technologies will help teachers to give more control and responsibilities to students. Students will create their own content, discuss and develop new materials, and establish relationships with various sources of information and with other students around the world interested in the same topics. Weblogs are highly suitable platforms for doing so, which will also encourage students to interact with many other technological tools. The study material is no longer plain text, it becomes multimedia (see Wesch's video "The machines is using us" http://www.youtube.com/watch?v=6gmP4nk0EOE), and this fact implies the maximization of students' abilities and development. They will have to develop creativity, imagination, concept relations, etc.

From the educational socio-constructivist point of view, students become the protagonists of their own learning. Teaching shifts from being centered on the teacher's point of view to being focused on the students; that is, it emphasizes the learning process rather than the teaching one (Oravec 2002). In this context, learning with and from blogs provides a place where students can post their experiences, thoughts, discoveries, difficulties, and so forth; this is done with the following aims:

1. To reflect about their own learning process
2. To share their thoughts and ideas, as well as to receive input from other students
3. To help students with digital alphabetization
4. To track and guide the learning process by teachers

Even though the plain use of technology does not guarantee a more effective learning (Ramsden 2005), weblogs can be used as a resource and supporting tool to promote some aspects of this educational model. Concentrating all the work, activities, personal information, reflections, and so forth, in an organized place, creates favorable conditions for the students to reflect on their learning process and allows the teacher to follow their development easily by visiting the students' blogs.

The work posted in a blog can be shared with people interested in similar topics, as well as with those interested in the student's development (parents,

tutors, teachers, etc.). Therefore, blogs are not only used as personal portfolio space, but they also allow for interaction with others. Students select their best solutions for the tasks proposed by the teacher and reflect about them (Why did he/she choose these particular solutions? Which resources they needed to accomplish the tasks? What were the contributions of the tasks toward his/her learning?). This reflection is then published on the blog to be shared with others, exposing different ways of learning that are more hidden in a traditional methodology.

Based on the socio-constructivist approach, students will be the center of the process, so teachers must guide them in the use of the tool:

- What they are expected to do with it and how
- What the evaluation criteria will be
- If there is a minimum number of posts per week
- How they should manage time
- What is appropriate and inappropriate behavior on the blogosphere
- Privacy elements

Introducing Blogs in the Classroom

Teachers must feel comfortable with the technology before attempting to use it as an educational tool. The following process is suggested to develop this familiarity (Richardson 2006):

1. Reading other blogs
2. Following the recommended links
3. Paying attention to the structure and organization of the information (use of tags, categories, etc.)
4. Start commenting on others' blogs
5. Creating a blog and start posting links with a few descriptions
6. Start posting elaborated content
7. Maintaining the conversation alive, answering comments, connecting your posts with other blogs, etc.

Likewise, blogs should be introduced gradually in the classroom. Students can follow the same process to gain confidence in the use of the tool. This is particularly important when each student is required to create and maintain his or her own blog. The teacher should also consider the workload that will be imposed on the students and their real opportunities to access the Internet, from home or from school, making sure that

the adoption of the technology will not be too difficult for anyone. In addition, guidelines for the use of blogs in the educational context must be established; these have to be argued with and accepted by all the participants in the process.

More specifically, weblogs can be used to promote the transfer of the learning process control to the students. As the social-constructivist approach states, the student has to be the main character of his learning process. Blogs have the potential to motivate students, giving them responsibilities. A shared responsibility is obtained, for example, from group work where the blogs facilitate the participation of all students, helping the shy or fearful ones to participate and feel supported by their peers (Richardson 2006). Giving students more control and making them the protagonists of their own learning process implies a change in the traditional teacher's attitude and role, which is mostly unidirectional and based on teacher's knowledge.

Evaluation of Students as a Continuous Process

Using technology or not, the evaluation has to correspond to the main objectives and methodology used during the teaching process (Balagué 2009). If evaluation is considered a process rather than a specific moment at the end of the course, blogs can help teachers to track students' progress and guide them throughout the term, instead of telling students what is right or wrong after a final examination.

"People study better when they are involved in the creation of something specific and they have objectives for activity that they can reflect on." Seymour Papert.

Important Scientific Research and Open Questions

In the last 5 years, the use of weblogs in education has risen very fast, so has the research about them. This section summarizes the conclusions and important facts of some of these studies:

Conole et al. (2006) relates the students' experience with technology, concluding that, by their own initiative, students use the Web to organize their study, and as a place to find and synthesize information from different sources.

Jenkins (2008) concludes that new alphabetizations imply social abilities developed through collaboration and social networks. These abilities are based on the

traditional alphabetization grounds, such as research skills, technical knowledge, and critical analysis. They are related also with the different types of learning distinguished by Johnson (1992), who says that knowledge is generated under a continuous negotiation process and cannot be achieved until all the participants are included; this types of learning are:

- Learning by doing: teachers can use Web tools that allow students to experiment and, therefore, learn by trial-and-error.
- Learning by interacting: a range of hypermedia tools allow students to share ideas with anyone on the Net, such as discussions boards, chat, e-mail, social networks, etc.
- Learning by searching: one of the most popular uses of the Web is information searching, which may

involve different sources, electronic encyclopedias, etc.

- Learning by sharing: the exchange of knowledge and experiences lets students participate in a truly collaborative learning process.
- Learning by building knowledge: education is not only about sharing information and opinions; knowledge can be built also by creating a product together. Blogs can strongly help these processes although they have not been developed for education purposes and some adjustments are needed to perfectly fit new educational models.

Richardson (2006) explains the flexibility of blogs to adapt to different levels of complexity along the learning process, from the easiest to the more complex ones. For example, blogs may contain:

Learning with and from Blogs. Fig. 1 Stephen Downes' illustration of a PLE

1. List of tasks
2. Personal diary (what I did today)
3. List of links
4. List of links with small description
5. Links with content analysis
6. Reflexive and metacognitive writing about the practice, without links
7. Links with analysis and synthesis related to the linked content, aiming at the target audience.
8. Extended analysis and synthesis constructed along a period of time by posts, links, comments, etc

In addition to the above issues, Richardson (2006) highlights some reasons blogs have a transversal positive impact in education:

● Promote critical and analytical thinking
● Promote creativity, as well as intuitive and associative thinking
● Are a highly potential means to access quality information
● Combine individual reflection with social interaction

The Web contains a large number of tools that have the potential to assist learning, such as *Twitter*, *Facebook*, blogs, wikis, and social bookmarks. This variety inspired one of the current hot topics in education and technology research: *Personal Learning Environments* (PLE), which are places where each student has the tools that suit his/her learning process. Stephen Downes (2006) illustrates a PLE in Fig.1.

Blogs can be used as a PLE because they are very easy to be embedded in and to interact with other Web tools. Nevertheless, as blogs were not built for that purpose originally, they may impose limitations, which might mean that a more specific platform is needed. How this platform should be is still unclear and developing it is a future challenge.

Finally, further research is needed for identifying the most suitable educational situations that fits the use of blogs when compared with other tools, studies to uncover the time investment required for the use of blogs in the classroom, and quantitative studies comparing students' results and achieved learning objectives with and without blogs.

Cross-References

References

Balagué, F. (2009). Use of weblogs as a supporting tool for teaching and learning process at higher education. Ph.D. thesis. http://www.tdx.cat/bitstream/handle/10803/2944/FBP_TESI.pdf.

Conole, G., de Laat, M., Dillon, T., & Darby, J. (2006). JISC LXP: Student experience of technologies: Final report. http://labspace.open.ac.uk/file.php/1/kmap/1176712833/references/LXP%20project%20final%20report%20dec%2006.pdf.

Downes, S. (2006). PLE diagram. http://halfanhour.blogspot.com/2006/10/ple-diagram.html.

Jenkins, H. (2008). Confronting the challenges of participatory culture: Media education for the 21st century. Massachusetts Institute of Technology. http://digitallearning.macfound.org/atf/cf/%7B7E45C7E0-A3E0-4B89-AC9C-E807E1B0AE4E%7D/JENKINS_WHITE_PAPER.PDF.

Johnson, B. (1992). Institutional learning. In B. A. Lundvall (Ed.), *National systems of innovation: Toward a theory of innovation and interactive learning.* London: Printer.

Oravec, J. (2002). Bookmarking the world: Weblog applications in education. *Journal of Adolescent and Adult Literacy, 45*(7), 616–621.

Ramsden, P. (2005). *Learning to teach in higher education* (2nd ed.). London: RoutledgeFalmer.

Richardson, W. (2006). *Blogs, wikis, podcasts, and other powerful web tools for classrooms.* California: Corwin.

Learning with Collaborative Mobile Technologies

Marcelo Milrad[1], H. Ulrich Hoppe[2]
[1]Center for Learning and Knowledge Technologies (CeLeKT), School of Computer Science, Physics and Mathematics, Linnaeus University, Växjö, Sweden
[2]University of Duisburg-Essen, Duisburg, Germany

Synonyms

Mobile CSCL (Computer-Supported Collaborative Learning)

Definition

Mobile technologies are essentially materialized at the learner's side in terms of different kinds of portable devices of either general type (cellular phones or "smart phones," PDAs,) or more specific nature (such as

handheld playing devices or digital cameras). Considering the collaborative perspective, we are particularly targeting such devices supporting communication. Although the learning with such devices can still be individual (such as in certain language-learning applications), the focus here is on collaborative scenarios in which mobile technologies support learning in groups or communities. The now widely distributed mobile devices and applications provide new social tools for people to connect and interact; changing the ways we communicate, learn, and collaborate (Sharples et al. 2009). Educational environments are subject to these changes, and this creates new opportunities for supporting teaching, learning, and curriculum implementation. Mobile and wireless technologies enable new types of interaction with the physical world as they allow allocating computational power and interaction away from the limitations of desktop computers. These facts provided innovative ways of interacting with the environment, but they also present design opportunities for multiple kinds of collaboration to support different aspects of the learning process (Rogers and Price 2009).

With collaborative mobile technologies, the learning process can be supported in a variety of situations; students can switch from one scenario to another easily and quickly using their personal mobile devices as mediators (Zurita and Nussbaum 2004). These scenarios include individual learning, in pairs or small groups, or a large online community, with possible involvement of teachers, relatives, experts, and members of other supportive communities, face-to-face or in different modes of interaction and at a distance in places such as classroom, outdoors, parks, and museums. From this perspective, learners are given the opportunity to collaborate in new and interactive ways in the classroom and within the physical world, as well as the physical world can be augmented through digital technologies.

Theoretical Background

Learning and collaboration have their roots in various theories of cognition and social development that support different types of interactions between peers and experts. Moreover, learning as a social process happens in collaboration between people and together with technology. So, when introducing collaborative mobile technologies to support learning, the view should be

shifted from seeing them as a cognitive delivery system to considering it as means to support collaborative conversations about a topic in the context of an educational activity (Laurillard 2009). Actually, there is an ongoing discussion about how this kind of collaborative mobile technologies can promote new forms of inquiry, thinking, social interaction, and reflection (Sharples et al. 2007; Laurillard 2009; Pachler et al. 2010) in different educational settings and situations.

Sharples and colleagues (2007) have proposed a theory of mobile learning that they describe as "the process of coming to know through conversations across multiple contexts amongst people and personal interactive technologies (p. 225)." Based on this definition, it can be argued that the theory they propose is guided by a technology perspective, as it takes advantages of the affordances of mobile technologies to support learning and not the other way around. Moreover, the theory does not emphasize the importance regarding the role of the teacher and the classroom, which makes the theory especially suitable for learning in informal settings. One of the major drawbacks of this theory is the fact that it does not contemplate current theories of classroom or workplace learning. Laurillard (2009) claims that we need a better theoretical understanding of the nature of collaborative learning that includes all kinds of learning and teaching, traditional and enhanced by digital technologies, mobile- and classroom-based, formal and informal. Such a wide theoretical perspective would make possible for the educational community to both promote and justify the use of collaborative mobile technologies to support the learning process.

It is not only pragmatically relevant but also of theoretical interest to characterize and classify the range of typical applications of collaborative mobile learning technologies to avoid a mismatch between general claims and actual practices. According to Giemza et al. (2010), most of the existing practice in mobile learning (not restricted to collaborative applications) can be subsumed under only a few specific lines of research and development. The following standard types of applications are identified:

- Handheld classroom devices (for a recent description see Roschelle et al. 2009)
- Location-independent delivery on mobile devices, e.g., smart phones (Yang et al. 2008)

- Language-learning applications with interactive exercises, e.g., on mobile phones (Joseph and Uther 2009)
- Field trips with handheld and smart devices such as "smart" RFID-tagged objects, cameras, etc. (Spikol and Milrad 2008)

Rogers and Price (2009) provide another classification of mobile applications and tools that have been developed to augment learning with a focus on outdoor activities. They introduce the following four categories:

- Physical exercise games
- Participatory simulations
- Field trips and visits
- Content creation

As a synthesis of these two suggestions, limiting the list to clearly collaborative scenarios, we would particularly consider (1) field trips/visits, (2) participatory simulations, and (3) classroom scenarios involving handheld devices, whereas language-learning applications as well as physical games are not necessarily collaborative.

Mobile learning, and especially its collaborative variants, is often put in the context of informal learning (see, e.g., Sharples et al. 2007). Here, the possibility of triggering learning episodes through situational affordances of work situations or of leisure activities can be seen as beneficial. However, it is unclear if the ensuing knowledge-building and knowledge-integration processes based on these local, often spontaneous experiences will actually lead to knowledge structures that are adequately organized in a global perspective. Especially, sequencing effects, which are certainly relevant to knowledge building, may have a strong influence on the learning outcomes. The issue to be dealt within this respect has been characterized as the "knowledge fragmentation problem" (Hoppe 2006). It is plausible to assume, however, that this problem would be diminished if the ordering of situated episodic experiences was taken in a pedagogical context with scaffolding mechanisms.

Important Scientific Research and Open Questions

The idea that new technologies will transform learning practices has not yet been fully realized, especially with regard to collaborative mobile technologies to support learning across contexts. The task of designing effective computer support along with appropriate pedagogy and social practices is more complex than imagined (Laurillard 2009). The design of mobile systems and technological tools to support collaborative learning is a difficult process, not only because the learners may be separated by time and space, but also because they may not share the same learning physical context. Establishing common ground and mutual understanding, two important ingredients for collaborative learning, becomes a challenge. One of the major challenges for educational technologists and researchers is to find useful ways to design, to implement and to evaluate ubiquitous technologies and innovative pedagogical ideas in a variety of educational settings. The current design challenges faced by educational technologists and learning scientists can be enumerated as follows:

- How to design collaborative learning activities that support innovative educational practices?
- How to orchestrate collaborative learning that integrates activities in informal and formal settings?
- How to design learning activities that reflect the cultural diversity of learners?

Another main challenge still lies in the integration not only between software components in distributed environments, but also in the combination of software with new hardware and peripherals (e.g., sensors), as well as the support for content delivery on different types of devices. The overall challenge is to define rich scenarios in which different tools and technologies are used to integrate collaborative learning processes more seamlessly than in traditional environments (Hoppe 2007). Some of the current technological challenges in this area can be formulated as follows:

- What features and capabilities should collaborative mobile tools and systems provide to support a variety of desirable learning activities?
- Which combinations of mobile technologies with other interactive computing facilities and backend technologies are particularly well suited for which types of collaborative learning scenarios?
- How to develop robust concepts and methods for integrating contextual information as part of the metadata to be stored in the learning objects created by students?

- How to create adaptable computational mechanisms that would enable personalization and reusability of the learning content for different users across different platforms and tools?

Cross-References

► Collaborative Learning Supported by Digital Media
► Computer-Supported Collaborative Learning
► Mixed Reality Learning
► Mobile Learning

References

Giemza, A., Bollen, L., Seydel, P., Overhagen, A., & Hoppe, H. U. (2010). LEMONADE: A flexible authoring tool for integrated mobile learning scenarios. *Proceedings of the 6th IEEE international conference on wireless, mobile, and ubiquitous technologies in education* (pp. 73–80). Los Alamitos: IEEE Society Press.

Hoppe, H. U. (2006). How can we integrate mobile devices with broader educational scenarios? In M. Sharples (Ed.), *Big issues in mobile learning* (pp. 31–34). Nottingham: University of Nottingham. http://www.lsri.nottingham.ac.uk/Publications_PDFs/BIG_ISSUES_ REPORT_PUBLISHED.pdf

Hoppe, H. U. (2007). Integrating learning processes across boundaries of media, time and group scale. *Research and Practice in Technology Enhanced Learning (RPTEL), 2*(1), 31–49.

Joseph, S., & Uther, M. (2009). Mobile devices for language learning: Multimedia approaches. *Research and Practice in Technology Enhanced Learning (RPTEL), 4*(1), 7–32.

Laurillard, D. (2009). The pedagogical challenges to collaborative technologies. *International Journal of Computer-Supported Collaborative Learning, 4*, 5–20.

Pachler, N., Bachmair, B., & Cook, J. (2010). *Mobile learning: Structures, agency, practices.* New York: Springer.

Rogers, Y., & Price, S. (2009). How mobile technologies are changing the way children learn. In A. Druin (Ed.), *Mobile technology for children* (pp. 3–22). Boston: Morgan Kaufmann.

Roschelle, J., Rafanan, K., Estrella, G., Nussbaum, M., & Claro, S. (2009, June). From handheld collaborative tool to effective classroom module: Embedding CSCL in a broader design framework. *Proceedings of CSCL 2009*, Rhodes, 395–403.

Sharples, M., Taylor, J., & Vavoula, G. (2007). A theory of learning for the mobile age. In R. Andrews & C. Haythornthwaite (Eds.), *The sage handbook of e-learning research* (pp. 221–247). London: Sage Publications Ltd.

Sharples, M., Milrad, M., Arnedillo Sánchez, I., & Vavoula, G. (2009). Mobile learning: Small devices, big issues. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology enhanced learning: Principles and products* (pp. 233–249). Heidelberg: Springer.

Spikol, D., & Milrad, M. (2008). Physical activities and playful learning using mobile games. *Research and Practice in Technology Enhanced Learning (RPTEL), 3*(3), 275–295.

Yang, S. J. H., Zhang, J., & Huang, A. F. M. (2008). Applying web page adaptation techniques to the augmentation of mobile learning.

Research and Practice in Technology Enhanced Learning (RPTEL), 3(3), 253–273.

Zurita, G., & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers in Education, 42*(3), 89–314.

Learning with Expert Advice

KRISZTINA MOLNAR
Department of Economics, Norwegian School of Economics (NHH) and Business Administration, Bergen, Norway

Synonyms

Adaptive learning; Rational expectations

Definition

Rational expectations assume agents are able to calculate correct expectations, given the structure of the economy, conditional on their information set.

Least squares learning is a departure from rational expectations in a way that still attributes a lot of rationality to agents. Agents do not know the structure of the economy, but they use past data, and estimate regressions, to form expectations. As Marcet and Sargent (1989) show under some conditions these agents eventually learn the rational expectations equilibrium.

Theoretical Background

The importance of expectations has long been recognized in economics; however, the modeling of expectations remains a matter of controversy. Many economists suggest that not everybody is rational. However, once we depart from fully rational expectations, there are many ways to do so. There are many ways agents can form their expectations.

One alternative to model this is agent-based models. In these models agents behave according to a set of simple rules, and choose between these rules depending on their past forecasting performance. One drawback is that both the set of rules and the mechanism how agents choose between them is arbitrary. If agents have access to a better forecasting rule, for example, the correct rational expectation, they should

be allowed to abandon their ad hoc expectation rules. Indeed, the early literature motivated rational expectations by saying that if agents did not behave rationally they would disappear from the market. Rational agents would be more successful in the economy, because they make better forecasts, and eventually they would drive out nonrationals from the market.

Important Scientific Research and Open Questions

In this note, we address the question: "What happens if agents follow least squares learning but have access to expert advice, which is rational expectations?" Would learners be driven out of the economy? We assume the experts' expectation is rational within the model, namely, rational expectation is formed given the structure of the economy including how many learners form their expectations and also including how many learners and rationals are there in the economy.

We assume the population weight of learners and rationals evolves dynamically. We model an economy where there is a clear definition of optimal performance of forecasts. Private agents choose between the learning and the rational predictor, and choose the one that has better performance.

The key assumption is that private agents do not know ex ante which is the rational and which is the learning predictor, and differentiate between them depending solely on their past performance. Whichever predictor made better forecasts in the past will have a higher weight in the population: more private agents will use this predictor. If for example the rational predictor is always having a better performance, eventually their population weight will converge to 1, all private agents will use the predictor that is performing always better. An important feature of this weighting is that heterogeneity can be an equilibrium outcome, if the predictors have similar forecasting performance.

In order to have a clear definition of economic performance, let us consider an economy that is populated by a set of firms $[0, 1]$ who maximize expected profit. Economic performance then is measured by how much profit is generated. Firms consider themselves to be atomistic, and so assume not to influence the aggregate price level. Firm i produces a nonstorable good and faces a production lag; thus, the firm makes its supply decision with a lag, that is,

$$
\begin{aligned}
S(E_{t-1}^i[p_t]) &= \arg \max_{q_t^i} E_{t-1}^i \, \pi_t^i \\
&= \arg \max_{q_t^i} E_{t-1}^i[p_t]q_t^i - c(q_t^i) \\
&= (c')^{-1}\left(E_{t-1}^i[p_t]\right),
\end{aligned}
$$

where p denotes the price level, q the quantity of the non-storable good, π profit, $S(\cdot)$ the supply function, and $c(q)$ a cost function increasing in q. We assume a quadratic cost function $c(q) = q^2/2b$, $b > 0$, which implies that the supply decision of firm i is a simple linear function of the firm's expectation about the price level next period: $S_t^i = bE_{t-1}^i[p_t]$ and the profit of firm i is

$$
\pi_t^i = p_t E_{t-1}^i[p_t] - \frac{\left(E_{t-1}^i[p_t]\right)^2}{2b}. \tag{1}
$$

Firms face a stochastic demand on a competitive market:

$$
D(p_t, \mu_t) = A\mu_t - Bp_t, \quad A, B \in \mathbb{R}, \quad \mu \sim \mathrm{AR}(1).
$$

Market equilibrium is given by equating demand and supply:

$$
p_t = \lambda \int_0^1 E_{t-1\,p_t}^i \ d_i + m_t, \tag{2}
$$

where $\lambda = -b/B$. For convenience, we have redefined the stochastic process $m_t = (A/B)\,\mu_t$, $m_t = \varrho m_{t-1} + \varepsilon_t$, $\varepsilon \sim i.i.d.N\left(0, \sigma_\varepsilon^2\right)$.

Firms choose a predictor from a set of two types of predictors, the least squares (LS) predictor and the rational expectations (RE) predictor. Market expectations formed at $t-1$ depend on the fraction of firms using the LS predictor and the RE forecast at time $t-1$:

$$
\int_0^1 E_{j,t-1}p_t \ dj = \omega_{t-1} E_{t-1}^{LS}p_t + (1 - \omega_{t-1}) E_{t-1}^{RE}p_t, \tag{3}
$$

where $\omega_{t-1} = \in [0, 1]$ is the population weight of the LS predictor.

The weight of LS evolves in a recursive fashion:

$$
\omega_t = \omega_{t-1} + \frac{1}{t} \left\{ F[\pi_t^{LS} - \pi_t^{RE}] - \omega_{t-1} \right\}, \tag{4}
$$

where $F : \mathbb{R} \to [0, 1]$, $F(x) \leq F(y)$ for $x \leq y$, and $F(x) = 1 - F(-x)$, given $E_0^{LS}p_1$, $E_0^{RE}p_1$, ω_0.

In designing this weighting algorithm, we build on a recent approach in learning theory known as

prediction with expert advice (see Cesa-Bianchi and Lugosi 2006). In contrast to other models where the weights evolve dynamically, like Brock and Hommes (1997), we assume agents do not have to pay for the rational forecasts. Instead, we assume agents (firms) can obtain the rational forecast free of charge, but they are not certain which is the rational forecast, therefore, decide depending on which forecast generated bigger profits.

Now let us discuss what properties $F(\cdot)$ must fulfill. Since ω denotes the percentage of firms using the LS predictor, weights are naturally within the interval [0, 1]. Because $F(\cdot)$ is *monotone* a better LS forecast implies a bigger F, so the weight on LS is adjusted toward a higher value than the weight on RE. A key feature of F that the "expert" literature imposes is *symmetry* around 0; formally, $F(x) = 1 - F(-x)$. This condition means that firms do not ex ante differentiate between the two predictors: a similar performance of LS or RE is valued the same way. Finally, we will also assume *continuity* of F, which together with the symmetry condition implies that $F(0) = 0.5$.

Alternatively, the weighting algorithm can be written as

$$\omega_t = \frac{\sum_{k=1}^{t} F[\pi_k^{LS} - \pi_k^{RE}]}{t}.$$

The weight on LS indicates how the success of LS over RE was valued on average. Observe that if $F = 0.5$ (i.e., if $\pi^{LS} = \pi^{RE}$) infinitely many times, then the weights converge to 0.5.

One example of F is an indicator function that takes the value 1 whenever LS has a larger profit than RE and 0 otherwise. Here F at time t simply indicates whether LS was better than RE at time t, and ω_t measures how many times LS forecasted better than RE up to time t. In the limit, ω has an intuitive interpretation: ω converges to the probability that LS has smaller forecast error than RE.

When F is the indicator function, any infinitesimal difference between profits is rewarded. Also, any small difference is rewarded in the same way as bigger differences. Whenever LS is better its weight is adjusted toward 1, and whenever RE is better its weight is adjusted toward 1. By choosing another functional form for F we can also give a measure to how firms evaluate the relative forecasting success of LS. (For more examples, see Molnar 2007.)

Least Squares Learner

If all firms use the rational predictor, the *minimum state variable* (MSV) rational expectation solution is $p_t = \varrho/(1-\lambda)m_{t-1} + \varepsilon_t$, $E_{t-1}p_t = \varrho/(1-\lambda)m_{t-1}$. We assume the learner runs a least squares regression of this functional form, and regresses p_t on m_{t-1}

$$E_t p_{t+1}^{LS_\beta} = \beta_t m_t, \quad \beta_t = \frac{\sum_{i=1}^{t} p_i m_{i-1}}{\sum_{i=1}^{t} m_{i-1}^2}. \quad (5)$$

Rational Expert

The rational expert takes into account how many firms are using the rational and the learning prediction, and he or she also knows the learning prediction, therefore forms expectations as

$$R_t^{RE} p_{t+1} = E_t p_{t+1} = \frac{\lambda \omega_t \beta_t + \varrho}{1 - \lambda(1 - \omega_t)} m_t.$$

Equilibrium

The dynamics of this model is analyzed in Molnar (2007). The main result is that in the limit firms will use both the learning and the rational predictor, even though the rational predictor is clearly superior to the learning one, and it is costless to use any of the predictors. The intuition for this result is that, when firms ex ante do not know which is the rational and which is the learning predictor, it takes time to find out which is the rational one, and in the meantime the learning predictor can learn to produce good forecasts and survive. With time, the forecast of the learner and the rational expert will eventually be negligibly close to each other and close to the rational expectations equilibrium. Because the shocks are symmetric about the mean, in the limit the learner and the expert have the same probability of producing the better forecast. Thus, shocks guarantee that in some periods the learner in other periods the rational get closer to the actual outcome. In the limit, both the learning and the rational predictor generate the same profit and the population weight converges to 0.5. Half of the firms use the learning predictor, the other half uses the rational predictor. This holds true even if firms pay attention to any infinitesimal difference in predictor performance.

The equilibrium of this economy is the rational expectations equilibrium. When learning can converge to the rational expectations equilibrium, the presence of a rational expert does not alter the equilibrium itself.

The presence of rational "expert advice," however, alters stability conditions of the learning algorithm, that is, it introduces stability to the economy. Learning without the rational expert is stable when $\lambda < 1$. When we introduce a rational expert to the economy, learning is stable for $\lambda < 1$ and $\lambda > 2$. For $\lambda > 2$ there is an interesting interaction between them. The rational expert dampens the explosive nature of the learning prediction by giving forecasts with the opposite sign. Whenever the learning prediction would start to explode forecasting a high positive price level, the rational expert counterbalances this with giving a negative forecast, therefore bringing down aggregate expectations, which also decreases the aggregate price level. This brings down the learning expectation as well. The rational expert can do so when both λ and the weight on the rational predictor are sufficiently high – when the rational expert prediction influences the outcome to a sufficiently high extent.

In this simple environment, learners (firms using the learning predictor) are not driven out of the market by rationals (firms using the rational predictor). Even though learners know less about the economy than rationals, they can learn to make a good forecast and once this happened with a positive probability they even provide a better forecast than rationals. This result rationalizes empirical work on survey expectations suggesting that expectations actually combine backward- and forward-looking elements (see, e.g., Roberts 1998).

Cross-References

▶ Agent-Based Modeling

References

Brock, W. A., & Hommes, C. H. (1997). A rational route to randomness. *Econometrica, 65*(5), 1059–1096. http://ideas.repec.org/a/ecm/emetrp/v65y1997i5p1059-1096.html.

Cesa-Bianchi, N., & Lugosi, G. (2006). *Prediction, learning, and games*. Cambridge: Cambridge University Press.

Marcet, A., & Sargent, T. J. (1989). Convergence of least squares learning mechanisms in self referential linear stochastic models. *Journal of Economic Theory, 48*, 337–368.

Molnar, K. (2007). Learning with expert advice. *Journal of the European Economic Association, 5*(2–3), 420–432.

Roberts J. M. (1998). *Inflation expectations and the transmission of monetary policy,* (Finance and Economics Discussion Series, 1998-43). Washington, DC: Federal Reserve Board.

Learning with External Representations

Erica de Vries
Laboratory for Educational Sciences, Pierre-Mendès-France University of Grenoble II, Grenoble, Cedex 9, France

Synonyms

Learning with graphical representations; Learning with symbol structures; Learning with visualizations

Definition

External representations designate structures in the environment that allow the learner to interact with some content domain. They most often consist of configurations of inscriptions using a two-dimensional plane (paper, screen), but three-dimensional physical objects (mock-up, beads of an abacus, objects of a game or pieces of a puzzle) also fall under the designation. Representation comes from the Latin *repraesentatio*, which refers to the act of presenting something to someone's eyes or to someone's mind. In research on learning with external representations, the noun "representation" is used in a metonymic way for the result of the act, for that which represents, such as the figure, the picture, the graph, the statue, or the model; the adjective "external" specifies that these are outside the head and should be distinguished from internal mental representations. Learning with external representations thus involves inspecting, manipulating, modifying, or assembling components of external representations that stand for the objects, relations, and phenomena to be learned.

Theoretical Background

The sheer idea of learning with external representations raises issues described as early as in Plato's Allegory of the Cave. Consider the analogy: How and what may Plato's prisoners learn about reality from contemplating shadows on the wall of the cave and listening to echoes? How do the people on the walkway decide what figures of men and of animals to carry on their heads to produce appropriate shadows? Of course, in modern times, learners no longer only watch and listen, but also interact with instructional material. Furthermore,

teachers and instructional designers exploit a variety of techniques to bring domain content to the learner, for example, through text, pictures, animations, static and dynamic graphics, and visualizations. The development of modern technology raises important issues, for example, regarding the appropriate choice of (combinations of) external representations and the interaction possibilities for a particular knowledge domain and learner audience. At the same time, some of the old questions, such as those formulated above, are still relevant today.

From a historical perspective, the interest for learning with external representations builds on developments within cognitive science. More specifically, it follows extensive cognitive psychological research on mental representations, the hypothetical internal symbol structures that represent reality in the human mind. Palmer (1978), in reference to the classical *aliquid stat pro aliquo*, defined the contours of such internal representational systems and the ways in which an internal representation can be said to be "something that stands for something else." Research into learning with external representations builds on scientific knowledge of internal representations in two ways. The first approach studies the adaptation of instructional material to the human as an information-processing system, for example, by using texts and pictures to be processed by the two internal propositional and imagistic representational systems. The second approach considers learning as a task that involves the processing of information distributed across both the internal mind and the external environment, i.e., "a distributed cognitive task" (Zhang 1997). It defines external representations as structures in the environment, as written symbols, objects (e.g., the beads of an abacus), or dimensions, and as rules, constraints, or relations embedded in physical configurations. The *interplay* of internal and external representations is of particular interest in mathematics both for experts and novices. Teaching and learning mathematics in effect exploits all three functions of external representations (Duval 1995). They serve individual purposes of *objectification*, which is the process of making some abstract idea perceivable by the senses. Thus, through construction of their own external representations, learners may gradually develop more precise knowledge in some domain. Furthermore, external representations serve the collective purpose of *communication*; they allow

expressing something to someone else. Teacher–learner and learner–learner interactions exploit external representations for presenting, questioning, and discussing aspects of the domain to be learned. Finally, external representations allow *computation*; they function as an external memory and operational device for producing new information. For example, symbol structures that can be scanned for information, beads can be counted, two or more elements can be compared, and operations can be carried out to obtain new information.

External representations may be categorized according to:

- *Sensory channel.* Traditionally, instructional material mostly takes advantage of visual perception. But, next to sight, learning with external representations may also tap on the other senses, i.e., hearing and touch.
- *Representational possibilities of the medium.* The representational characteristics of the two-dimensional plane have been extensively described by Bertin (1967/1983). Graphics makes use of different marks (spots, lines, areas) that vary according to visual variables such as position, size, orientation, shape, color, and texture. The representational characteristics of sound are limited to auditory variables, such as frequency, duration, and chronological order. These representational possibilities condition *intrinsic* representation, which is when the inherent constraints on the representation are identical to the constraints on the domain. An example of intrinsic representation is to represent an asymmetric, transitive relation, such as size or weight, by another asymmetric, transitive relation, such as the length of a line (see also Palmer 1978). In *extrinsic* representation, the represented relation imposes its structure on the representation in a more or less arbitrary way, for example, when representing differences in size or weight through the arrows in a node-and-link structure.
- *Compliance with a formal representational system.* The prevailing view is that external representations must comply with a set of formal rules, such as in mathematical equations, logical formula, tables, histograms, pie charts, line graphs, and lists of propositions. Such representational systems are said to be *monosemic* (Bertin 1967/1983), i.e., the attribution of the signification of an inscription

precedes observation of the configuration of inscriptions. However, in a less strict sense, informal texts, pictures, diagrams, sketches, and illustrations are also considered to be external representations. According to Bertin, these operate according to *polysemy*; the attribution of the signification of an inscription *succeeds*, and has to be inferred from the observation of the configuration of inscriptions. Failing to appreciate the difference between the two may lead to severe misunderstandings.

- *Area of application.* Text, pictures, and graphical representations, such as line graphs, are *generic* external representations. They can be used to represent any type of information, such as qualitative or quantitative, numerical, logical, spatial, temporal, structural, functional, or behavioral information. Besides primary schooling, no specific instruction is needed to comprehend their representational format. Some other types of graphical representations, such as concept maps and flowcharts, also gradually become part of a common representational repertoire. On the other hand, electrical circuit or molecular structure diagrams are *domain-specific* representations that involve domain knowledge. Finally, emergent visualization techniques introduce new representational formats invented "on the fly." These representational formats are *situation-specific*, such as, for example, in algorithm visualizations and educational game environments.

- *The type of mapping between the representation and the represented objects, relations, and phenomena.* The most pervasive distinction in the literature distinguishes *iconic* representations based on resemblance relations from *symbolic* representations based on rules, habits or conventions. Peircean semiotics in addition identifies *indexical* representations based on contiguity (causal) relations.

- *The type of mapping between the representation and intended or inferred meaning.* Traditional instructional material relies heavily on *literal meaning* (denotative semiotics). It quasi-exclusively takes into account the meaning given by the context of the domain at hand. For example, the meaning of the word "lever" or of a picture of a lever in a physics context is limited to the physical object that allows lifting something. In such cases, the intended meaning is identical to the represented object. However, many representational techniques involve *figurative meaning* (connotative semiotics). For example, the word "dog" may be used to evoke the concept of dedication; a picture of a light bulb may be used to signify an excellent idea; the color red may indicate something that is actually red (blood, mouth, rose) or may represent a concept like socialism, danger, or love. Figurative meaning, in text and in graphics, is subject to cultural background.

Important Scientific Research and Open Questions

An important area of learning research concerns the choice of external representations depending on the context, the domain, and learner variables. The main issue concerns the fact that the different types of representations described above have different potential for expressing information, for inference making, and for computational purposes. In cognitive science, this is known as the representational effect, i.e., the phenomenon that different external representations of the same structure of objects and relations lead to different cognitive reasoning processes. Thus, external representations must be selected as a function of their appropriateness to the learning task, i.e., chosen for their advantages in terms of the possibilities for re-representation, computational offloading, and graphical constraining (Ainsworth 2006). A major problem, however, is that it is difficult to *anticipate* the actual effectiveness of a particular external representation for the intended audience. As of today, most external representational environments follow the intuitions of their designers and at best are founded on research-based recommendations or rules of thumb. A number of complementary approaches can be identified for alleviating the effects of possibly nonoptimal external representations. First, in order to balance the effects of individual external representations, learning environments may offer multiple external representations that complement each other, constrain the interpretation of each other, or synergistically enhance deep understanding (Ainsworth 2006). Furthermore, in addition to studying prefabricated external representations, an interesting instructional strategy is to encourage learners to construct their own external representations (diSessa 2004). Finally, much benefit is to be expected from deliberately

teaching how to translate one external representation into another, a crucial cognitive activity called "conversion" by Duval (1995).

Another area of scientific endeavor concerns the question whether external representations should be treated exclusively according to the prevalent cognitive view on representation as a two-term relation: "something that stands for something else." The alternative view incorporates Peircean semiotics and considers representation as a three-term relation: "something that stands for something else to someone from a certain point of view." Distinguishing three entities, such as in the semiotic triangle (object, symbol, thought), instead of only two, dates back to Aristotle, and brings up the issue whether external representations, in particular in learning situations, can be categorized *prior* to a particular instance of a signification process. In other words, whereas external representations are often considered normatively from the point of view of the teacher or the domain expert, a semiotic view shows the way to the study of the manifold points of view engendered by learners' cultural background and former experience with external representations.

Cross-References

► Multimedia Learning
► Pictorial Representation and Learning
► Semiotics and Learning
► Visualizations and Animations in Learning Systems

References

Ainsworth, S. E. (2006). DeFT: A conceptual framework for learning with multiple representations. *Learning and Instruction, 16,* 183–198.

Bertin, J. (1983). *Semiology of graphics.* Madison: University of Wisconsin Press. Original work published 1967.

diSessa, A. A. (2004). Metarepresentation: Native competence and targets for instruction. *Cognition and instruction, 22,* 293–331.

Duval, R. (1995). Sémiosis et pensée humaine, registres sémiotiques et apprentissages intellectuels. In *Semiosis and human thought, semiotic registers and intellectual learning.* Bern: Peter Lang.

Palmer, S. E. (1978). Fundamental aspects of cognitive representation. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 259–203). Hillsdale: Lawrence Erlbaum Associates.

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science, 21,* 179–217.

Learning with Games

Emmanuel G. Blanchard[1,2], Claude Frasson[1]
Susanne P. Lajoie[2]
[1]Department of Computer Science and Operations Research, University of Montréal, Montréal, QC, Canada
[2]Department of Educational and Counselling Psychology (ECP), McGill University, Montréal, QC, Canada

Synonyms

Edutainment; Game-based learning; Serious game

Definition

The term *Learning with Games* refers to a broad domain of research. Three elements have to be considered for the purpose of framing the current overview: Learning, Games, and the implications of their associations.

Learning

Learning is a complex topic as illustrated by the variety of entries in the current encyclopedia. In the frame of this entry, it is thus referred to as the process of acquiring or enhancing knowledge and skills, whether they be cognitive, physical, social, etc.

Games

Defining *Games* is also a very disputed topic and, according to Botturi and Loh (2009), no agreed upon definition of Games exists. Games are linked to the concept of *Play*. Playing is innate to many species including human beings. The specific study of Play led to several theoretical approaches that have historically been influenced by research on childhood development (Piaget 1962; Vygotsky 1966). However, Play is not a prerogative of children, any human being can play and experience its benefits (Botturi and Loh 2009). Sociologist and philosopher Roger Caillois discussed the genuine nature of Play and Games in his seminal book "*Man, Play and Game*" (Caillois 2006) and proposed the following definition of Play as an activity that is:

► *"(1)* **free** *- in which playing is not obligatory [...], (2)* **separate** *- circumscribed within limits of time and*

space [. . .] -, (3) **uncertain** *- the course of which cannot be determined, nor the result attained beforehand, and some latitude for innovations being left to player's initiative –, (4)* **unproductive** *– creating neither goods, nor wealth, nor new elements of any kind [. . .] –, (5)* **governed by rules** *– under conventions that suspend ordinary laws, and for the moment, establish new legislations [. . .] -, (6)* **make-believe** *– accompanied by a special awareness of a second reality [. . .]"* (Caillois 2006).

Caillois further classifies play (a) along a continuum from *païdia* (not structured) to *ludus* (structured through explicit rules), and (b) as a set of four types of activity: *Agôn* when the activity is based on competition like chess, *Alea* when it is based on uncontrollable aspects such as chance, *Mimicry* when the activity requires the player be immersed in an alternative reality or simulation such as in role-playing games, and *ilinx* when the player attempts to affect his/her physical sensors in order to provoke specific sensations like vertigo such as in rollercoaster.

However, Caillois did not provide a clear definition of Game or how it is different from other Play activities. The need to disambiguate both these notions is acknowledged by many scholars, and Botturi and Loh (2009) captured a dominant perspective when defining a Game as "*a structured set of rules that create a space where the playing mode of experience is possible*" (see also Gee 2007, p. 135).

Given these theories, we suggest that (a) a game is characterized as a set of structured rules and goals, (b) play is the behavioral format in which individuals (players) engage when doing a game activity, and (c) a game space is a space, formalized to a certain extent, where game rules and goals apply to players (such as 2D boards, playgrounds like soccer fields, etc.). Furthermore, a game can have varying game space representations. The chess game can be played on a real, a digital, or even a mentally represented board and, in all these settings, it remains the exact same game. But shifting from a representational setting to another may also lead to the emergence of different games. For instance, even though playing soccer in the real world or in a realistic videogame are generally grounded on many similar rules, they are genuinely different games that call the player for using different skills and knowledge. Indeed, a digital soccer field does not constrain the player in

a similar manner as a real one. Hence, mastering a soccer videogame usually requires the player to develop strategic skills using in-game characters as well dexterity at using control devices, rather than skilled leg and body control and a good physical condition as the real soccer game does.

Finally, even if rules and goals are probably the most frequently cited characteristics of games, they are not the sole ones scholars are interested in. Feedback, outcomes, choice, fun, interest, feelings of immersion, pleasure, engagement, interactivity, competition, challenge, and fantasy (Gee 2007; Squire 2007; Botturi and Loh 2009) are notions among others that are frequently associated with games. What becomes interesting in the context of this entry is that several scholars noticed that many such game characteristics also appear in modern theories of learning (Squire 2007) with Gee (2007), notably stating that good games model good learning theories. Modern research on Learning with Games lies on similar observations, and attempts to explore the potential of games as platforms for learning activities.

Learning with Games

The domain of *Learning with Games* focuses on analyzing, improving, and exploiting characteristics of game-based activities for learning purposes. More precisely, Squire (2007) listed the following research objectives for this field in the context of video games but they can be equally applied to any other game types: (1) developing basic theories of learning with games, (2) analyzing games to understand their positive influence on learning experiences, (3) understanding human interactions with games, (4) developing game-based pedagogical models, (5) analyzing the influence of the game domain on the evolution of educational practices, and (6) studying the adoption of game-based learning practices. The development of specific game-based educational technology is another important research focus of this domain.

Theoretical Background

Games have developed along with the evolution of civilization. The first currently known game, The Royal Game of Ur, dates back as early as 2600 BC. Games have rapidly been associated to learning since they provide opportunities for gaining experiences by confronting a player with metaphoric representations

of real-world situations. For example, chess or go games have been frequently associated with strategies applied in war situations. However, it is only quite recently that learning with games has become a field of research. Two research communities put particular emphasis in the study of learning with games. One is interested in game and play influence on childhood development, whereas the other one focuses on learning in the context of digital games. Both these research orientations are discussed in the next two sections.

Games and Childhood Development

Piaget (1962) and Vygotsky's (1966) respective frameworks on childhood development are still influential in learning-related research fields today, and both acknowledge the importance as well as the evolving influence of (Play and) Games on learning throughout the life span.

In the first 2 years of their childhood, children do not have the ability to cope with rules, which restricts them from being involved in pure Game activities (as it has been defined earlier in this entry). However, Play in less-structured activities already has a critical role in childhood development since it allows a child to develop sensorimotor skills (Piaget 1962). For instances, through Play, a child can develop distinctions between shapes, colors, sizes, or textures. He or she can also learn to master spatial positioning, and improve the efficiency of body movements accordingly. During this early stage, Play activities thus consist in concretely handling the world. Later, the child develops symbolic interpretations, thus becoming able to cognitively play with his/her world.

As children grow and develop, they are able to deal with more complex rules, and truly play Games, which improves their basic cognitive abilities such as the ability to stay focused, and fosters the development of higher order cognitive functioning such as mastering a language. From Vygotsky's perspective, childhood development is grounded in sociocultural interactions. Even though language is a critical element in developing mental concepts and cognitive skills, it is not the sole sociocultural construct. Games can provide a context for children to learn moral concepts and social rules that help them regulate their behavior and become social individuals. Hence, games can help promote the acquisition of various sociocultural skills assisting in the overall development of children.

Perhaps the most important aspect of play and game activities is the enjoyment they provide us. When games are motivating, they reduce the amount of effort needed to stay focused and to learn implicit and explicit learning content. Many games provide appealing opportunities for experiential learning, where children can discover and master skills, knowledge, and competencies they might use on a daily basis, later in life. Games provide opportunities for individuals to test different decisions and choices, and witness the varying outcomes, thus improving their situational appraisal and critical thinking skills. Through games, children can also experience a conscious realization of concepts, thus facilitating their internalization of new knowledge (Vygotsky 1966). For instance, through role playing with dolls, children learn the perspectives of others, such as playing a mother with a child, testing new concepts.

However, Vygotsky warns scholars that "enjoyment" is not a systematic outcome of play and game activities. The affective valence of a game activity and its resulting enjoyment can indeed vary according to many factors. For instance, losing a game can affect a child's self-worth and his/her feeling of pride. Nevertheless, Gee (2007) points out that games can also be "*pleasantly frustrating*" (p. 131), thus strengthening the willingness of children to master a game, and finally resulting in a positive outcome ("this was a difficult game, but once I learned/mastered its mechanism, I was able to succeed").

Learning with Video Games

Theoretical Grounding

Video games have a very strong impact on people's way of life in modern societies. Through video games, an individual can live exciting experiences (s)he would have never dreamt about a few decades ago.

Indeed, Papert (1998) noticed that it is in game designers' interest to make their commercial video games intrinsically motivating and appealing to potential players. Papert also insisted that, by tackling this element in an empirical manner, the game industry came to solutions that should strongly inspire modern curriculum design. Some scholars resist Papert's position, suggesting that some games can lead to violent behavior, social isolation, or a heighted focus on fun rather than work. However, more scholars support

Papert's view and research on the educational use of video games is rapidly growing, especially when considering that children learn many academic subjects first through entertainment media such as books, television, movies, the Internet, and video games (Squire 2007).

James Gee has produced an influential theoretical analysis of video games, and stressed how games can support learning. According to Gee (2007), several characteristics are present in good video games that promote deep learning:

– *Interactivity.* Players' actions produce visible outcomes that directly influence the game process. This fosters players' feeling of ownership and agency, as well as their "*ability to produce and not just passively consume knowledge*" (p. 154), all of these being highly profitable to learning.
– *Customization.* Good video games can be adjusted, for instance, to fit player's style, and to offer several solution paths. Similar customizations (learning style, various success opportunities) also characterize good learning practices.
– *Strong identities.* Good video games infuse players with an identity (a specific role such as knight, magician, detective, commander in chief, or even god) that fosters their involvement. The main power of video games is indeed in "*situating one's body and mind in a world from the perspective of an avatar* per se" (p. 16). In many situations, adopting a specific identity (for instance, a scientist identity when learning science) is reported to foster learning.
– *Well-ordered problems.* Well-designed games have a progressive approach with first problems allowing players to develop a good idea of how to proceed when facing harder problems later in the game. Similar ordering is essential for providing good learning in complex domains.
– *Pleasant frustration.* Difficulty level progressively rises in good games providing the correct element of challenge and complexity so that players can feel confident that their efforts will pay off. Many games also inform players through explicit or implicit feedback about what they did correctly or not, thus fostering in-game self-regulated behaviors. Pleasant frustration is argued to be an optimal state for learning.

– *Built around the cycle of expertise.* This cycle, consisting in (a) extended practice, (b) test of mastery, and (c) new challenge leading to (new) extended practice, is highly inspiring for both good game and learning designs.
– *"Fair" and "deep."* Good video games are fair because, even though they are challenging, they have been designed in order to be achievable by players. They are deep because their basic usage is easy to learn, but advanced challenges are more complex and require players to enhance their game mastery. Gee sees both these characteristics as highly interesting for learning activities.

According to Gee (2007), the previously mentioned characteristics suggest that video games can be excellent learning platforms, which led him to posit the following assumptions:

– Video games can have a positive social impact even though they are often taxed with the opposite. For example, when games are designed whereby players can only succeed through cooperation and skill sharing, individuals can then learn and develop social skills and abilities that are needed in the workplace.
– Appraisal of situations may vary in game contexts and make experiences more positive in such settings than in real life. Indeed, children often praise competition in video game settings as a positive social opportunity that involves them in the activity, whereas many of them tend to dislike competition when it occurs in a school context. Similarly, failure is part of a normal game experience and leads to the pleasant frustration feeling exposed earlier, whereas in school context, it may evoke negative feelings and is rarely exploited as a learning opportunity.
– Good video games can train people to deal with complexity. In order to succeed in a game, children happen to master game-specific language and knowledge, sometimes characterized by a high level of complexity. Mechanisms used in video games could be used in academic domains in early schools years. Furthermore, in video games, children learn to manage complex interconnected rule systems, that can help them cope with real-life issues. Games present opportunities for dealing with complex environments by having some of the necessary cognition for success embedded in virtual

characters, the remaining cognition being the responsibility of the player. Such distributed intelligence allows the players to begin to act with some degree of effectiveness before being really competent (performance before competence). The player can thus achieve competence through trial, error, and feedback, rather than reading a lot of text before engaging in an activity. In this way, he or she witnesses and experiences the skills and knowledge of a professional, along with the concomitant values (i.e., the collective cognition) of the domain. Finally, learning with video games can enhance digital technology literacy, a side effect that is highly relevant in modern technological societies.

– Last but not least, video game experiences goes beyond verbal descriptions of a domain and allow players to have situated experiences that convey much more information than verbal ones. When playing a game, an individual naturally detects affordances in the game space according to his/her in-game identity and (personal) objectives. According to Gee (2007), games can thus be used to train individuals to see affordances in real life from a specialist point of view (an anthropologist, a soldier...), in other words, to develop professional expertise through virtual and situated experiences.

Gee has had a strong influence on research in the field of learning with video games. However, this research field is still in its early stages, and further empirical evidence is needed to determine ways in which positive learning outcomes can be optimized and negative effects minimized.

Dedicated Applications

Learning with video games is not efficient without appropriate instructional guidance (Gee 2007). In the case of commercial video games, this can be achieved by adults and peers, or even by teachers if the game activity is performed within a classroom environment. But scholars tackle this issue directly through dedicated applications that both entertain and educate people with systems known as edutainment and serious games. Edutainment and serious games are not always clearly distinguished, but in general:

– An *edutainment system* is a reference to an application for *educational entertainment*, an educational

technology that, through the use of game principles and characteristics, tries to strengthen learner's interest and motivation for the educational content. Edutainment systems are designed according to an educational objective(s), whereby the game component makes learning more educationally efficient. Since game principles are sometimes loosely integrated in the educational application, the motivational effect is not always achieved. Yet some edutainment systems have successfully embedded game characteristics, resulting in more appealing learning activities.

– A *serious game* (in a learning context) refers to an application where learning and game objectives are both of primary concern, which means that, within the game world, game and learning elements are often intertwined to a greater extent than in traditional edutainment, for instance by distributing the domain cognition within objects and characters of a virtual 3D environment in order to foster situational understanding. Serious games often make more efficient use of Gee's prescribed game characteristics than edutainment does. Research and development of serious games for educational purpose is a strong trend. Industry is also considering serious games for other purposes such as interactive advertisement that can engage people in seeing what the company can provide.

Important Scientific Research and Open Questions

An avenue that still needs further exploration is the merging of game principles with adaptive techniques of computer-supported education. Good human tutoring particularly lies in the human tutors' ability to adapt their pedagogical interaction to the needs and styles of each student. However, such effective educational practice is constrained by the limited time of teachers, lack of experts, and large classroom sizes. Intelligent Tutoring Systems (ITS) try to tackle this issue by attempting to model learners' characteristics (cognition, learning styles, affect, etc.), as well as structure the domain knowledge in a way that is dynamically adaptive to each learners' characteristics. ITS can assist learners by: (a) supporting human tutoring by providing teachers with additional teaching options or extended analysis of students' activity, or (b) by

occasionally supplementing human experts when they are not available (due to geographical limitations for instance) or when the cost of an educational activity is too high. Following educational and cognitive theories (among which, Vygotsky and Piaget's respective works introduced earlier in this entry), many edutainment systems and serious games try to foster their educational support with ITS-inspired adaptive techniques, for instance through the insertion of embodied pedagogical agents (autonomous virtual characters, capable of pedagogical decision-making) within virtual worlds.

New technologies in the field of Human–Computer Interaction offer new opportunities for game control than just the use of a joystick, a keyboard, or a mouse. For instance, Nintendo's Wiimote system first made body-based control available, and with appropriate adjustments, the Wii-Fit game dedicated to console-based physical exercising has been adopted by several rehabilitation physicians as a way to foster physical activity of injured people. Other innovative game controllers have also appeared in the last few years (fake instruments, dance carpets...) with emerging brain–computer interfaces holding a lot of expectations in the near future. What makes such new controllers particularly interesting for learning with games is that they enhance the authenticity and fidelity of virtual experiences. Hence, skills needed to be good in a game simulation are more comparable to those needed in real life.

Furthermore, the frontier between real and virtual worlds is fading. Augmented reality allows people to access and interact with virtual and real data and objects within the same context. Mobile technology and geolocalizable devices fill in people with real-time contextualized information. Mixed real–virtual environments are just starting getting explored as new game spaces and as original learning contexts. The learning potential of augmented assistance in a realistic context through game-like technology is huge and should bring important developments within the next few years.

In fact, technology is progressing so fast that it is useless to try to present all the new opportunities for learning with games that are now available. But such growing technological dependence of good and innovative learning practices raises the issue of its access

equity. As Gee (2007, p. 138) mentioned, "*richer children may attain productive stances toward design and tech savvy identities to a greater degree than poorer ones.*" What is true in western countries is even worse in third world societies where computer access is already limited. The next great challenge for scholars working on game-based education may thus be more accessibility globally.

Cross-References

► Adaptive Game-Based Learning
► Designing Educational Computer Games
► Epistemic Games and Learning
► Experiential Learning
► Piaget's Learning Theory
► Play, Exploration and Learning
► Serious Games
► Simulation-Based Learning
► Situated Learning
► Video Games for Prosocial Learning

References

Botturi, L., & Loh, C. S. (2009). Once upon a game: Rediscovering the roots of games in education. In C. T. Miller (Ed.), *Games: Purpose and potential in education* (pp. 1–22). New York: Springer.

Caillois, R. (2006). The definition of play and the classification of games. In K. Salen, & E. Zimmerman (Eds.), *The game design reader: A rules of play anthology* (pp. 122–155). Cambridge, MA: MIT Press (Originally published in 1961 in R. Callois (Ed.), *Man, play, and games*).

Gee, J. P. (2007). *Good videogames + good learning: Collected essays on video games, learning, and literacy.* New York: Peter Lang.

Papert, S. (1998). Does easy do it? Children, games, and learning. *Game Developer* June, 88.

Piaget, J. (1962). *Play, dreams, and imitation in childhood.* New York: Norton.

Squire, K. D. (2007). Games, learning, and society: Building a field. *Educational Technology, 4*(5), 51–54.

Vygotsky, L. (1966). Play and its role in the mental development of the child. *Voprosy Psikhologii, 12*(6), 62–76 (Originally published in 1933).

Learning with Graphical Representations

► Learning with External Representations

Learning with Monte Carlo Methods

Tristan Cazenave
LAMSADE–Université Paris-Dauphine, Paris, Cedex 16, France

Synonyms

Monte Carlo tree search; UCT

Definition

The Monte Carlo method in games and puzzles consists in playing random games called playouts in order to estimate the value of a position. The method is related to learning since the algorithm dynamically learns which moves are good and which moves are bad as more playouts are played. The learning is achieved by keeping statistics on the outcomes of the random games that started with a move. This algorithm is strongly linked with the area of machine learning named reinforcement learning. It has benefited from research on the multiarmed bandit problem in the area of machine learning (Auer et al. 2002).

The method is related to learning since the algorithm starts learning a position from scratch each time it has to play: it learns the moves that are good for any given position.

When there are no good heuristics for a problem, Monte Carlo methods can learn to solve an instance of the problem. Consider, for example, the game of Go, this is a difficult problem for artificial intelligence since evaluating a position with rules and knowledge is very difficult, moreover there are more than 250 possible moves on average and it is necessary to look multiple moves ahead, therefore there is a combinatorial explosion of the number of positions to look at. On the other hand, in the game of Go, it is very simple to program a computer to play many random games. The system can also keep the mean result of the games that start with a given move. After many games the system can stop playing random games and choose to play the move that has the greatest associated mean. This method for choosing a move is called Monte Carlo Go.

Monte Carlo Tree Search is a recent refinement of the method. It consists in growing a tree of previous playouts in memory and choosing a move according to the mean result of the playouts that start with this move (Coulom 2006; Kocsis and Szepesvári 2006). It is currently the best algorithm for games such as the game of Go and the game of Hex.

The method can also be used in other games, and as the method is general and can be used without domain knowledge it is used by the best artificial general game players (Björnsson and Finnsson 2009). The principle of general game playing competitions is to give the rule of the game to the player just before they start to play. The goal is to write general programs that have more general intelligence than usual game programs that are tailored to only one game.

Theoretical Background

Monte Carlo Tree Search is based on the theoretical analysis of multiarmed bandits. The main algorithm is UCT which means Upper Confidence Bound applied to Trees. The principle of the algorithm is to add an exploration term to the mean of an arm in order to minimize the regret of choosing an arm. The formula used to select the next arm to pull is:

$$\text{mean} + C * \sqrt{(\log(t)/s)}$$

where mean is the mean result of the arm, C is a tunable constant, t is the number of times any arm has been pulled, and s is the number of times the arm has been pulled (Auer et al. 2002; Kocsis and Szepesvári 2006). The C constant has to be tuned to the problem. A great C constant favors exploration over exploitation, whereas a small C constant will more often lead to play moves that have the greatest means. Some of the best programs that combine UCT with other heuristics claim that the best constant is 0 because the heuristics are good enough to direct the search when the number of playouts is low.

Important Scientific Research and Open Questions

Monte Carlo Tree Search is currently the best algorithm for games such as Go, Hex, Lines of Action, or Amazons. It has also beaten world records in single

player games such as Morpion Solitaire or SameGame. The method can be extended to other games and puzzles. It is not clear which games and which puzzles the method is well suited for, and it is the subject of active research.

A promising research is to combine the method with other methods. For example using low variance statistical estimates of moves did improve much on UCT for the game of Go (Gelly and Silver 2007), the idea here is to keep statistics on a move even if it is played anywhere in the playout and not only after the current node of the UCT tree.

Another line of research that has been effective in Lines of Action and Amazons is to replace random playouts with an evaluation function.

Other researchers are also trying to introduce knowledge in the playouts, biasing the choice of the moves to play. Such pseudo-random playouts might help the Monte Carlo Tree Search algorithm converge faster. This is a tricky area of research since it is not yet clear which type of knowledge accelerates convergence. For example, introducing knowledge so that good moves are more often played by the pseudo-random player does not necessarily lead to a better overall player. However effective use of relevant knowledge in the playouts has proven very useful both in Go and Hex.

Cross-References

▶ Machine Learning
▶ Reinforcement Learning
▶ Statistical Learning Theory and Induction

References

Auer, P., Cesa-Bianchi, N., & Fischer, P. (2002). Finite-time analysis of the multiarmed bandit problem. *Machine Learning, 47*(2), 235–256.

Björnsson, Y., & Finnsson, H. (2009). CadiaPlayer: A simulation-based general game player. *IEEE Transactions on Computational Intelligence in AI and Games, 1*(1), 4–15.

Coulom, R. (2006). Efficient selectivity and backup operators in Monte-Carlo tree search. In *Proceedings of the 5th international conference on computers and games*, Turin, pp. 72–83.

Gelly, S., Silver, D. (2007). Combining online and offline knowledge in UCT. In Z. Ghahramani (Ed.), *ICML*, Vol. 227 (pp. 273–280). New York: ACM

Kocsis, L., Szepesvári C. (2006). Bandit based Monte-Carlo planning. In *ECML 2006*, Berlin, pp. 282–293.

Learning with Multiple Representations

Ton de Jong, Jan van der Meij
Faculty of Behavioral Sciences, University of Twente, Enschede, The Netherlands

Synonyms

Symbolic expression

Definition

A representation consists of symbols that take the place of something else (from the real world).

Theoretical Background

An important aspect in the process of learning, which can be defined as transforming information into knowledge, is the way the information is brought to the learner. In learning situations, learners hardly ever interact with the real system they need to understand. Instead, they use a representation that provides them with information about an event, process, or system in the "real world." Learners may use representations when the real system is too complicated to bring into the classroom (e.g., certain physics experiments), is too dangerous (e.g., surgical interventions), or is not directly accessible at all (like events from history). As representations most often have insufficient expression facilities to describe a real system completely or adequately, they are not an equivalent of real systems but only descriptions. Therefore, representations only present an approximation of reality. This may hinder but also foster learning. This is done by deliberately manipulating the information presented (by hiding distracting information or by highlighting specific aspects of a system) or by enabling certain inferences to be made. These two functions are largely determined by the format in which the representation comes (e.g., text, diagram, table, chart, graph, formula, picture, animation, movie) and the modality that is being used (vision, audio, touch, smell). In this contribution, we focus on the role of the representational format.

Representations basically have two functions. The first one, as expressed above, is to display the "real system" to the learner, the second one is to facilitate

learning processes. Each representational format has its own strength to display certain information or to facilitate specific inferences on this information. Textual representations, for example, are well suited to convey abstract concepts that cannot be expressed graphically, whereas pictorial representations more easily express concrete information. Differences in affordances for learning become evident when the information displaying function is the same for two representations, in other words when the two representations are informationally equivalent. In their seminal work, Larkin and Simon (1987) compared textual representations of physics and mathematics problems with diagrammatic representations of the same problems. In a detailed analysis, they showed that diagrammatic representations need less inferences to find the same information on positional relations between elements than textual information. In this way, diagrams facilitate solving problems that are highly dependent on this information. Another example concerns information on trends and interactions. Whereas equations can display these kind of relations as adequately as graphs, less effort is needed to read trends and interactions from graphs than from equations. In a recent study, Cromley et al. (2010) had students think aloud when reading about biology in either textual or diagram format. They found that in processing text learners use a wider range of cognitive processes but in processing diagrams a larger percentage of the processes was characterized as a high-level strategy (e.g., coordinating information resources or summarizing). Schnotz and Kürschner (2008) found that this differential effect between representational formats may even be more specific. They showed that two informationally equivalent but different types of diagrams (a carpet vs. a circle diagram) each facilitated different inferences concerning the content that was being displayed (in this case, daylight distribution around the world).

As different representational formats can convey different aspects of a domain and can facilitate different learning processes, a logical step would be to combine virtues of representational formats. Multiple representations can better cover the complete domain and elicit a wider range of learning processes. This is also what educational practice does; most educational material houses a multitude of representational formats. There is, however, certainly no consensus on what are the best combinations of representational formats and even not on the idea that using multiple representational formats is useful for learning. Whereas "cognitive load theory" asserts that the coordination of two representational formats may lead to cognitive overload (especially if the information offered in the two formats shows redundancy), other theorists assert that offering multiple representations may lead to deeper knowledge in its own right since for the processes of relating representations and making translations between them abstractions are necessary (Ainsworth 2006).

Literature is not only not unequivocal on the effects of multiple representations but also empirical results of specific representational formats vary. For example, some studies show large advantages for learning from diagrams whereas others report that students have difficulties processing these diagrams (Cromley et al. 2010). Several factors may influence the effectiveness and efficiency of representations. These include characteristics of the learner such as processing skills and domain knowledge and task characteristics such as the learning goal involved.

The virtue of (combinations of) representational formats for learning clearly depends on the skills that learners have in processing those representational formats. Students need to know the "language of the representation" (Ainsworth 2006). Being able to read formulas, for example, depends on knowing what the sequence of operations is. As another example, novice chess players normally lack the expertise to "visualize" the development of a chess game from an algebraic chess notation, whereas for expert chess players this is a very efficient and vivid representational format. Studies that have used eye tracking show that more proficient learners focus more on the salient aspects of a representations, whereas less proficient students give more attention to less relevant parts. This suggests that processing a representation is a skill in itself. In addition to this, the processing of visual representations calls upon students' spatial abilities for which large individual differences exist. If we compare the processing of a single representation with learning from multiple representations, students not only have to understand a single representation, they also have to relate (link similar variables at the surface level) and translate (understanding the relations between) different representations. If students are not able to

adequately process representations, they may need training in using the representational format or they may need to receive support during the learning process. For example, to relate elements from different representations, students can be supported by the use of color coding for identifying similar elements over representations. If representations are presented in a dynamical digital form, also synchronization (dynamical linking) may be used to highlight the relation between variables in different representations. Domain knowledge is another learner characteristic that influences the processing of representations. In their work on learning from chemical representations, Wu et al. (2001) show that the ability to make translations between representations is dependent on students' domain knowledge.

The effectiveness of representational formats largely depends on the learning goals. Again, this may concern domain content or cognitive aspects. First, a learning goal always describes content and it may be needed to use more than one representation to convey the complete content to the learner. Ainsworth (2006) calls this the "complementary information" function. Second, goals may differ in their cognitive aspects. If the goal of learning is to remember information, simple representations may suffice. For example, a pictorial representation may help to remember visual aspects that are harder to remember from a textual representation. Multiple representations may be used because according to Paivio's dual coding theory (that has also been followed in Mayer's cognitive theory of multimedia learning), having access to two different information channels may simply increase the likelihood that information is recalled (for a short overview see, Schnotz and Kürschner 2008). For understanding, representations that require specific inferences seem better suited (e.g., diagrams instead of text) and multiple representations may be used to have learners engage in higher cognitive processes (of translation) that foster understanding.

Important Scientific Research and Open Questions

Learning with (multiple) representations is a multilayered area where research has not been able to answer all, sometimes obvious, questions. It is not always clear which representational format is the most effective and efficient one to use. Each representation can be theoretically analyzed for the type of content it can display and the type of inferences it affords, but the eventual effect depends on a complex interplay of domain, student characteristics, and learning goals. For this reason, despite the fact that in general diagrams may seem to function better than text, one study may find that diagrams are superior to text, whereas another study may show the opposite (Anglin et al. 2004). The main research question in this field, therefore, concerns the charting of the factors that influence the effectiveness of representations.

A second research question concerns the role of multiple representations. Here, there are two competing stances of which one asserts that the use of multiple representations may lead to cognitive overload and the other states that making translations between representations has a value on its own. An important factor in this debate seems to be the skills that learners hold. If learners have adequate skills to process multiple representations and if the learning environment offers the right support in linking different representations, the risk of cognitive overload may be reduced, resulting in an advantage for multiple representations. Training or supporting learners in processing (multiple) representations is therefore another interesting research theme.

Learners receive year-long training in processing one type of representational format, this is text. Other formats, maybe apart from mathematical notations, are hardly trained. Cromley et al. (2010) found advantages for diagrams but also found that students disliked working with diagrams. Also Wu et al. (2001) found that students preferred a representation (a molecular model) that was not the representation most beneficial for learning (a "ball-and stick" model) because of students' impression that the first model more closely resembled reality. Training students in processing less familiar representational formats (such as diagrams) may also result in a better proficiency in choosing the most adequate representation.

A final, and upcoming, research area concerns students who create representations themselves. Modern technologies enable students to make their own representations that go beyond traditional text, for example in the form of graphical modeling languages. It is an open research question if representational formats that enhance learning are also the ones students should use when making representations themselves.

Cross-References

References

Ainsworth, S. (2006). Deft: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*, 183–198.

Anglin, G. J., Vaez, H., & Cunningham, C. L. (2004). Visual representations in learning: The role of static and animated graphics. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd ed., pp. 865–916). Mahwah: Lawrence Erlbaum.

Cromley, J. G., Snyder-Hogan, L. E., & Luciw-Dubas, U. A. (2010). Cognitive activities in complex science text and diagrams. *Contemporary Educational Psychology, 35*, 59–74.

Larkin, J. H., & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science, 11*, 65–99.

Schnotz, W., & Kürschner, C. (2008). External and internal representations in the acquisition and use of knowledge: Visualization effects on mental model construction. *Instructional Science, 36*, 175–190.

Wu, H., Krajcik, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom. *Journal of Research in Science Teaching, 38*, 821–842.

Learning with Symbol Structures

Learning with Visualizations

Learning Without Reward

Learning/Programming from/by Demonstration

Learning: A Process of Enculturation

James R. Gavelek[1], Ailing Kong[2]
[1]Department of Curriculum and Instruction, University of Illinois at Chicago, Chicago, IL, USA
[2]Department of Teacher Education, Saint Joseph's University, Philadelphia, PA, USA

Synonyms

Cultural development; Cultural learning

Definitions

The term "culture" is generally defined as the shared practices constructed and accumulated over generations by a group of people in their effort to create a better physical and social living environment for the group. They include the common language, religion, ways of thinking and acting, material and cognitive tools, as well as social institutions and organizational structures.

Enculturation is the process whereby individuals learn their group's culture through experience, observation, and instruction. To learn is to develop the knowledge and skills needed to participate in the communal, cultural practices and to become a fully functioning member of the community. At the same time, cultures are constantly evolving with new cultural practices and new tools to improve their interaction with the physical and social environments.

Theoretical Background

In understanding learning as a process of enculturation it is important to distinguish cultural psychology from cross-cultural psychology. Cross-cultural psychology treats culture as a means of testing the universality of psychological processes (e.g., learning) rather than understanding how psychological processes are culturally formed. Culture is assumed to be a source of

variance rather than the constitutive medium within which all human psychological processes are formed. In so doing it reinforces a problematic dualism between individuals and their environments.

As a cultural psychology, Vygotsky's cultural-historical theory offers a comprehensive framework that examines the relationship between culture, learning, and development on four interrelated levels: the evolution of the species (phylogeny), the origins and history of human culture and cognition, the development of the individual (ontogeny), and the development of the individuals' higher psychological processes in their moment-to-moment interactions with others and things (microgenesis).

The Evolution of the Species (Phylogenesis)

Bruner (1990) cites the anthropologist Clifford Geertz who maintained that "without the *constituting* role of culture we are unworkable monstrosities . . . incomplete or unfinished animals who complete or finish ourselves through culture" (p. 12). In offering this starkly worded claim Geertz thus sets the predicate for understanding human development as a unique cultural achievement. Thus, while continuities in the processes of human learning with their phylogenetic forebears have been well documented by behavioral psychologists and primatologists, the capacity for the creation, communication, and continuance of culture is what sets humans apart from all other species. Primatologist and developmental psychologist Michael Tomasello (1999) identifies what he characterizes as a cultural "ratchet effect" unique to humans such that each successive generation is able to build upon the collective experience of preceding generations without ratcheting back to earlier levels. With the biologically enabled emergence of culture, human evolution can be characterized as Lamarckian in that humans are now able to convey behavioral tendencies by means of culture as well as by genes thus resulting in a species that is "biologically cultural" (Rogoff 2003).

Cultural-History

While not assuming the sudden emergence of culture, Donald (1991) discerns three general stages in which human cognition developed in conjunction with the development of culture. Even before language was invented, our ancestors, *Homo erectus*, shared

a nonverbal communicative culture sometime between 500,000 and two million years ago. They were able to imitate each other's body movements to learn to make tools, and they used facial expressions and gestures to communicate feelings. Unlike other primates whose imitations were context-dependent, human ancestors imitated movements with an understanding of the purposes of these actions, which potentially led to delayed reenactments of the movements removed from their original context. This voluntary motor control provided early humans with a new means of representing reality. Donald (1991) called this first evolutionary stage of culture and cognition the *mimetic* culture.

Donald's second and third stages of human cognitive development chronicle the creation of a spoken language and creation of semiotic writing system, respectively. The invention of these meaning-representing techniques of communication, such as body movements, spoken language, writing system, and other cultural tools, allowed humans to create representations of their knowledge of the world and to accumulate and store that knowledge for later generations. These techniques thus aided in overcoming the limitations of biological memory by storing shared memories outside of the human brain and making them accessible to all members of the community. Interacting with the techniques and the cultural artifacts (or knowledge) in communal practices, humans were now able to remember, reflect, synthesize, and evaluate both self-experiences and group-accumulated knowledge to help improve their environment. Furthermore, as humans acquired the knowledge and the cultural tools they inherited from previous generations, they could also now construct modifications and additions to be passed on to their progeny. The cultural evolution of humankind is not unidirectional. Part and parcel of this evolution are the multiple trajectories characterizing the development of different cultures. Different cultures have evolved different tools and associated practices along with different social institutions.

Individual Development (Ontogenesis and Microgenesis)

The ontogenetic and microgenetic development of individuals goes hand-in-glove with the emergence, historical evolution, and variability of culture described above. It is the microgenetic or moment-to-moment

development of a person's psychological processes that in the aggregate comprise a person's enduring ontogenesis.

While human children are born into a world full of cultural traditions and artifacts unique to their community, they can only benefit from what their culture has to offer if they have evolved the uniquely human capabilities to enter into meaningful social interactions with already acculturated individuals. According to Tomasello (1999), children demonstrate their unique human ability to understand others as being "intentional and mental beings like the self" at about the age of nine months. He believes that this ability is "the social-cognitive key to the historically constituted cognitive products of [their] social group" (p. 8). With this key, human children have the potential to participate in joint activities with their caretakers and embark on a lifetime of cultural learning. It is this ability to read others' intention and to enter into joint attention with conspecifics that underlies the earlier described cultural ratchet effect. Absent from this ability is frequently the case with children of autism, who are denied these benefits of culture.

When children are exposed to and included in the ongoing cultural practices of their community, they have the opportunity to observe how members interact with each other and learn how cultural tools are being used, in effect, to participate in an extended apprenticeship in learning and thinking. Engaging in "guided participation" (Rogoff 2003) in a community's cultural practices, they receive feedback and guidance from more knowledgeable members and learn and develop the needed knowledge and skills on their route to becoming full participants in the social, cultural, economic, and political activities of their community. Vygotsky (1978) sees this guided interaction as essential for creating opportunities for the learners to internalize the cultural knowledge and communal practices. He summarizes this process in his "general genetic law of cultural development": "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological)" (p. 57).

In this process of cultural development, cultural tools, especially semiotic systems, are essential for mediating the co-construction of knowledge. Cultural tools are not only entities to be learned but also act as mediating agents to shape individual's cultural learning and his/her ways of thinking and acting. They help forge the link between the social and individual levels and aid the transition from interpsychological processes to intrapsychological processes. Dynamic cultures are constantly expanding new additions to cultural practices and new cultural tools. Cultural learning is thus understood as a lifelong endeavor.

Ontogenetically, individuals growing up in different cultures at different times are likely to manifest different developmental trajectories. However, with the emergence of oral language common to all cultures, children's induction into a culture is altered significantly, thus enabling what Bruner has described as the "evolution of educability." More knowledgeable others are able to aid those in the processes of learning culturally accumulated knowledge.

Important Scientific Research and Open Questions

Enculturation is not a one-way transmissive process in which individuals simply reproduce what has evolved before. Part and parcel of the development of individuals within a culture or all cultures is a process by which each individual is transformed and continues to evolve. Any conception of enculturation must account for transformation in artifacts and practices at both the individual and cultural levels as well as the ongoing dialectical relationship between the two.

To address these issues Cole (1996) and Engeström (1999) have modified and elaborated Vygotsky's original theory in what is known as cultural-historical *activity* theory (CHAT). The notion of "expansive learning" postulated by Engeström seeks to account for both individual and cultural transformations in learning by focusing on the conflict that results when individuals and groups interact within and across contexts occurring in multiple activity systems (e.g., contexts associated with play, learning, and work). An activity system consists of an individual or groups of individuals using mediating artifacts acting on objects to bring about intended outcomes. Such actions are further governed by community-sanctioned rules and divisions of labor. Engeström maintains that expansive transformations in activity systems may occur as individuals experience contradictions while moving within and across multiple settings. For example, children who may have learned to engage in cooperative play in activity

settings outside of school must acquire and create new strategies to successfully function at an independent level to meet the formal demands of learning (and being assessed) in school.

The digital revolution and dispersive effects of digital communication associated with globalization have greatly enhanced opportunities for processes of enculturation to occur while at the same time further complicating any notion of cultures as unified wholes. Such transformations present significant theoretical and methodological challenges for conceptualizing and studying enculturation in an increasingly connected world. Theoretically, the very notion of what a culture is may need to be increasingly qualified with new fault lines delineating what constitutes a culture being created. Indeed, the age segregation pervasive in certain countries (e.g. the USA) may hasten the influence of popular and youth culture among already wired current and future generations. Methodologically, questions abound as to how to go about measuring and assessing such influences.

A further consequence of globalization along with the increased physical and digital permeability of national borders concerns issues related to acculturation. How do we best go about studying individuals who move from one culture to another? What are the consequences for the learning of individuals for whom the process of acculturation involves the acquisition of a second language?

Finally, while the notion of enculturation generally carries a positive valence, i.e., to have become a member is preferable to the "unworkable monstrosity" characterized earlier by Geertz, it begs the sensitive question of whether there are cultures to which individuals become enculturated which lead to learning that is maladaptive. If so why – and by what criteria?

Cross-References

▶ Activity Theories of Learning
▶ Anthropology of Learning and Cognition
▶ Biological and Evolutionary Constraints of Learning
▶ Enculturation and Acculturation
▶ Evolution of Learning
▶ Learning in the Social Context
▶ Repeated Learning and Cultural Evolution
▶ Situated Learning
▶ Socio-cultural Research on Learning
▶ Zone of Proximal Development

References

Bruner, J. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Donald, M. (1991). *Origins of the modern mind: Three stages in the evolution of culture and cognition*. Cambridge, MA: Harvard University Press.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engestrom, R. Miettinen, & R.-L. Punamaki (Eds.), *Perspectives on activity theory*. New York: Cambridge University Press.

Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Learning-Based Therapies

▶ Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning

Learning-Community

▶ Asynchronous Learning Networks

Learning-Dependent Progression of Mental Models

NORBERT M. SEEL, DIRK IFENTHALER
Faculty of Economics and Behavioral Sciences, Department of Education, University of Freiburg, Freiburg, Germany

Synonyms

Changing mental models; Mental model convergence

Definition

Agents and learners must form and update their mental models in a wide range of domains during the progression of learning. Learning progression is defined as

a change in cognitive structures based on conceptual awareness along with increasing complexity and integration of knowledge units into coherent mental models. More specifically, learning-dependent mental model progression is understood as a specific kind of transition which mediates between preconceptions, which describe the initial states of the learning process, and causal explanations, which are described as the desired end states of learning. With regard to the continuous progression of mental models, it is possible to distinguish two approaches: an *elaborative approach* aiming at "fleshing out" models (Johnson-Laird 1983) and a *constrictive approach* aiming at "minimal mental models" that correspond to the ▶ parsimony principle for mental models.

Theoretical Background

The idea of learning-dependent progression of mental models has been expressed by Johnson-Laird (1989) as follows: "What is at issue is how such models develop as an individual progresses from novice to expert" (p. 485). The basic assumption underlying this verdict is that mental models are constantly evolving and changing as a result of learning experiences.

In the original framework of mental models theory (Johnson-Laird 1983), mental models are a medium for mental representation for which two aspects can be distinguished: The first aspect can be described as *modeling as process* and focuses on the cognitive operations involved in the emergence of mental models; the second aspect refers to the external representations of models as *results of the modeling process* that can be manipulated in the course of learning. The cognitive operations involved in modeling as process are, of course, and the true mental states of learners will never be directly accessible. Thus, a very simple conception puts mental models into the black box of the behaviorist's paradigm of learning (Rouse and Morris 1986) in order to explain things like reasoning, the competent operation of complex systems, or the comprehension of texts. The following method is often applied: After an initial training which is experimentally varied, the subjects have to perform specific tasks considered indicative of the successful application of a mental model. Evidently, the trickiest problem with this kind of mental model research is defining adequate dependent variables to evaluate the quality of the modeling process. Alternatively, specific diagnostic methods can be used to collect and interpret data with the aim of determining which of a set of basically non-observable states may be the "true state" of nature. Of course, it is not possible to influence or determine what state of nature will occur; what researchers can do is collect and process information in order to arrive at a probabilistic estimation of the true mental states. This, however, is based on the ability of humans to create artifacts, i.e., physical representations of ways of thinking that can be manipulated in simple ways to obtain answers to very difficult and abstract problems of information processing, such as the construction and use of mental models.

Rumelhart et al. (1986) suggest that *external representations* play a crucial role in thought since experiences with them involve imaginations which can be processed mentally. Thus, the idea that learners operate and reason with mental models is a powerful one precisely because it is about this process of imagining an external representation and operating on it. Most of what people know is based on their experience developing and refining external representations for particular things and events. Mislevy et al. (2007) have pointed out that several properties of external representations are highly relevant for assessment purposes. One property is that an external representation does not include everything that can be represented about a subject but rather only certain facts or entities and relationships between them. This so-called *ontology of the external representation* corresponds to the assumption that a model is an idealized reduction to relevant characteristics of its original which serves to create a concrete, comprehensible, and feasible representation of nonobvious or abstract objects or phenomena of possible worlds of objects and events (Seel 1991). If external representations, discussed here in terms of externalizations of cognitive artifacts, are to be considered as reliable and valid representations of mental models, they have to meet the hypothesized characteristics of mental models (Johnson-Laird 2006), such as parsimony and fallibility due to incompleteness and uncertainty.

It is possible to distinguish two approaches for promoting the constant evolution and change of mental models: An *elaborative approach* aiming at "fleshing out" models and continuously enriching them with details (Johnson-Laird 1983) results in increasingly complex and detailed models. According to Crain and

Steeedman (1985), there are at least two factors determining more or less complex models. One is the number of presuppositions that have to be adjusted when integrating a new piece of information. A second factor concerning complexity is the number of entities to be represented in a mental model. Increasing the number of entities increases the complexity of the model. Alternatively, a *constrictive approach* aims at "minimal mental models" that correspond to the parsimony principle for mental models. A preference for parsimonious models guarantees the construction of mental models with the minimum amount of entities necessary to represent something.

Another central issue of the learning-dependent progression of mental models is concerned with the question of how mental models change to form more stable and persistent cognitive schemas. Ifenthaler and Seel (2005) conceive the learning-dependent progression of a mental model as a discrete dynamic system that changes at discrete points in time. In a dynamic system, the current state depends on the previous state. Dynamic systems sometimes have equilibrium states, which are states in which the system does not change. This theoretical conception can be illustrated metaphorically as in Fig. 1.

Learning is represented as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the cognitive or behavioral system. The process of learning can be expressed in the form $y(k) = f(y(k-1),\ldots, y(k-n_y), u(k-d),\ldots, u(k-d-n_u), e(k-1),\ldots, e(k-n_e)) + e(k)$, where $y(k)$ is the system output, $u(k)$ the input, $e(k)$ is a zero-mean disturbance term, d is the relative degree, and $f()$ is some nonlinear function. This model is known as the NARMAX model (Leontaritis and Billings 1985). In accordance with this model, the process of learning can be seen as a stochastic process that moves in a sequence of phases through a set of states. Although the probability of entering a certain state in a certain phase is not necessarily independent of previous phases, it depends at most on the state occupied in the previous phase. This is known as the *Markov property*.

In accordance with this model, the change of mental models is conceived as discrete learning process with Markov property. The whole process involves the following steps: *Representation* of an initial working model, which is relied upon the individual's ability to use memory contents to find information, *interpretation* of the model in terms of explanatory plausibility, revision of the initial model and generation of a second model which is again tested with regard to explanatory plausibility followed by a revision of the model that leads to the next test and revision and so on. Based on this sequential creation, testing, and revision of models, the individual will create a *generalization* of a sufficiently stable mental model to a variety of situations. At this point, the learning process reaches a state of equilibrium and the system does not change anymore. Discussed in terms of cognitive psychology, at this point the mental model is merging to a generic knowledge structure also known as schema, or script, or frame (Seel 1991; Seel et al. 2009). From that point on, the individual can apply the schema in order to accomplish new tasks, and there should be only a slight variation.

Accordingly, we argue that as long as it is possible to observe fluctuations in the probability of change of a measurable performance, such as qualitative

Initial States — Transition of Knowledge Structure — Final States

Mental model

M1 M2 M3 M4 M5 m1

Schemata

Learning-Dependent Progression of Mental Models. Fig. 1 Transition of knowledge structures from mental model to schema

reasoning, at various measurement points, the individual evidently relies on an evolving and changing mental model, whereas a significant decrease in the probabilities of change from one task to the next indicates the use of a schema, defined as a slot-filler structure that runs automatically whenever it fits with the requirements of a task.

In order to precisely track the learning-dependent transitions between the states of mental models at different time points, and more importantly to find the equilibrium state, i.e., the emerging schema, these changes must be measured with reliable and valid techniques. Additionally, Ifenthaler and Seel (2005) argue that such investigations require suitable mathematical models of stochastic processes.

Important Scientific Research and Open Questions

Research on the learning-dependent progression of mental models demands the reliable and valid assessment of a mental model and its external representations at all phases of the learning process (Seel 1999). In the past, various standard methods of assessment, such as protocol analyses, verbal data, concepts maps, causal diagrams, etc., have been applied more or less successfully for the assessment of mental models. This research indicates that a simple pre- and post-measurement does not provide the necessary detailed insight into the progression of an individual's learning process over time. Today, manifold computer-based tools and methods can be used for the diagnosis and analysis of knowledge structures and especially for the assessment of their learning-dependent change (Ifenthaler et al. 2010).

On the basis of these assessment methods, Seel has carried out several replication studies (with a total of more than 600 students of various ages and backgrounds) on the learning-dependent progression of mental models and their external representations (see the summary of these studies in Seel and Schenk 2003). The results of these replication studies indicate that mental models are not fixed cognitive structures that can be retrieved from memory but rather are constructed when needed to master the specific demands of a new learning situation. In consequence, learners dynamically modify and restructure their mental models when evaluating externally provided information they judge to be more plausible and convincing than their prior knowledge. With regard to the stability and change of mental models, the various studies agreed on the observation that mental models are highly situation dependent and in constant change. When measured at various points during the learning process, the external representations of mental models were not constructed independently from each other, but their structures varied significantly. Evidently, it was cognitively less demanding for the students to construct a new model at each point of measurement than to remember previously constructed models. In none of the replication studies was the transition to a schema observable.

Based on these findings and novel approaches for the computer-based diagnostics of knowledge structures, Ifenthaler and Seel conducted several studies on time-series measurements, which focused specifically on the stability and change of mental models and their possible transition to cognitive schemas (see, e.g., Ifenthaler et al. 2011; Ifenthaler and Seel 2011). Even in these studies, which operated with up to ten measurements in sequence, the external representations of mental models clearly mirrored ad hoc constructions which a person builds over and over again while solving new and unfamiliar tasks. Again, there was no evidence for the emergence and consolidation of a cognitive schema during the time-series measurements.

Currently, research is focusing on emotional experiences and their impact on the learning-dependent progression of mental models. It is argued that whenever assimilation in a schema fails, this schema enters a state of disequilibrium which in turn evokes arousal. The term "motive" can be used to denote the presence of disequilibrium. Whenever an attempt at assimilation fails and corrective attempts are not immediately successful, a motive will be created. Accordingly, cognitive processes and the reciprocal interactions with emotional states are the basis for goal-directed actions (Gross 1998). More specifically, positive emotions promote the activation of schemas and mental models, whereas negative emotions restrict these activating functions. In light of these observations, Ifenthaler and Seel (2011) assume that measurements of the learning-dependent progression of model-based reasoning and the emotional experiences associated with it will improve our understanding of these complex cognitive functions. As a result, it will be possible to

identify the most appropriate instructional materials and instructor feedback for various phases of the learning process.

Cross-References

References

Crain, S., & Steeedman, M. (1985). On not being led up the garden path: The use of context by the psychological parser. In D. Dowty, L. Karttunen, & A. Zwicky (Eds.), *Natural language parsing: Psychological, computational and theoretical perspectives.* Cambridge: Cambridge University Press.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2*(3), 271–299.

Hemforth, B., & Konisczny, L. (2006). Language processing: Construction of mental models or more? In C. Held, M. Knauff, & G. Vosgerau (Eds.), *Mental models and the mind. Current developments in cognitive psychology, neuroscience, and philosophy of mind* (pp. 189–204). Amsterdam: Elsevier.

Ifenthaler, D., & Seel, N. M. (2005). The measurement of change: Learning-dependent progression of mental models. *Technology, Instruction, Cognition and Learning, 2*(4), 317–336.

Ifenthaler, D., & Seel, N. M. (2011). A longitudinal perspective on inductive reasoning tasks. Illuminating the probability of change. *Learning and Instruction, 21*(4), 538–549.

Ifenthaler, D., Pirnay-Dummer, P. N., & Seel, N. M. (Eds.). (2010). *Computer-based diagnostics and systematic analysis of knowledge.* New York: Springer.

Ifenthaler, D., Masduki, I., & Seel, N. M. (2011). The mystery of cognitive structure and how we can detect it. *Tracking the development of cognitive structures over time. Instructional Science, 39*(1), 41–61. doi:10.1007/s11251-009-9097-6.

Johnson-Laird, P. N. (1983). *Mental models. Towards a cognitive science of language, inference, and consciousness.* Cambridge: Cambridge University Press.

Johnson-Laird, P. N. (1989). Mental models. In M. I. Posner (Ed.), *Foundations of cognitive science* (pp. 469–499). Cambridge, MA: MIT Press.

Johnson-Laird, P. N. (2006). *How we reason.* Oxford: Oxford University Press.

Leontaritis, I. J., & Billings, S. A. (1985). Input-output parametric models for nonlinear systems. *International Journal of Control, 41*(2), 303–344.

Mislevy, R. J., et al. (2007). *On the roles of external knowledge representations in assessment design.* National Center for Research on Evaluation, Standards, and Student Testing (CRESST). Graduate School of Education and Information Studies. University of California, Los Angeles.

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models. *Psychological Bulletin, 100*(3), 349–363.

Rumelhart, D. E., Smolensky, P., McClelland, J. L., & Hinton, G. E. (1986). Schemata and sequential thought processes in PDP models. In J. L. McClelland & D. E. Rumelhart (Eds.), *Parallel distributed processing. Explorations in the microstructure of cognition* (Psychological and biological models, Vol. 2, pp. 7–57). Cambridge, MA: MIT Press.

Seel, N. M. (1991). *Weltwissen und mentale Modelle.* Göttingen: Hogrefe. (World knowledge and mental models].

Seel, N. M. (1999). Educational diagnosis of mental models: Assessment problems and technology-based solutions. *Journal of Structural Learning and Intelligent Systems, 14*(2), 153–185.

Seel, N. M., & Schenk, K. (2003). Multimedia environments as cognitive tools for enhancing model-based learning and problem solving. An evaluation report. *Evaluation and Program Planning, 26*(2), 215–224.

Seel, N. M., Ifenthaler, D., & Pirnay-Dummer, P. N. (2009). Mental models and problem solving: Technological solutions for measurement and assessment of the development of expertise. In P. Blumschein, W. Hung, D. Jonassen, & J. Strobel (Eds.), *Model-based approaches to learning: Using systems models and simulations to improve understanding and problem solving in complex domains* (pp. 17–40). Rotterdam: Sense.

Learning-Related Changes of β-Activity in Motor Areas

ANDREAS DAFFERTSHOFER

Research Institute MOVE, VU University Amsterdam, Amsterdam, The Netherlands

Synonyms

Beta power; Cortico-spinal entrainment; Motor learning; Neural synchrony

Definition

Synchronization at different levels along the neural axis forms an important vehicle for motor timing, in particular when timing changes in the course of learning. A change in amplitude modulation in the β-frequency band (15–30 Hz) reflects a reorganization of neural activity in the motor cortex: neural populations adjust their capacity to produce short epochs of β-synchronization, leading to brief and hence expedient, properly timed motor commands. These sustained changes in β-synchronization patterns within and between primary motor areas occurred even in tasks that had not previously been learned. Most likely, this cortical synchronization also entrains the spinal motor system

so that cortico-spinal β-synchrony can serve higher-level motor control functions as primary means of information transfer along the neural axis.

Theoretical Background

Motor performance is usually accompanied by β-activity, that is, by oscillatory activity of larger neural populations in a frequency range of about 15–30 Hz. When the neurons in a population are (locally) synchronized, their activity shows constructive interference and can be measured from a distance, e.g., via encephalography. When recording above contralateral motor areas, the amplitude of this synchronized β-activity decreases during motor performance followed by a rebound, i.e., an increase after movement termination. Amplitude decrease and increase are referred to as event-related β-desynchronization (β-ERD) and synchronization (β-ERS), respectively (Pfurtscheller 1981).

Empirical findings on event-related β-ERD/ERS cycles are often interpreted as follows: when moving voluntarily, neurons in the motor area switch from an activated state ($\sim$β-ERD) to a resting state ($\sim$β-ERS), or from a processing to an idling mode. However, the post-movement β-rebound often exceeds the level of beta activity during rest, suggesting that event-related synchronization does not just reflect a passive shift back to a resting state but is likely to have a more active role, such as active immobilization or inhibition of cortical networks. The β-amplitude typically decreases back to base level not earlier than about a second after movement termination. Interestingly, β-ERD/ERS cycles also emerge during rhythmic motor production. For instance, during rhythmic isometric force production, with hands or fingers as end-effectors, the motor-related cortical activities display a pronounced decrease in β-amplitude around 100 ms before the motor event (β-ERD) followed by a β-rebound after approximately 200 ms (β-ERS). Rhythmic performance can be viewed as a continuously active motor state and β-ERD/ERS cycles as timed changes in cortical state, i.e., changes in the balance between excitation and inhibition within motor cortex, instead of correlates of movement initiation and termination per se (Boonstra et al. 2007).

What are the contributions of mean β-power (i.e., base-line β-amplitude) to motor control as compared to the β-amplitude modulation, i.e., the amplitude differences between epochs of β-ERD and β-ERS?

When learning a new motor skill:

- Mean β-power drops; whether these power changes are truly indicative of motor learning or mere by-products of ongoing practice is yet unclear and interpretations require great care.
- β-amplitude modulation is enhanced and becomes more focused in time as performance improves.

Changes in mean β-activity are most pronounced in motor areas contralateral to the end-effectors agreeing with the classic view that primary motor areas "control" the opposite side of the body (in a somatotopic fashion). Note that a change in β-power and/or β-amplitude modulation reflects a reorganization of neural activity in the motor cortex during skill acquisition. This might not be restricted to the cortex but one finds a general consensus that motor-related β-activity is generated in the contralateral motor area located anterior to the central sulcus, although other brain areas may also be altered in the course of motor learning.

The significance of the β-synchronization patterns for motor learning and performance is further underscored by the presence of an equivalent synchronization along the cortico-spinal (or cortico-muscular) tract. Equivalent to the encephalographic signals, the electromyogram (EMG) also reveals an event-related modulation of the β-amplitude superimposed on the event-related EMG burst. By this, the pivotal role of properly timed and synchronized neuronal activity for motor control is beyond doubt. There are intermittent phase-locking episodes between β-oscillations in contralateral primary motor cortices and the corresponding EMG. Cortico-spinal phase locking occurs at small, distinct individual delays, implying a (nearly) zero-lag phase synchrony, that is, in-phase locking. The strength of locking correlates with β-amplitude modulation and increases with improved performance so that accurately timed β-activity appears crucial for achieving proper performance. Periods of strong coupling between muscle and motor cortex become more localized, both in time and in frequency, when performance improves due to learning (Houweling et al. 2010). Thus, in view of its covariation with both β-amplitude in the cortex and β-amplitude in the EMG, phase locking reflects a neural control process by which the primary motor cortex imposes its dynamics on the muscle.

After learning, i.e., during accurate performance, synchrony-based motor control appears brief and discrete despite the continuous, ongoing motor output. Fixed neural populations adjust their capacity to construct short epochs of synchronization leading to brief, and hence expedient, motor commands and accurate motor timing (Davidson et al. 2007). Accurate timing of beta band activity is thus crucial for motor performance and is thus a central target for motor learning. Put differently, motor learning might be grounded in neural mechanisms that are or become capable of responding instantaneously to changes in timing and feedback. That is, motor learning is facilitated by diligent adaptive control. Fast oscillators are capable of exchanging information at the time scale needed for motor control. If tightly phase-locked, these oscillators can stabilize (bimanual) coordination. During periods of strong β-synchrony, the phase locking between (sub) systems increases, and this mutual intermittent coupling generally supports the necessary information exchange (Tass 1999).

Important Scientific Research and Open Questions

The functional role of changes in the beta band has yet to be clarified, in particular in light of the high variability in β-ERD and β-ERS – this variability renders an exclusive role of β-modulation for movement production and hence for motor learning unlikely. Apparently, movements can be generated quite properly even when a clear-cut β-modulation is absent. Here, it seems important to note that the strength of β-modulation can also be affected by other motor parameters, for instance, it is diminished at higher movement frequencies and higher force levels. The common denominator of numerous studies is a reduction of β-modulation with increased motor demands that appears consistent with the view that during the initial stage of motor learning additional attention is required, as the motor skill is not yet automated.

In the primary motor cortex contralateral to the dominant hand, the attenuation of β-amplitude (β-ERD) is often weaker than for the nondominant hand, indicating that this amplitude modulation in the β-frequency band relates differentially to demands for motor control. Interestingly, bimanual iso-frequency performance, in which two hands act in unison, displays even weaker β-amplitude modulation, reflecting the apparent ease with which these motor tasks can be accomplished. The control of such bimanual performances is – by virtue of symmetry – redundant, especially because left and right motor cortices not only show β-ERD/ERS cycles, but also their β-activity is synchronized between hemispheres (β-phase locking). This interhemispheric phase locking is also event-related and decreases with learning, however, in the γ-frequency band (>30 Hz). These long-lasting decreases in cortico-cortical synchrony might be attention-related "aftereffects." This interpretation, however, might be questioned as γ-power (in motor areas) is known to decrease with learning which may render the change in interhemispheric phase locking a mere epiphenomenon – in the presence of noise, a drop in power yields a smaller signal-to-noise ratio, thus a decrease in synchrony.

To date, the research about local and distant neural synchronization is primarily empirical in nature. Thorough theorizing is still lacking, rendering the predictive value of the current findings limited. What is the precise relationship between motor timing and the (dynamics of) cortico-cortical and -spinal synchronization? Which physiological factors provide the apparent constraints for β-ERD/EDS to act as a mechanism for motor control? And, most importantly, what is the mechanism responsible for changes of these parameters in the course of learning? A welcome step toward a more conceptual understanding might be found through computational neuroscience. Promising attempts range from neural mass models like the one of Jansen and Rit (1995) to more generic mathematical approaches to phase synchronization and resetting (e.g., Tass 1999).

Cross-References

► Cognitive Skill Acquisition
► Cross-Modal Learning
► Music and Learning
► Sensorimotor Adaptation

References

Boonstra, T. W., Daffertshofer, A., Breakspear, M., & Beek, P. J. (2007). Multivariate time-frequency analysis of electromagnetic brain activity during bimanual motor learning. *Neuroimage, 36*, 370–377.

Davidson, A. G., Chan, V., O'Dell, R., & Schieber, M. H. (2007). Rapid changes in throughput from single motor cortex neurons to muscle activity. *Science, 318*, 1934–1937.

Houweling, S., Dijk, B. W., Daffertshofer, A., & Beek, P. J. (2010). Cortico-spinal synchronization reflects changes in performance when learning a complex bimanual task. *Neuroimage, 49*(4), 3269–3275.

Jansen, B. H., & Rit, V. G. (1995). Electroencephalogram and visual-evoked potential generation in a mathematical model of coupled cortical columns. *Biological Cybernetics, 73*(4), 357–366.

Pfurtscheller, G. (1981). Central beta rhythm during sensorimotor activities in man. *Electroencephalography and Clinical Neurophysiology, 51*, 253–264.

Tass, P. A. (1999). *Phase resetting in medicine and biology.* Berlin: Springer.

Learning-Related Motives and Motivational Quality of the Learning Environment

JESÚS ALONSO-TAPIA
University Autónoma of Madrid, Madrid, Spain

Synonyms

Definition

Classroom climate of discipline: The set of discipline strategies usually employed by teachers to manage their students' behavior in relation to rules governing classroom behavior.

Classroom goal structures: The kinds of reason and purpose that teacher's messages convey to their students to instigate their academic activity.

Classroom motivational climate: The set of teaching patterns that contributes to instigate and direct student's activity to different learning or performance goals.

Classroom prosocial climate: The set of students' and teachers' interaction patterns that support students' prosocial behavior and social integration.

Goal orientations: The general purposes or reasons for engaging in achievement tasks combined with some general standards for evaluating progress.

Student's motivation: The process whereby goal-directed activity related to learning and academic outcomes is instigated and sustained.

Theoretical Background

Teachers often ask, "What can I do to increase my students' interest and effort in developing competencies through effective learning". "What can I do" means "what kind of teaching, learning organization and interaction patterns should I adopt in order to configure a classroom learning environment highly motivating." However, what makes a learning environment highly motivating and what kinds of variables moderate the effects of such an environment?

Motivational Quality of Teaching Patterns

The answer to the above questions comes from research based on different methodologies. First, *experimental research* has shown the positive value for ▶ student's motivation of different teaching patterns such as: (a) providing academic tasks and activities that are challenging and personally meaningful and relevant for students, (b) infuse the curriculum with fantasy, novelty, and humor, (c) promoting perceptions of control and autonomy, for example, by allowing students to make choices about classroom experience and the work they engage in, (d) focusing students on mastery, skill development, and the process of learning rather than just focusing on outcomes like test scores or relative performance, (e) helping students to develop and pursue proximal, challenging, and achievable goals, (f) giving students competence feedback that is informational, not just evaluative, and (g) assessing students' knowledge, self-efficacy, and attribution patterns in order to give them the kind of help they need to progress (Urdan and Turner 2005).

Second, *correlational research* based on answers to questionnaires in which students are asked about the different teaching patterns they perceive in their classrooms has provided evidence about the motivational value that students attribute to different specific teaching patterns or strategies. Moreover, this research has also shown that if patterns having high motivational value are used in combination, they define a ▶ classroom motivational climate oriented to learning that is perceived as such by students (Alonso-Tapia and Pardo 2006; Ames 1992). However, there are also patterns defining motivational climates or ▶ classroom goal structures that orient students toward performance or avoidance goals, instead of orienting them to leaning (Kaplan et al. 2002).

In any case, according to research, high-quality teaching patterns defining a classroom motivational climate oriented to learning can be organized around

different points along the learning sequence, as described next:

1. *At the beginning of learning activities, when teachers need to activate the learning intention.* At this point, it seems important *to arouse curiosity, to show task relevance in relation to students' interests, values, and objectives*, and to design learning tasks with *a reasonable degree of challenge*. Strategies such as the presentation of new or surprising information and the setting of problems and questions are useful for the first purpose, whereas the use of authentic tasks that show the usefulness of knowing what the student has to learn or the explicit indication of task functionality can be useful for the second purpose.

2. *During the development of learning activities, when teachers need to keep students' attention focused on the learning process rather than on outcomes.* Depending on the academic subject to teach, teachers explain concepts, principles, theories, procedures, and strategies; design activities that students have to carry out in classrooms or as homework, working alone or in group; induce – or force – students in lesser or greater degree to publicly participate in classroom discussions and activities; and give different amount of feedback and help. Teachers act in different ways when carrying out these activities, but the literature revised suggests the convenience to adopt the following teaching patterns:

   - In the first place, when *introducing subjects or activities* – after arousing curiosity and showing task relevance – teachers' messages and instructions should focus students' attention on learning processes and intrinsic goals, instead of focusing their attention on outcomes, social comparison, and assessment outcomes. Teachers should also help students to visualize and develop a precise planning of activities to be carried out. This help can prevent students to become lost while trying to follow an explanation or to develop a project, and helps them to self-regulate their work.

   - In the second place, when *giving information and explanations*, teachers should make sure that students' experience understanding and competence. This can be achieved if teachers make use of hierarchical and coherent discourse, properties that are not warranted a priori by its formal characteristics. It is necessary to build a bridge between "the given" – what the student already knows – and "the new" – the ideas that the teacher is trying to convey and explain. This objective is better achieved if teachers induce the students to participate, thus showing whether they understand or need clarification. Moreover, the experience of understanding can also be achieved if teachers make use of illustrations and examples that help to build more concrete mental representations of abstract ideas.

   - In the third place, when teachers *interact* with their pupils, research on autonomy-supportive teaching behaviors as well as on classroom motivational climate has shown that it is beneficial for students' motivation to allow pupils to intervene spontaneously, to listen to them attentively, and to request more explanation of their answers if necessary, to reinforce these "echoing" them or nodding while pupil is speaking, to highlight the positive elements of responses even if they are incomplete, to praise "quality" of performance, to ask for reasons behind incorrect answers, to devote time to any pupil who asks for help, and to avoid comparison between students, favoring perception of equity.

   - Finally, when teachers have to propose learning activities in which their pupils should involve independently, motivation can supposedly be favored – once curiosity has been activated and relevance has been shown – if teachers (a) suggest the establishment of personal goals, (b) gave opportunity for options, (c) teach their pupils to ask themselves "How can I do it?" and to look for the necessary means and strategies, (d) suggest to their pupils to divide tasks into small steps, challenging but attainable, (e) underscore the importance of asking for help, (f) give careful feedback and help as often as needed and demanded, (g) highlight progress and pupils' active role in it, and if the working rhythm is neither slow nor stressful.

3. *At the points – during or at the end of learning activities – at which assessment takes place.* Research on assessment implications for motivation and learning has shown that assessment processes can

positively influence motivation to learn and conceptual understanding depending on certain conditions: (a) If they provide information – to the teacher or the student himself or herself, as is the case with portfolio assessment – that may help students to overcome their difficulties and to self-regulate their understanding and learning processes; (b) if tasks demanding the *application and use* of knowledge for solving problems implying some degree of novelty (*analogous* and *transfer tasks*) are used, especially if teachers make explicit for what goals understanding of a particular content is relevant, (c) if tasks are designed to allow teachers to identify specific factors in students that hinder conceptual change and procedural learning, and if teachers give specific help based on assessment, whether this takes place before, during, or after instruction; (d) if teachers avoid messages and classroom practices stressing the relevance of assessment for goals extrinsic to understanding, and give messages focusing student's attention on progress as an intrinsic goal.

Motivational Characteristics as Moderators of Teaching Patterns' Motivational Effect

As far as the motivational quality of the above mentioned teaching patterns and of the classroom motivational climate they configure are well established, it could be thought that if teachers know and use such patterns, they could easily motivate their students. However, students arrive to classroom with different personal characteristics (Alonso Tapia et al. 2010). In different degree, they may be interested in learning and developing competencies, or may only be interested in grades; they may try to avoid failure and not to look dumb in front of others; they can be interested in learning only as far as they see the relevance and usefulness of what they have to learn for their own purposes; they may be interested more in improving social interactions and gaining social support than in academic learning, etc. That is, students differ in ▶ goal orientations and in the specific goals and motivational processes underlying such orientations. These differences between students cause that teaching patterns, whether considered in isolation or as components of the classroom motivational climate, have not the same motivational value for all the students (Meece et al.

2006). For example, it is a well-established fact that the greater is student's *orientation to learn*, the greater is the motivational value attributed to teaching patterns that, according to evidence, configure a classroom climate oriented to learning. This implies, however, that a low orientation to learn makes students to perceive teachers activities conceived for improving motivation and learning as activities of low motivational value. In the same way, as specific motives such as the *desire to avoid failure* or the *desire to achieve rewards extrinsic to academic tasks* increase, many teaching patterns that supposedly favor learning progress and learning motivation seem to have just the opposite effect, according to students' evaluations. For example, if a teacher gives the students the opportunity of choosing topic for personal projects, a strategy that should be beneficial for all of them according to self-determination theory, this action affects negatively the student's effort to learn due to his/her motivational profile. These negative relations are problematic especially when teachers have to deal with students very low in "Learning orientation" and its related motives, and very high, for instance, in "Extrinsic motivation" or in the "Desire of avoid failure." What can teachers do in these cases?

First of all, teachers should be aware that having a negative perception of the motivational value of teaching patterns that supposedly favor learning does not mean that these patterns cannot have a positive effect in changing interest, effort, expectancies, satisfaction with teachers, and learning. It means only that the effect may be lower than if students, due to their motivational characteristics, have a positive perception of the teaching patterns referred to. So, teachers should go on using the teaching patterns that configure a classroom motivational climate oriented to learning.

Second, it is necessary to consider the reasons that make student to be less oriented to learning and, as a consequence, to attribute a lower motivational value to teaching patterns that supposedly favor motivation and learning. In fact, what sometimes happen is not that "*students do not learn because they are not motivated to learn*" but that "*students are not motivated because – even trying – neither learn nor experiment progress because of lack of adequate knowledge of what to do to achieve learning.*" In consequence, it seems necessary to give more individualized support to help these students to confront their learning difficulties.

This line of intervention is very important because it could help to prevent the disappearance or diminution of personal strivings to learn. However, as failure experience increases, to give support to students may be perceived as a form of external control that could induce them to task rejection. Due to this possibility, it may be necessary to use incentives and rewards external to learning itself for enhancing personal strivings at least in three situations, as even the main advocates of favoring intrinsic motivation suggest: First, when initial interest on task is very low; second when task attraction can be experienced only after a time of practice; and third, when this attraction can be experienced only after having achieved a certain degree of mastery in it.

Third, students that accumulate failures and that are less oriented to learning do not only consider that they are not competent for achieving most learning objectives, but also that school work is useless and that going to school is a loss of time. In contrast, they consider that authentic knowledge is learned while working when one has a job or through daily experience. So, in order to create a classroom climate highly motivating it may be necessary to create learning environments with greater personal meaning for the students – defined around more authentic tasks – with an organization of learning activities different from the organization that is usually found in schools.

Important Scientific Research and Open Questions

Research has identified different teaching patterns that, when used in combination, define learning environments of high motivational quality. The perceived classroom motivational climate that characterizes these environments is associated in a great degree to increments in perceived interest, effort, perceived ability, success expectancies, and satisfaction with teacher's work. However, several points deserve and are object of research in the binomial "learning motives-motivational quality of learning environment."

First, research on the generalization of the perception of characteristics that define learning environments of high motivational quality has shown that there are differences in the degree in which students attribute motivational value to teaching patterns depending on several variables such as age, sex, and cultural background. For example, the motivational value attributed to feedback on errors has been found to be greater in adults than in adolescents. So, it is important to identify the motivational value that different groups attribute to different teaching patterns in order to use this information to improve the classroom motivational climate for each group.

Second, researchers differ in the importance they give to different teaching characteristics in the creation of learning environments of high motivational quality, that is, of classroom motivational climates that orient to and favor learning. Research on classroom goal structures stresses the importance of teacher's messages (Kaplan et al. 2002). The review carried out by Urdan and Turner (2005) stresses the general characteristics summarized in the theoretical background section, whereas research on students' perception of the motivational quality of teaching patterns suggests the need not only of considering more patterns, but of considering them at a more specific level (Alonso-Tapia and Pardo 2006). So, it is necessary more research to clarify the teaching patterns that contribute to the creation of powerful learning environments perceived as such by different students' groups.

Third, motivation to learn and students' perception of the motivational quality of learning environments may be affected by personal and classroom variables usually not considered when studying learning environment quality. When arriving to classroom, students differ in their social needs and goals, and classroom interactions configure a social context that may or may not help to achieve them. Classroom interactions define the quality of the ▶ classroom prosocial climate and the ▶ classroom climate of discipline. These climates relate to social motives and goals, and may interfere with motivation to learn if these are not dealt with in an appropriate way. So, research should try to clarify the relation between classroom motivational climate, classroom prosocial climate, and classroom climate of discipline.

Cross-References

- ▶ Achievement Motivation and Learning
- ▶ Climate of Learning
- ▶ Environmental Influences on Learning
- ▶ Goal Theory/Goal Setting
- ▶ Learning Environments
- ▶ Motivation Enhancement

References

Alonso Tapia, J., Huertas, J. A., & Ruiz, M. (2010). On the nature of motivational orientations: Implications of assessed goals and gender differences for motivational goal theory. *The Spanish Journal of Psychology, 13*(1), 231–242.

Alonso-Tapia, J., & Pardo, A. (2006). Assessment of learning environment motivational quality from the point of view of secondary and high school learners. *Learning and Instruction, 16*, 1–15.

Ames, C. (1992). Achievement goals and the classroom motivational climate. In D. H. Schunk & J. L. Meece (Eds.), *Students perceptions in the classroom* (pp. 327–348). New York: Erlbaum.

Kaplan, A., Middleton, M. J., Urdan, T., & Midgley, C. (2002). Achievement goals and goal structures. In C. Midgley (Ed.), *Goals, goal structures and patterns of adaptive learning* (pp. 21–55). Hillsdale: Erlbaum.

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology, 57*, 487–503.

Urdan, T., & Turner, J. C. (2005). Competence motivation in the classroom. In A. J. Elliot & C. Dweck (Eds.), *Handbook of competence and motivation* (pp. 297–317). New York: Guilford.

Learning-to-Learn

▶ Structural Learning in Sensorimotor Control

LEM

▶ Learning Edge Momentum

Lengthwise Research

▶ Longitudinal Learning Research on Changes in Learning of University Students

Lens Model

▶ Multiple-Cue Probability Learning

Lesion

An area of abnormal tissue in an organ such as the brain caused by injury or disease.

Lesson Plan

▶ Alignment of Learning, Teaching, and Assessment

Lesson Planning

▶ Didactics, Didactic Models and Learning

Lessons-Learned Systems

▶ Introspective Learning to Build Case-Based Reasoning

Lev Vygotsky's Theory of Development

▶ Cultural-Historical Theory of Development

Level Descriptors

▶ Learning Criteria, Learning Outcomes, and Assessment Criteria

Lewin, Kurt (1890–1947)

ULRIKE HANKE
Department of Educational Science, University of Freiburg, Freiburg, Germany

Life Dates

Kurt Tsadek Lewin, who is often called the father of social psychology and is considered to be one of the most important psychologists of the twentieth century, was born on September 9, 1890, in Mogilno. At that

time Mogilno was a little village that belonged to Germany, but is now part of Poland. Lewin's family was Jewish, causing Lewin's emigration to the USA in 1933 when Hitler and the National Socialists came into power in Germany. Lewin's father had a little store as well as a small farm, but his parents moved to Berlin when Kurt was 15 years old in order to enable him to attend the Gymnasium (secondary school). After finishing school, Kurt Lewin left to study medicine in Freiburg, Munich, and Berlin before switching to Philosophy, Philosophy of science, and Psychology. After being injured during World War I, Lewin returned to Berlin and completed his Ph.D. with Carl Stumpf. At the beginning of the 1920s, he qualified as associate professor. However, at this time it was not possible for him, as a Jew, to become a full professor in Germany. During these years as associate professor, he conducted a lot of very popular experiments with students that resulted in the field theory, Lewin's most popular work. After his emigration to the USA, Lewin applied himself to research in developmental and educational psychology and developed a new way of research in social psychology. For the first 2 years he worked at Cornell University and then went to the University of Iowa (1935–1944). In 1944, Lewin was asked to establish the Research Center for Group Dynamics at the Massachusetts Institute for Technology (MIT) in Cambridge. In the same year he established the Commission on Community Interrelations (CCI) for the American Jewish Congress (AJC) in New York. The idea of this commission was to study the basis for religious and racial prejudice. Both projects resulted in an enormous number of publications from Lewin and his associates. In 1947 Lewin died from a heart attack.

Although Lewin is seen as the father of social psychology today, it is important to stress that Lewin worked in the field of developmental psychology most of his time as a researcher. That is why a lot of his research and his publications center on the development of children and used children as subjects in his experiments. This was also the case in Lewin's most well-known experiments concerning leadership styles. In these experiments Lewin and his colleagues White and Lippitt (1939) wanted to find out what effect different styles of leadership had on the climate in groups. They found out that the frequency of aggressive behavior and quarreling among the children was much higher under autocratic and laissez-faire leaders than

under democratic leaders. These experiments have been discussed and criticized in various contexts. But in spite of all criticism, these experiments can still be found in almost every textbook on social psychology.

Lewin's most important theoretical work is the field theory (Lewin 1936). The main assumption of this important theory is that human behavior is driven by the forces of a field. This idea resulted in the famous equation of behavior: B=f (P, E) (B=behavior, P=person, E=environment). In other words: human behavior is a function of the person and his or her environment. In order to understand and explain the current behavior of a person, the current environment has to be analyzed from the perspective of this person, that is, it "should be described not in 'objective physicalistic' terms, but in the way in which it exists for that person at that time" (Lewin 1942, p. 62). How the person perceives the environment at that time depends "partly upon the state of that individual as a product of his history, partly upon the nonpsychologic – physical and social – surroundings" (Lewin 1942, p. 62). In this sense, different parts of the environment can be attractive and other parts can be unattractive for the person at that time. Those parts of the environment that are attractive for the person at that time have in the terminology of the field theory positive valence, those which are unattractive have negative valence. Those parts of the environment that have positive valences are goals which the person will try to approach. In order to visualize the field and its forces at a certain time, Lewin used mathematical topology.

As a consequence of his understanding of the field of a person at a special time, Lewin used the methodology of so-called action research in his experiments. This methodology aims at social changes and is carried out in three steps: planning, social intervention, and reflection on the changes that result.

Contribution(s) to the Field of Learning

"According to the field theory, all changes are due to certain forces (directed entities). In regard to the forces which bring about a change in cognitive structure, it is convenient to distinguish two types: one resulting from the structure of the cognitive field itself, and the other from certain valences" (Lewin 1942, p. 83). In this sense, Lewin (1942) described learning as a change in cognitive structure and in motivation (Lewin 1942,

p. 66). He also mentions learning as consisting of changes in group cohesion, and in the meaning of voluntary control of the body musculature (Lewin 1942, p. 66), but he does not go into further detail concerning these two ways of learning.

According to Lewin, learning as a change in cognitive structure (knowledge) can take place in three ways: as a differentiation of the field, as a restructuring of the field, and/or as a change in time perspective. Differentiation can be understood as the "subdividing of regions into smaller units" (Lewin 1942, p. 72): An individual gets to know parts of the field that have been unknown until that time. In order to clarify the idea of differentiation as an expansion of the cognitive structure, Lewin gives the example of a person that has moved to a new town and finds his or her way through the new town bit by bit.

Another way of learning is by restructuring the field. During the process of restructuring, previously separated areas of the field become connected. This restructuring of the field results in different understandings of directions and meanings. In order to clarify the idea of restructuring, Lewin used the example of a child that tries to reach a goal that is separated by a barrier. In order to reach the goal, the child has to restructure the field, that is, has to recognize that it has to "go away" from the goal first in order to reach it.

Another way of learning in the sense of changing the cognitive structure is by a change in time perspective and in the relationship between reality and irreality. Whereas the small child lives in the present, the "time dimension of the life space of the child grows with increasing age; more and more distant future and past events affect present behavior" (Lewin 1942, p. 75). This enlargement in time perspective results in perceiving the environment differently and in different classifications of the environment. As a consequence, behavior changes; learning has taken place. In addition to the enlargement of the time perspective, learning also takes place as a differentiation in the reality-irreality dimension. The capacity to differentiate between facts and wishes and between hopes and expectations changes the way the environment is perceived because the cognitive structure is changed.

Another way of learning takes place in the change of motivation. Learning in this sense "deals either with a change in needs or a change in the means of their satisfaction" (Lewin 1942, p. 84). These kinds of change

result in changed valences and values and take place, for example, "during the so-called crisis, such as adolescence. Oversatiation, too, may lead to a permanent dislike for an activity" (Lewin 1942, p. 79). In this context, the level of aspiration is very important. "The level of aspiration is influenced partly by the ability of the individual as manifested in his past and present successes and failures, partly by certain group standards" (Lewin 1942, p. 81/82). A change in the level of aspiration results in different classifications of the facts in the environment. As a consequence the forces change and have different effects.

The merits of Lewin's research are, in general, to analyze the whole situation in order to explain human behavior, and as a consequence to understand human behavior as a function of the person with his or her own needs and the environment as it is perceived by that person. In this sense, a person's behavior changes when the needs of the person and/or his or her perception of the environment changes, that is, learning takes place as a change in the needs and/or as a change in the way the environment is perceived.

Cross-References

► Field Theory of Learning
► Gestalt Psychology of Learning

References

Lewin, K. (1936). *Principles of topological psychology.* New York: McGraw-Hill.

Lewin, K. (1942/1964). Field theory and learning. In D. Cartwright (Ed.), *Field theory and social science. Selected theoretical papers by Kurt Lewin* (pp. 60–86). New York: Harper & Row.

Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues, 2*(4), 34–46.

Lewin, K., Lippitt, R., & White, R. K. (1939). Patterns of aggressive behavior in experimentally created 'social climates'. *The Journal of Social Psychology, 10*, 271–299.

Lück, H. E. (2001). *Kurt Lewin. Eine Einführung in sein Werk.* Weinheim und Basel: Beltz.

Marrow, A. J. (1977). *Kurt Lewin. Leben und Werk.* Stuttgart: Klett.

Lexical Acquisition

► Word Learning
► Word Learning and Lexical Development Across the Lifespan

L

Lexical Development

Lexical Representation

Lexicalization

The process by which a newly learnt word becomes entrenched in the mental lexicon, and develops lexical behavior characteristic of other entries in the mental lexicon.

Cross-References

Life Course

Lifelike Characters

Lifelong and Worklife Learning

Stephen Billett
School of Education and Professional Studies, Griffith University, Mt Gravatt, QLD, Australia

Synonyms

Continuing education and training; Personal enrichment; Professional development

Definition

In much of the English speaking world, the phrase or proper noun – Lifelong Learning – is usually associated with adults' learning across their lives as directed toward particular intentions associated with enrichment of the cultural, recreational, or occupational kinds. That is, learning for a range of educational purposes, whose purposes are often premised on betterment. Hence, unlike concepts associated with human development across the lifespan, which has an emphasis on phases of development across ontogeny (i.e., personal history) associated with maturation, the emphasis is on specific kinds of intentional learning. So, it is a term used to refer to learning through participation in programs in fields of personal recreational or cultural interest. However, the term "lifelong learning" was co-opted by key global agencies in the Year of Lifelong Learning in 1996 and, whilst still referring principally to adults' ongoing learning, this term was redefined to have a strong economic emphasis and imperative. In this way, it is now more aligned with concepts such as professional development and continuing education and training, both of which usually have an intentional emphasis on occupationally focused learning. Indeed, the Organisation of Economic and Cultural Development (OECD) (1996) identified two key qualities for this new concept of lifelong learning as individuals needing: (1) to continue learning occupationally specific knowledge throughout their working life to resist becoming redundant, to maintain their competence, and develop further their work-related capacities and (2) to take responsibility for this learning, rather than relying upon government or employers. Hence, in an era of global economic competition in which the competence of the workforce is central to securing national economic and social well-being, lifelong learning as a process of ongoing learning across individuals' lives is now being defined by governments and key global agencies in economic terms for both personal and community purposes (Field 2000).

As a variation of this conception to adults' learning, the term *worklife learning* appears to have its origins in the social democratic movements of Scandinavia. The term captures a broader set of concerns about learning for work that goes beyond the technical aspects of particular occupations. Instead, it includes factors associated with the wider aspects of the quality of

working life, particularly occupational health and safety, involvement in workplace decision-making, and the workplace as a community of workers.

Theoretical Background

Conceptually, there are two distinct ways to consider lifelong and worklife learning as they are defined above. One way – the developmental perspective – views learning as an ongoing process that occurs continuously through individuals' conscious engagement with the world around them in its social and brute (i.e., natural) forms. That is, our learning is not distinct or separated from other aspects of human thinking and acting. This view tends to be the perspective adopted through disciplines that focus upon human development, often with a psychological orientation. Here, learning is the inevitable consequence of engaging in thinking and acting, and it both shapes personal or ontogenetic development across individuals' life courses. Some of these perspectives emphasize processes of maturation, perhaps most focused in the earlier and the latter stages of the human life course, and engage with brute considerations of biological factors, such physical strength, visual acuity, etc. These and other perspectives, to a greater or lesser degree, include considerations of the social worlds and factors of human development. Some perspectives also consider the relationship between individuals' ontogenetic development and phylogenetic development (i.e., the ongoing remaking and development of the human species). So, learning and development within these perspectives is taken as occurring inevitably through human processes of thinking and acting that occur across life histories. It is noteworthy that the Russian psychologist Vygotsky is claimed to have appropriated the essentially biological terms such as ontogentic and phylogentic development to emphasize the way that social and cultural contributions shape human development. Although much of developmental considerations focus on children's learning, and then at the other end the decline of capacity is brought about by maturation, many of the key precepts within these developmental approaches apply to adults' learning and development. For instance, although both individual and social constructivist movements have focused on children's development, key concepts such as equilibrium, viability of what is experienced, accommodation, appropriation, and negotiation apply

equally to explain adults' development. So, the key theoretical distinctiveness here is that learning will occur as individuals think and act as part of a human process of making sense of what is encountered.

Consequently, there are well-established developmental theories that can inform the processes of adults' learning and development across their life course. Even though many of these are premised on children's learning, there is a body of theorizing about adults learning, and as being in some way different than that of children's. Most popular is the concept of andragogy that was advanced by Knowles (1975) who argued that adults' learning processes are quite distinct from children's because adults are used to being self-directed and that direct teaching whilst appropriate to children is inappropriate for adults. Instead, it was claimed that adults needed to identify what they needed to learn and how they wanted to learn that knowledge, and then proceed to learn it. Hence, a powerful concept within adults' lifelong learning is the capacity to be self-directed in their learning. Within the overall purview of adult learning, other movements focused on emancipatory and critical perspectives of adult and lifelong learning also emerged (Mezirow 1985). However, others have suggested that these distinctions are false because children are also all self-directed in their learning and have an interest in understanding what and how they might best learn (Tennant 1986). Moreover, it has been found that while they may need to be self-directed, beyond their existing domains of competence, they may not be very effective in being self-directed learners in domains of activities that are novel to them. This is because they lack the capacities to direct, enact, and monitor their own learning. Therefore, rather than making assumptions about adults being self-directed and able to learn in ways which are described as being facilitated by others, often it is likely they require a close guidance of more expert partners who can assist them to understand, come to practice, and to value the knowledge which they do not initially possess.

However, a quite different perspective of lifelong learning is the one now most commonly referred to, and increasingly so by governments, global agencies, and employers. That is, adult learning as directed to particular and socially derived purposes. These perspectives are informed by historical and social considerations, through identifying and proposing the kinds of learning that adults need. For instance, in many

Western countries, arrangements for adults' continuing education were developed over the last couple of hundred years. Some of these arrangements arose from concerns about the relative social disadvantage of adults as learners, through either the inadequacy of their initial education, or the emerging needs that arose in adults' working lives. Sometimes, these arrangements were either organized by individuals who have particular concerns (e.g., Birkbeck) and which then became movements (e.g., further education) or through affiliations such as trade unions that sought to advance the interests of adults through education (workers' education) or through their community (further education courses, School of the Arts). So these kinds of movements sought to educate post-school-age adults through programs and courses that had various purposes according to the institutional interests that promoted them. Mostly this account of lifelong learning is really lifelong education. George Birkbeck, for instance, was concerned to develop the occupational competence of male adult workers through teaching them engineering principles and their mathematical underpinnings in what became known as Mechanic Institutes (Bennett 1938). Workers' education movements often focused on courses promoting literacy and cultural development to affect a more broadly educated adult population. Yet, much of the further education movement in countries like Britain and Australia was associated with personal enrichment through developing capacities that were not necessarily directly related to adults' paid work, but often sought to develop capacities (i.e., concepts, procedures, and dispositions) associated with a particular field practice (e.g., language, hobbies, music, cooking).

However, this institutional and, in some cases, societal commitment to adults' enrichment has become largely redefined since the mid-1990s in many Western countries, through a greater concentration on the direct promotion of economic aspects of public and private life. This occurred most pointedly through the Year of Lifelong Learning in 1996 as promoted by the OECD to focus more directly on adults lifelong learning as referring to them directing their learning toward developing further their occupational competence, in order to resist unemployment, be more productive, and contribute to the productivity of their workplace, and sustaining contributions of their work activities in ways which strengthened their communities.

Commensurate with this initiative and the other changes that underpinned this reordering of the concept of lifelong learning has been the running down of provisions for adult education in countries such as Britain and Australia. In the former, societal or governmental focus on more directly economic educational programs has seen the closing down of adult education courses in higher and tertiary education. In Australia, the continuing education provision that focused on personal enrichment has been removed from some governments' programs and now is taken up in relatively ad hoc ways, for instance, by schools offering such programs as fund-raising ventures, and adult literacy development programs, now shifting to offering full fee paying English classes to migrants and overseas students. Consequently, this second view of lifelong learning is one that is aligned to particular societal concerns at a particular point in time which emphasize adults' development being directed toward particular purposes.

Clearly, the differences between a provision of lifelong learning centered on adult personal enrichment and one on addressing the changing economic landscape has profound implications for the provision of adult learning and education. These issues are curiously analogous to debates occurring elsewhere (i.e., in schooling and higher education) about the degree by which education should be focused toward general or domain specific purposes. Although set as two different perspectives on lifelong learning, it is a consideration of both perspectives which are now required to advance understandings about and practices within adult education and other provisions that focus on developing adults' capacities for working life and beyond. That is, a consideration of learning as an ongoing process that is shaped by brute (i.e., those of nature) and social factors, yet also mediated by individuals' constructions and construals.

Important Scientific Research and Open Questions

The key questions arising for lifelong and worklife learning are required to be understood through a consideration of adults' development across the life span and also the kinds of purposes to which individuals are being directed. For instance, it is unlikely that global agencies, governments, or employers will be able to achieve their specified goals for lifelong learning

unless individuals' interests and intentionalities are aligned with those purposes. Consequently, salient questions need to be addressed. These include:

How can the provisions of lifelong and worklife learning be organized in ways that meet both the purposes of their sponsors and the interests and needs of adults as lifelong learners?

What kinds of instructional and pedagogic practices can be utilized in educational, workplace, and community settings and in ways that will most likely effectively engage adult learners?

What are the kinds of practices that adult learners themselves need to develop and exercise in order to be effective and agentic learners across their lives?

As proposed, there is evident alignment between everyday lifelong learning and that for work life, yet these important alignments are not fully understood. Hence, a question guiding such an inquiry is: In what ways are alignments or misalignments between adults' ongoing lifelong learning and those realized for and through working life?

Cross-References

▶ Adult learner characteristics
▶ Adult learning theory
▶ Adult learning/Andragogy
▶ Authenticity in learning activities and settings
▶ Guided learning
▶ Vocational learning
▶ Workplace learning

References

Bennett, C. A. (1938). The ancestry of vocational education. In E. A. Lee (Ed.), *Objectives and problems of vocational education* (pp. 1–19). New York: McGraw-Hill.

Field, J. (2000). Governing the ungovernable: Why lifelong learning promises so much yet delivers so little. *Educational Management and Administration, 28*(3), 249–261.

Knowles, M. (1975). *Self-directed learning*. New York: Association Press.

Mezirow, J. (1985). A critical theory of self-directed learning. In S. Brookfield (Ed.), *Self-directed learning: From theory to practice* (pp. 17–30). San Francisco: Jossey Bass.

Organisation of Economic and Cultural Development (OECD). (1996). *Lifelong learning for all*. Paris: OECD.

Tennant, M. (1986). An evaluation of Knowles' theory of adult learning. *International Journal of Lifelong Education, 5*(2), 8–12.

Lifelong Education

▶ Confucian Educational Philosophy and Its Implication for Lifelong Learning
▶ Lifelong Learning

Lifelong Learning

PAUL J. HAGER
University of Technology, Sydney, Sydney, NSW, Australia

Synonyms

Education permanente; Learning society; Lifelong education; Recurrent education

Definition

At first sight, lifelong learning is an easily understood concept. It captures the seemingly simple idea that in order to flourish in the contemporary world humans need to learn significantly across the different phases of their lifespan. This idea contrasts sharply with the view that held sway until recently, that an appropriate quantum of learning during childhood, and in some cases into the early years of adulthood, would be sufficient for a productive lifetime. This "front-end" view which tends to equate "learning" with "formal education" was increasingly challenged during the twentieth century. By the 1970s, the basic idea that humans at all ages are able to and, increasingly, need to, benefit from ongoing learning was embedded in each one of the cluster of related concepts that gained prominence in international policy circles: lifelong education (UNESCO, Council of Europe), lifelong learning (UNESCO), recurrent education (OECD), and *education permanente* (Council of Europe).

Though this basic idea was an agreed common thread through each of these related concepts, differences quickly became apparent as the various concepts were subjected to closer scrutiny.

Not only were there different philosophical assumptions underpinning the various concepts, there was also fundamental disagreement about the value or otherwise of different kinds of learning. Central to

these disagreements is the status of learning that occurs outside of formal educational situations.

Theoretical Background

There have been two distinct international surges of interest in lifelong learning. Firstly, during the 1970s, lifelong learning was but one of a cluster of related but different concepts that together served to highlight the importance of education and learning beyond the first few decades of peoples' lives. Besides lifelong learning, notable concepts in this cluster were "lifelong education," "recurrent education," and "*education permanente*" (see Kallen 1979).

Although there were commonalities across these various key concepts, there were also crucial differences that served to fuel conflicting understandings. Bagnall (2001) offers a useful schema that classifies and elucidates the different diverse prior traditions and philosophies that served to inform the various conflicting understandings of lifelong learning and cognate concepts. Firstly, Bagnall identifies three distinctive progressive sentiments: one centered on democratic cultural reform through education, another centered on individual growth and development as the key purpose of education, and yet another centered on the need for individuals, groups, organizations, and, even, nations to adapt to the ever accelerating impact of cultural, social, and technological change. Yet within these three progressive categories there is significant divergence. For instance, within the individual growth and development strand, Bagnall identifies four distinctively different kinds of liberatory commitment. Thus, even though the 1970s proponents of lifelong learning and cognate concepts were agreed on the fundamental importance of humans learning across their lifespan, major disagreements quickly surfaced once proponents started to spell out what this meant for them in practice.

As well, this 1970s first wave of enthusiasm for lifelong learning and related concepts was met with significant opposition from within the field of education itself. A major concern was the perception that informal learning was being accorded the same status as formal learning. The worry was that whilst formal learning featured all kinds of quality controls, informal learning was subject to no such standards. A different way of raising the same basic worry was to point out that learning was a much broader concept than education. Whilst much learning is undoubtedly educational,

there are plenty of other instances of learning that are more dubious. Hence the worry that equating lifelong *learning* with lifelong *education* would serve to debase education. Of course, there was much more nuanced argument on these matters from all sides (see Hager and Halliday 2006), but these points do capture the main outlines of a debate that saw interest in lifelong learning decline markedly during the 1980s.

Important Scientific and Research Open Questions

The second surge of interest in lifelong learning dates from the 1990s onward and continues unabated today. This 1990s resurgence coincided with the term "lifelong learning" becoming the preeminent concept in this field, with the cognate concepts discussed above having receded markedly into the background. This rise of interest in lifelong learning was fuelled by various contemporary pressures. Prominent amongst these were neoliberal economic imperatives, globalization trends, and the increased emphasis on knowledge creation.

A notable fact about this second wave of enthusiasm for lifelong learning was that it exhibited key features that were not prominent in the first wave. As Field (2004, p. 2) pointed out, the second wave, "is marked by a more anxious and uncertain perspective." This is clear from the contemporary pressures just listed above: underlying each is worries about an undesirable future: of nations becoming uncompetitive, of their not being sufficiently clever or innovative. However, the most significant new feature of the second wave of enthusiasm for lifelong learning is the major emphasis that it places on *learning* itself. As already noted, "learning" is a much broader concept than is "education." Learning comes in many kinds and encompasses diverse settings from formal educational arrangements of all different types, through the multiplicity of types of non-formal educational situations, to the innumerable life events and contexts that can cause informal learning to happen. Typically, lifelong learning policy documents presuppose a fairly broad understanding of learning, i.e., they incline toward what might be termed a "maximalist view" of lifelong learning. However, a maximalist view creates some tensions because of certain features of learning in general. Firstly, learning comes in many shapes and forms, and it is clear that not all of these kinds of learning are equally valuable or desirable. Secondly,

much of the best of informal learning is not specifiable in advance, nor is it intentional. Rather, it is contingent and opportunistic. Take, for example, prisons. They are the sites of a wide range of learning, much of it that would be regarded doubtlessly as socially undesirable. But at the same time, crucial life-enhancing and character forming informal learning can happen for people who are forced into dire situations such as incarceration, internment, or oppressive social circumstances (Hager and Halliday 2006, pp. 246–247).

Thus, by shifting the spotlight so strongly onto learning itself, the lifelong learning concept was bound to provoke divergent opinions about its role and significance, since there exist very different understandings of the nature and value of learning in its diverse manifestations. Some people view worthwhile learning as an activity that largely occurs within formal educational systems, since they offer a form of quality control on the learning that is absent elsewhere. For this perspective, the main issues raised by lifelong learning revolve around new kinds of curriculum, teachers, teaching methods, and educational providers. They will likely be wary of maximalist lifelong learning policies. At the same time, others see the lifelong learning concept as stimulating a long-overdue widening of the scope of learning to include all kinds of informal learning, most of which had been hitherto invisible. However, this kind of view raises questions about the scope of the term "learning" within "lifelong learning." Is all learning to be accepted as worthwhile? As Field (2004, p. 1) notes, this potentially represents a paradigm shift for educational policy. On maximalist understandings of lifelong learning, the "... . idea of learning is . . . . so broad as to pose serious challenges of definition and measurement for policy makers."

Given that it is impossible to pre-specify and accredit all worthwhile learning, it would seem that prudent maximalist lifelong learning policies should foster social arrangements that encourage a culture of rich informal learning.

However, perhaps reflecting a fear of the scope of socially approved learning being made too open, others prefer a more minimalist understanding of lifelong learning, restricting it to the existing educational provision as currently operating in many countries. This means that lifelong learning is viewed merely in terms of existing provision: compulsory schooling, followed by post-compulsory education, followed by assorted adult and continuing education as required by a person's circumstances. This interpretation reads the "learning" in lifelong learning as "formal learning." It maintains the hegemony exerted by formal education systems over what learning is valued and how it is assessed and accredited. However, this minimalist understanding is a significant dilution of the intent of most lifelong learning policy documents.

What about more recent debate on lifelong learning? Has the argument moved on? The answer seems to be that it has in part been transmuted into the emerging concept of the *learning society*. Field and Leicester express the intimate connection between lifelong learning and a learning society as follows:

▶ Lifelong learning . . . . . serves to reject the school and post-school division to endorse learning across the lifespan, a learning which is worthwhile to the individual citizen and, therefore, to the society of which she is a part. Lifelong learning is thus often linked with the notion of a learning society – society which will, that is to say, be so organized as to provide (maximum) learning opportunities for each of its members, and also so as to value a broad range of that learning. (Field and Leicester 2000, p. xvii)

However, learning societies can take very different forms. For instance, Wain (1987) views a learning society as being essentially democratic, whereas Field denies that the advent of a learning society requires the realization of any egalitarian or communitarian ideals. For him, the "core idea" of the learning society is simply:

▶ ... the plasticity of the human adult: however much has been invested in initial schooling, the belief is central that untapped potential is the norm rather than the exception. (Field 2006, p. 47)

It is not surprising, then, that Coffield (2000) identifies ten different models of a learning society.

Thus, though discussions of lifelong learning policies have moved on by shifting attention to the concept of the learning society, essentially the same kinds of philosophical differences about the nature of learning and the aims of education continue to shape the ongoing debate centering on open questions, such as follows:

How might research on informal learning be employed to enrich understandings of lifelong learning?

Which learning metaphors are most conducive to developing rich accounts of lifelong learning and the learning society?

How might the concepts of group learning and team learning help to enrich our understanding of lifelong learning?

How might the concept of social capital contribute to furthering our understanding of lifelong learning and the learning society?

How might the concept of a learning career contribute to furthering our understanding of lifelong learning and the learning society?

Cross-References

▶ Adult Learning Theory
▶ Adult Teaching and Learning
▶ Biographical Learning
▶ Confucian Educational Philosophy and Its Implication for Lifelong Learning
▶ Informal Learning
▶ Learning from Counseling
▶ Learning to Learn
▶ Professional Learning and Development

References

Bagnall, R. (2001). Locating lifelong learning and education in contemporary currents of thought and culture. In D. Aspin, J. Chapman, M. Hatton, & Y. Sawano (Eds.), *International handbook of lifelong learning* (pp. 35–52). Dordrecht/Boston/London: Kluwer.

Coffield, F. (Ed.). (2000). *The necessity of informal learning*. Bristol: The Policy Press.

Field J. (2004). *Lifelong learning and cultural change: A European perspective*. Paper presented at the conference on lifelong learning and new learning culture, National Chung-Cheng University, Chia-Yi, Taiwan, 1–2 October 2004. www.ioe.stir.ac.uk/staff/docs/field-lifelonglearning.pdf. Accessed 20 Nov 2009.

Field, J. (2005). *Social capital and lifelong learning*. Bristol: The Policy Press.

Field, J. (2006). *Lifelong learning and the new educational order* (2nd ed.). Stoke on Trent/Sterling: Trentham Books.

Field, J., & Leicester, M. (Eds.). (2000). *Lifelong learning: education across the lifespan*. London/New York: RoutledgeFalmer.

Hager, P., & Halliday, J. (2006). *Recovering informal learning: Wisdom, judgement and community*. Dordrecht: Springer. Reissued as a paperback in 2009.

Kallen, D. (1979). Recurrent education and lifelong learning: Definitions and distinctions. In T. Schuller & J. Megarry (eds.), *Recurrent education and lifelong learning* (World Yearbook of Education 1979). London/New York: Kogan Page/Nicholls.

Wain, K. (1987). *Philosophy of lifelong education*. London: Croom Helm.

Lifespan Development

▶ Cognitive Aging

Likeness

▶ Analogy/Analogies: Structure and Process

Line of Reasoning

▶ Argumentation and Learning in Science Education

Linear and Nonlinear Models of Innovation

▶ Learning Adjustment Speeds and the Cycle of Discovery

Linear Functions

▶ Learning via Linear Operators

Linear Maps

▶ Learning via Linear Operators

Linear Regression

▶ Learning via Linear Operators

Linguistic and Cognitive Capacities of Apes

Duane M. Rumbaugh[1], Michael J. Beran[2]
[1]Departments of Psychology and Biology, Language Research Center, Georgia State University, Atlanta, GA, USA
[2]Language Research Center, Georgia State University, University Plaza, Atlanta, GA, USA

Synonyms

Ape language; Comparative cognition; Rational behaviorism

Definition

The linguistic and cognitive capacities of great apes are reflections of many of the same capacities demonstrated by humans. These are the result of a shared evolutionary history and reflect the psychological continuity that we argue accompanies biological continuity.

Theoretical Background

Data from the past century provide very clear support for the following statement: Great apes share with humans several basic linguistic and cognitive abilities. This is remarkable; their brains are approximately one-third the size of ours, and their early rearing is only rarely conducive to the optimal development of their language skills. Their language skills are far greater than those of monkeys and the lesser apes (Rumbaugh and Washburn 2003). Although some monkeys are impressive in their abilities to learn highly complex tasks, they are not nearly as facile as the great apes in learning complex tasks. Neither have they evidenced competence for semantics as have the great apes.

We focus here on a subset of the long-term studies with great ape species that demonstrate their linguistic capacities in a variety of symbol systems, including sign language, word-lexigram comprehension and use, and speech comprehension (see Hillix and Rumbaugh 2004, and Rumbaugh and Washburn 2003). Our knowledge of the linguistic and cognitive capacities of the great apes has been obtained from decades-long studies with apes studied from infancy to adulthood. Notable apes include Washoe, Lana, Koko, Chantek,

Sherman, Austin, Ai, Kanzi, Panzee, and Panbanisha. Short-term language studies that terminated in late childhood or began in late infancy have produced little or no learning of any dimension of language. Perhaps the superior mentality of the great apes, compared to the lesser apes and monkeys, reflects their ability to transfer even minimal amounts of learning to a new task. Early environment is a critical determinant of the capacity to learn any aspect of language and complex relationships. Infancy is the progenitor of intellect.

An early project was the Lana Language Project. It differed from previous projects in that it successfully interfaced a chimpanzee (Pan troglodytes) with a word-lexigram computer-controlled keyboard (Rumbaugh 1977). First with operant training and later in socially interactive contexts, Lana mastered grammatically structured stock sentences and used them to obtain specific foods and drinks, company, movies, music, and views. She learned her word-lexigrams and computer-controlling sentences by direct experience of their effects, by verbal feedback, and by observation. Importantly, without additional specific training, Lana creatively solved new challenges verbally. As but one instance, when shown the fruit, orange, but without knowledge that "orange" was the name of the fruit as well as its color, she asked for it as "…the apple which-is orange." She also rejected the offer of an orange (tennis) ball by stating that "Lana want eat ball which-is orange."

She also made novel requests of her technicians. For instance, she asked to share in the drinking of a coke with her experimenter outside her room – "Lana drink coke out-of room?" Similarly, she directed the attention of caregivers to "move behind" her room so that they might see that a vending device for a requested food was jammed. When given access to an expanded keyboard, she applied her lessons of grammar, spontaneously erasing errors and then correcting them. Contrary to claims by a critic, she rarely imitated the use of lexigrams by her teachers in conversation.

With but minimal training, she executed cross-modal tests of transfer in which she judged whether what she saw was identical to what she could feel but could not see. Therein she innovatively used "no-same" rather than "different" when, indeed, the objects were not identities. If the objects so perceived had names (e.g., word-lexigrams) her judgments were more

accurate than if they did not. Skillfully, she categorized colored chips and gave either the name or color of objects (e.g., "What color of this shoe" or "What name of this that's red," with six objects presented in six colors).

Later, she mastered approximate ordinal counting up to six items, demonstrating that she could learn and flexibly use another type of symbol system. She also demonstrated remarkable long-term memory for the real-world referents not used in 20 years. Lana, now 40 years old, also demonstrated many other capacities in the realms of memory, numerical cognition, self-control, attention, and other areas in which her symbol competence facilitated high-level cognition. Lana's contributions unequivocally contradict the bias of marginally informed critics who hold that apes cannot master symbol relationships germane to human language. Although Lana will never speak or publish, she has formulated many novel sentences and has used her specifically trained stock sentences creatively. Lana and some other apes do have significant competencies for some, but not all, language.

Subsequent research demonstrated that chimpanzees Sherman and Austin mastered skills that permitted them to ask one another for specific tools with which to solve problems with accessing items of food and drink. They learned to announce intentions (e.g., what they were going to do) through lexigram communication. They sorted not only real-world items and photos of those items on the basis of categories such as food and tool, but also the lexigrams for those same items into those same categories, thereby demonstrating the semantic meaningfulness of their word-lexigrams. These chimpanzees and others also demonstrated an understanding of the relative values of numerals (e.g., Beran and Rumbaugh 2001).

Subsequent research in our laboratory documented that the bonobo (*Pan paniscus*), Kanzi, acquired word-lexigram meaning by observation and through direct life experiences. He even learned to understand the meanings of specific words and their use in rather complex sentences of request, as spoken by both experimenters and visitors (Savage-Rumbaugh et al. 1993). The bonobo, Panbanisha (*P. paniscus*), and the chimpanzee, Panzee (*P. troglodytes*), showed the critical role of early environment in the emergence of speech comprehension in the genus *Pan* (see Rumbaugh and Washburn 2003).

Important Scientific Research and Open Questions

That the competencies of Lana, Sherman, Austin, Kanzi, Panzee, and Panbanisha went well beyond the boundaries of their early specific training has encouraged us to formulate a new perspective of learning and behavior, one not based on stimulus–response reinforcement or habits, but on associations among contiguous salient events that form composites, termed amalgams. The constituent events that come to form amalgams are postulated to share interactively their saliencies and response-eliciting properties. Neural integrations of these life-event-based composites into templates, so as to achieve the optimal best-fit among them all, are posited to induce relationships that can generate novel "emergent" behaviors and knowledge vital to the procurement of resources for facile adaptation, even to new challenges (Rumbaugh et al. 2007). Perhaps there are no better examples of emergents than those that inhere in language acquisition in great apes. Research into nonhuman animal language and cognition will continue to provide data that better inform our views of the interaction between early rearing, the principles of learning as they are manifest in intelligent nonhuman animals, and the resultant effects on language and cognition.

Acknowledgments

Cross-References

References

Beran, M. J., & Rumbaugh, D. M. (2001). "Constructive" enumeration by chimpanzees (Pan troglodytes) on a computerized task. *Animal Cognition, 4*, 81–89.

Haywood, H. C. (2009). Historical notes and indications of the future. In P. Naour (Ed.), *E. O. Wilson and B. F. Skinner – a dialogue between sociobiology and radical behaviorism* (pp. 107–115). New York: Springer.

Hillix, W. A., & Rumbaugh, D. M. (2004). *Animal bodies, human minds –ape, dolphin, and parrot language skills*. New York: Springer.

Rumbaugh, D. M. (Ed.). (1977). *Language learning by a chimpanzee – the Lana project*. New York: Academic.

Rumbaugh, D. M., & Washburn, D. A. (2003). *Intelligence of apes and other rational beings*. New Haven: Yale.

Rumbaugh, D. M., King, J. E., Beran, M., Washburn, D. A., & Gould, K. (2007). A salience theory of learning and behavior. *International Journal of Primatology, 28*, 973–996.

Savage-Rumbaugh, E. S., Murphy, J., Sevcik, R. A., Brakke, K. E., Williams, S., & Rumbaugh, D. M. (1993). Language comprehension in ape and child. *Monographs of the Society for Research in Child Development, 58*, 3–4.

Linguistic Factors in Learning

Imran Ho-Abdullah, Norsimah Mat Awal
School of Language Studies & Linguistics, Faculty of Social Sciences and Human, Universiti Kebangsaan Malaysia, Bangi, Selangor DE, Malaysia

Synonyms

Educational linguistics; Linguistics disabilities and learning; Linguistics in education

Definition

Linguistic factors in learning are normally subsumed within the field of educational linguistics. This field encompasses research into multilingualism; language situations and policies including medium of instructions; how linguistic practices and factors can guide effective pedagogy; and classroom discourse analysis for effective teaching and learning. Linguistic factors in learning also include more current approaches in relation to linguistics variables and learning (dis) abilities.

Theoretical Background

The role of linguistics and language in learning has often been associated with second language pedagogy. As noted by Spolsky (1978) the intersection between language studies and education has not always been clear. The application of linguistic theorizing and descriptions, or "applied linguistics" in the past has narrowly been associated with language teaching and language pedagogy. However, from a different viewpoint, namely the perspective of learning and theory of learning, it is just as important to examine how learning is affected by linguistics variables, just as educational psychology examines the various psychological factors in teaching and learning settings.

Stubbs (1986) following Halliday, emphasizes the functional view of linguistic theories which hold that the value of a theory depends on what use is to be made of it, which could be in translation, language acquisition, etc. As such, there will be different descriptions of language and different models for different goals. This theoretical pluralism implies that language is too rich and complex to be captured in a single theory. However, Halliday asserts that there is a common ground on what linguistics is and there is an understanding of "core" topics in linguistics. The core topics are, "phonetics, phonology, morphology, syntax and semantics; the interrelations between these levels of linguistic description; and the relation between a language so conceived and its use by individual speakers or by society" (Stubbs 1986, p. 4). In education, on the other hand, there is a general feeling of distrust of the role linguistics in learning. The view often held in education regarding linguistics is, it not being helpful to teachers to being too theoretical. Therefore, Stubbs offers a linguistic approach on discourse to provide explanations on language that would be useful to educationists. The linguistic approach suggested by Stubbs is using discourse analysis in teacher education, starting by analyzing classroom dialogues and written texts.

Previous studies on language in education tend to use language as evidence for educational statements. These studies use linguistic data as "markers," "indices," "indicators," or "evidence" for social–psychological statements that are of interest to educational theory and practice (Stubbs 1986, p. 233). The studies range from different teachers' use of pronoun; the functions of teachers' questions and different types of question–answer exchanges; functional categories of speech acts to intonation and paralinguistic features. These studies are seen as individual attempts to study different aspects of language that are often unrelated and as

a whole they lack coherence. Language is regarded as a system of systems and these systems are identified at different levels (phonology, morphology, syntax, and semantics) and Stubbs asserts that language in the educational setting must be examined as a system, not as isolated items and this could be achieved through discourse analysis.

In general, the language barrier in education is a major issue in educational literacy, e.g., as the skill of reading invariably has a linguistic dimension. In addition, children with cognitive and brain anomalies and injuries causing dyslexia and other language disabilities will surely affect their ability to learn. In the area of reading, which is a key component of successful learning, Tunmer and Hoover (1992) summarize research on the relationship between metalinguistic abilities and learning to read. Essentially, metalinguistic development and reading acquisition are highly correlated which in turn influences the learning strategies and literacy development of the learner.

Important Scientific Research and Open Questions

Linguistics factors in learning have long been acknowledged within education especially in bilingual and multilingual settings (Lambert and Anisfeld 1969; Gardner 1983). Open debates and research continue with regards to the pros and cons of bilingualism in education especially in relation to teaching and learning of academic content. Krashen (1996) outlines the advantages and disadvantages of learning content in a language which the learner is already proficient or good at. Limited proficiency in the language of instruction will in most cases be a major impediment to the learning process. Apart from that, advances in the area of neurology and clinical linguistics have given new impetus to research on linguistics factors and learning difficulties.

Cross-References

▶ Approaches to Learning and Studying
▶ Bilingualism and Learning
▶ Language Acquisition and Development
▶ Language and Learning
▶ Linguistic Learning

References

Gardner, R. C. (1983). Learning another language: A true social psychological experiment. *Journal of Language and Social Psychology, 2*, 219–239.

Krashen, S. (1996). *Under attack: The case against bilingual education.* Culver City: Language Education Associates.

Lambert, W. E., & Anisfeld, E. (1969). A note on the relationship of bilingualism and intelligence. *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement, 1*(2), 123–128.

Spolsky, B. (1978). *Educational linguistics.* Rowley: Newbury House.

Stubbs, M. (1986). *Educational linguistics.* Oxford: Basil Blackwell.

Tunmer, W. E., & Hoover, W. A. (1992). Cognitive and linguistic factors in learning to read. Reading acquisition. In P. B. Gough, B. Philip, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 175–214). Hillsdale: Lawrence Erlbaum.

Linguistic Interference

▶ Cross-Linguistic Influence and Transfer of Learning

Linguistic-Based Reasoning

▶ Pragmatic Reasoning Schemas

Linguistics Disabilities and Learning

▶ Linguistic Factors in Learning

Linguistics in Education

▶ Linguistic Factors in Learning

Linked Data and Learning

▶ Semantic Technologies and Learning

Linking Fear Learning to Memory Consolidation

Dong-oh Seo, Marie-H. Monfils
Department of Psychology, The University of Texas at Austin, Austin, TX, USA

Synonyms

Fear memory consolidation; Synaptic consolidation; Systems consolidation

Definition

Memory consolidation is the process by which learned information becomes stabilized into a persistent memory trace. This process takes place across many (if not all) types of memory. The acquisition of fear and its associated neural changes are often studied using a paradigm called Pavlovian fear conditioning. This form of learning is widely acknowledged to depend on, and to modify, the lateral nucleus of the amygdala (LA). When a fear association is acquired, it is initially susceptible to disruption; over time, the memory trace becomes more stable and persists into long-term memory (LTM) via consolidation at the synaptic level. Many different molecular cascades participate in this process, which occurs within the first few hours and lasts several hours to a few days after learning (Rodrigues et al. 2004).

Theoretical Background

The ability for organisms to adapt to ever-changing demands of dynamic environments is important. This is particularly true in fear learning – predicting danger is directly related to one's survival, and efficiently storing information of a fear experience will enable an appropriate response in the face of future threat.

Pavlovian fear conditioning is a very powerful model to understand defensive behaviors. In this paradigm, an initially neutral conditioned stimulus (CS; e.g., a tone) is paired with an aversive unconditioned stimulus (US; e.g., a footshock). Later, the presentation of the CS alone will result in behavioral fear responses such as freezing, enhanced reflex, and hypoalgesia. Well-established evidence indicates that the lateral nucleus of the amygdala (LA) is a key neural substructure involved in processing and storing the association between the CS and US through synaptic plasticity (for review, see Davis 2000).

Initially, CS-US pairings lead to glutamate-dependent excitatory synaptic transmission in LA, which leads to an influx of calcium (Ca^{2+}) in the postsynaptic neuron. After initial acquisition, the newly learned fear memory becomes stabilized into long-term storage through memory consolidation (cellular consolidation). Long-term memory is thought to require synthesis of new proteins, because infusion of RNA- or protein-synthesis inhibitor into the LA after conditioning interferes with long-term, but not short-term, fear memory and expression. The newly synthesized proteins are ultimately involved in maintaining synaptic strength between neurons. Various molecular signaling and cascades participate in this process. The increase in intracellular Ca^{2+} initiated by the coincident occurrence of the CS and US leads to the activation of protein kinases such as protein kinase A (PKA), protein kinase C (PKC), and mitogen-activated protein kinases (MAPK). In turn, these kinases activate gene transcription factors such as cAMP response element binding (CREB), which leads to RNA and protein synthesis. These series of activation based on the kinases are involved exclusively for long-, and not short-term, memory storage. These processes are thus regarded as an initial mechanism for the memory consolidation (for review, see Rodrigues et al. 2004).

Fear memories are very long lasting, and it is unclear, as of yet, what precise mechanisms allow the associated increases in synaptic strength to be persistently maintained. One proposed explanation is that the number of AMPA receptors is increased in existing synapses, which makes the cells more sensitive to depolarization. However, the half-life of the molecules involved in LTM, such as protein kinases, CREB, and receptor proteins, is too short relative to the duration of the memory. Therefore, it has been proposed that changes in synaptic structure might be important for long-term memory maintenance (e.g., the alteration of cellular cytoskeleton elements, and morphological changes in synapses leading to structural remodeling of dendrites and spines). Although we are only beginning to understand what molecular signals are necessary to initiate structural changes associated with fear memory consolidation in LA, recent studies

have suggested candidate molecular pathways. For example, profilin, which has a role of growing actin filament, moves to dendritic spines in LA after conditioning and regulates actin filaments, leading to enlarged postsynaptic densities (PSDs). The RhoGAP/ROCK pathway is also thought to be involving in synaptic remodeling in LA (Rodrigues et al. 2004).

Brain-derived neurotrophic factor (BDNF), a member of the neurotrophin family, is also necessary for long-term fear memory. Recent experiments have shown that BDNF increases in LA during consolidation period, and that preventing the activation of its main receptor (TrkB) interferes with long-term memory. The binding of BDNF to TrkB receptors activates the Ras, Raf, MEK, and MAPK pathway, which could lead to long-lasting morphological changes (Rattiner et al. 2005; also, see Cowansage et al. 2010 for a review). Further investigation is required to reveal precisely how Ras, Raf, MEK, and MAPK signaling impact fear memory consolidation in the LA (e.g., synthesizing new structural protein).

Important Scientific Research and Open Questions

We have focused on cellular consolidation as a consolidation model of fear memory; yet, two different types of memory consolidation have generally been investigated in parallel: cellular (synaptic) and system consolidation. Cellular consolidation is, as we mentioned previously, the process by which memory becomes stable at the molecular level. This process occurs in a local brain area (e.g., amygdala). On the other hand, system consolidation is a process by which information is transported between neural substructures within a memory circuit (Kim and Fanselow 1992; Dudai 2004).

These different points of view are not mutually exclusive, and have each been supported by different learning paradigms/systems. Whereas the majority of consolidation studies have investigated hippocampus-dependent learning paradigms in both the cellular and the system level studies; Pavlovian fear conditioning has mostly focused on cellular mechanisms of consolidation, based on the hypothesis that the amygdala is the storage location of fear memory. A different point of view offers that the amygdala serves to modulate

consolidation memory occurring in other brain regions (McGaugh 2000). The view of amygdala as a modulator has been supported by different types of learning paradigm, such as inhibitory avoidance that are hippocampus dependent. There is currently no evidence suggesting that fear memory in the amygdala transports to the other brain area spontaneously. For this reason, most of the research on Pavlovian fear conditioning has focused on the cellular/molecular view of memory consolidation. Compared to the vast body of work investigating consolidation mechanisms in the hippocampus, the research history in the field of memory consolidation in amygdala is relatively short.

Conventionally, LTM has been defined as memory that exists 24 hours post-learning in the rat, and many studies in the field of memory consolidation use this definition. It could be another question whether the mechanism currently revealed in LTM is necessary or sufficient to maintain memories into many days, weeks, and even years.

Cross-References

▶ Context Fear Learning
▶ Endogenous Opioids in Fear Learning
▶ Fear Conditioning in Animals and Humans
▶ Memory Consolidation and Reconsolidation
▶ Memory Persistence

References

Cowansage, K. K., LeDoux, J. Em., & Monfils, M. H. (2010). Brain-derived neurotrophic factor: a dynamic gatekeeper of neural plasticity. *Current Molecular Pharmacology, 3*(1), 12–29.

Davis, M. (2000). Neurobiology of fear responses: The role of the amygdala. *The Journal of Neuropsychiatry and Clinical Neurosciences, 9*(3), 382–402.

Dudai, Y. (2004). The neurobiology of consolidations, or, how stable is the engram? *Annual Review of Psychology, 55*(1), 51–86.

Kim, J. J., & Fanselow, M. S. (1992). Modality-specific retrograde amnesia of fear. *Science, 256*(5057), 675–677.

McGaugh, J. L. (2000). Memory–a century of consolidation. *Science, 287*(5451), 248–251.

Rattiner, L. M., Davis, M., & Ressler, K. J. (2005). Brain-derived neurotrophic factor in amygdala-dependent learning. *The Neuroscientist, 11*(4), 323–333.

Rodrigues, S. M., Schafe, G. E., & LeDoux, J. E. (2004). Molecular mechanisms underlying emotional learning and memory in the lateral amygdala. *Neuron, 44*(1), 75–91.

List Memory and Change-Detection Memory in Animals

ANTHONY A. WRIGHT
Neurobiology and Anatomy, University of Texas
Medical School at Houston, Houston, TX, USA

Synonyms

Memory for changes in pictures and displays; Memory for serially presented lists; Serial probe recognition memory

Definition

Memory is recollection of past events, remembering facts, skill performance, and learning; memory cannot occur without learning and learning cannot occur without memory.

List memory is memory for a (sequentially presented) series of items, like a misplaced list of foods and household items to purchase at the store.

Change-detection memory is memory for an array (simultaneously presented) of items, like a New York traffic scene where (later) one item changes (stop light from green to red).

Theoretical Background

List memory. Studies of animal list memory have followed those of human list memory. Typical graphs of list-memory results show how memory changes for each position in the list – a serial position function. Often, memory is best at the beginning (primacy effect) and at the end (recency effect) of lists – a U-shaped serial position function. Many theories have attempted to account for the serial position function since list memory was first studied more than 100 years ago. The most persistent theory of the serial position function has been the modal model (Atkinson and Shiffrin 1968) Fig. 1.

The modal model proposed that memory items come into a limited-capacity primary memory store. If they are rehearsed sufficiently they are moved to the more permanent secondary memory store, otherwise they are forgotten. The serial position primacy effect

Schematic of the modal model

Crowder, R. G. (1976). Principles of learning and memory. Hillsdale, NJ: Erlbaum

List Memory and Change-Detection Memory in Animals. Fig. 1 Schematic of the modal model. Crowder (1976)

was thought to be produced by rehearsal because there would be more opportunities to rehearse first list items than last list items. Overt verbal rehearsals tended to support this rehearsal theory as did the disappearance of the recency effect following delays ($\sim$30 s) where distractor activity (e.g., counting backwards) prevented further rehearsal. Studies of animal list memory have focused on these and related issues.

Change-detection memory. Like studies of animal list memory, studies of animal change-detection memory have followed some human change-detection memory studies. Human change detection has focused on fixed-capacity limits for short-term or working memory, similar to the temporary store of the (list memory) modal model. But there are important theoretical and practical differences between list memory and change-detection memory. In change detection, the items are presented simultaneously, whereas in list memory they are presented sequentially. Change detection occupies a comparatively unique role in exploring short-term/working memory. Change detection is different from its obverse – unchanged detection where all objects except one change (Rensink 2002). Change detection is different from the short-lived ($<.5$ s) iconic memory shown in a series of seminal "whole vs. partial report" studies by Sperling (1960). Change detection differs

from memory procedures of matching to sample and same/different conducted with animals and humans. Human visual-search experiments (a matching-to-sample procedure) yield fundamentally different results from change detection (Eng 2005). Change detection requires a temporal transformation; transformation depends upon recognizing that two object arrays (i.e., sample and test arrays; see Fig. 2) are related. Perhaps critical to this concept of transformation is that test objects are presented in the same locations as the sample objects, thereby providing a common context of "location" to identify the item that changed.

Important Scientific Research and Open Questions

Animal list-memory research. Studies of animal list-memory use the human serial probe recognition procedure; stimuli to be remembered are presented one after the other (serial list), followed by a retention delay, and then a single probe or test stimulus. On half of the trials, the test stimulus matches one list item and the other half it matches no list item; subjects make responses (e.g., lever movements, button touches/pecks) to indicate whether the test was in the list or not. Our animal list-memory studies showed, for the first time, primacy and recency serial position effects for a (nonhuman) animal – rhesus monkey (Wright 1998, 2007). These signatures of human list memory

have since been shown for a variety of species (e.g., pigeons, rats, capuchin monkeys, chimpanzees). Animal primacy effects raise the issue of whether rehearsal is a necessary requirement for primacy effects since animals do not have the ability to verbally rehearse their memory of the list items. The opportunity for rehearsal was manipulated by varying the time between list items. When briefly presented memory items were separated by long intervals, human (but not monkey) memory performance was equivalent to memory performance for items that were presented for the entire time. Moreover, when humans were tested with kaleidoscope pictures for which they had no names or labels, then they too showed no positive effect of longer intervals between items and hence no rehearsal, but nevertheless showed a strong primacy effect. When these same humans were trained to name kaleidoscope pictures, they then showed a positive memory effect of longer intervals between items, but the rehearsal affected memory for the middle list items (bottom of U-shaped serial position function) not the primacy effect. Thus, the animal memory experiments helped delimit the role of rehearsal in list memory.

Animal list-memory studies with short (4-item) lists showed that primacy and recency effects may occur at different retention delays. The recency effect appeared alone at very short delays (e.g., 0 s). The primacy effect developed after several seconds of

List Memory and Change-Detection Memory in Animals. Fig. 2 Two change-detection trials

retention delay. This was a new finding; human list-memory studies had used longer lists (e.g., 12–15) and delays necessary for the primacy effect to appear had taken place before list presentation was finished. Changes in the recency effect were opposite; the recency effect was strong initially but dissipated as retention delay progressed. Rhesus monkeys, capuchin monkeys, and pigeons tested with "travel" pictures showed these same changes in their serial position functions. These memory changes with retention delay were not limited to animals; humans tested with lists of four kaleidoscope pictures (to avoid ceiling performances) showed these same serial position function changes. But the time course of changes was longer for humans (∼100 s) than for monkeys (∼30 s) and longer for monkeys than for pigeons (∼10 s). Other rhesus monkeys were tested in auditory list memory showing serial position function changes opposite to those for visual memory.

Training animals in list-memory tasks often requires patience, persistence, and constant adjustment of contingencies and task parameters to achieve the high accuracy levels (>85% correct) required for memory testing. A universal requirement for success is the use of a large number of distinctively different stimuli to reduce proactive interference from previous trials. In list-memory tasks, the test items on half the trials match no list item; but if that test item was a list item in the previous trial, then subjects tend to be confused over whether it was in the list of the current trial and they tend to make more errors.

Open questions: One open question is regarding mechanisms responsible for serial position function changes with retention interval, including passive forgetting (decay) and/or retrieval inhibition among list item memories. Another open question is how far back in time (number of previous trials) can proactive interference adversely affect memory performance. With rhesus monkeys this effect can extend to more than ten, 10-item trials (100 previous list items) – a substantial amount of time. Proactive interference requires remembering the interfering item, and as such is a measure of memory. One can construct a proactive interference function and determine conditions that change it. For example, strategies to combat interference might reduce interference thereby revealing a conjunction of "what" memory (list items) within the "when" memory context (current list). Such conjunctions or "contexts" provide a means to segue from familiarity processing to a more recollective form of memory processing.

Animal change-detection memory. Most animals should be well equipped to perform change detection because it is based on a perceptual change and human research has indicated that verbal memory plays little or no role. We have trained pigeons and rhesus monkeys in change detection with two stimuli; one stimulus changes color and the correct response is a touch/peck to that changed-color stimulus (Wright et al. 2010).

Animals appear to learn change detection most rapidly when they are given single-stimulus pretraining to enhance attention to the color change and when trial events (viewing times, retention delays, intertrial intervals) are variable to enhance vigilance (for the change). Pigeons and monkeys can perform change detection at >90% correct accuracy, transfer to delays >6 s, and transfer to new colors. Monkeys learn a somewhat more general concept of change than pigeons by showing transfer to shape changes and location changes. Nevertheless, we are encouraged that pigeons will show a more general concept of change, similar to that of monkeys, by training pigeons to observe sample displays and not peck the sample objects. Both pigeons and monkeys have shown good performance (>80% correct) with sample displays containing as many as eight colored circles (with two colored circle testing displays, one of changed color).

Open questions: Open questions are differences and similarities across species in their functional relationships for change detection including change detection for different number of display items, different types of items (e.g., polygons, clip art, kaleidoscope pictures), and different retention delays. In addition to object ("what") memory, change detection can be used to study location memory ("where"). "Where" or location memory is often the context for "what" memory or vice versa, but the degree to which these two memory types are conjoined in change detection can be manipulated. The "what" and "where" along with the "when" are components of recollective, episodic-like memory and change detection provides a means to study them in a short-term or working memory task and make direct comparisons across species. Notwithstanding these important comparative memory studies, they provide unparalleled opportunities when combined with new developments in cognitive

neuroscience. Among the most burning questions are different brain areas and circuits that provide the neural foundations for these different types of memory (list memory as well as change-detection memory). Animals will play a critical role in these discoveries because recordings can be conducted from multiple brain areas during memory tasks and brain areas can be manipulated to complement fMRI studies conducted with humans.

Cross-References

▶ Comparative Psychology and Ethology
▶ Context Conditioning
▶ Evolution of Learning
▶ Human Cognitive Architecture
▶ Intelligence, Learning and Neural Plasticity
▶ Learning Object Identification (By Bayes Method)
▶ Learning Strategies
▶ Memory Codes (and Neural Plasticity in Learning)
▶ Memory Consolidation and Reconsolidation
▶ Memory Dynamics
▶ Memory for "What," "Where," and "When" Information in Animals
▶ Memory Persistence
▶ Relational Learning
▶ Sequence Learning
▶ Serial Learning
▶ Serial Processing
▶ Spatial Learning
▶ Temporal Learning in Humans and Other Animals

References

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89–105). New York: Academic.

Crowder, R. G. (1976). *Principles of learning and memory.* Hillsdale: Erlbaum.

Eng, H. Y., Chen, D., & Jiang, Y. (2005). Visual working memory for simple and complex visual stimuli. *Psychonomic Bulletin & Review, 12*, 1127–1133.

Rensink, R. A. (2002). Change detection. *Annual Review of Psychology, 53*, 245–277.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs: General and Applied, 74*(11), 1–29.

Wright, A. A. (1998). Auditory and visual serial position functions obey different laws. *Psychonomic Bulletin & Review, 5*, 564–584.

Wright, A. A. (2007). An experimental analysis of memory processing. *Journal of the Experimental Analysis of Behavior, 88*, 405–433.

Wright, A. A., Katz, J. S., Magnotti, J. F., Elmore, L. C., Babb, S., & Alwin, S. (2010). Testing pigeon memory in a change detection task. *Psychonomic Bulletin & Review, 17*(2), 243–249.

Listening

▶ Communication and Learning in the Context of Instructional Design
▶ Communication Theory

Listening Task Complexity

▶ Effects of Task Difficulty in Listening Comprehension

Literacies

▶ Literacy and Learning

Literacy and Learning

DONALD D. DESHLER, FRANCES IHLE, CARRIE MARK, DANIEL T. POLLITT, MICHAEL J. KENNEDY
Department of Special Education, University of Kansas, Lawrence, KS, USA

Synonyms

Language acquisition; Literacies; Print-based learning; Reading

Definition

Literacy generally refers to the ability to read and write, though numeracy and other skills are sometimes considered part of this construct as well. The capacity to read and write is not innate; humans have invented print systems and, therefore, literacy may be considered

a human *technology*. For this reason, literacy typically does not develop in the absence of formal schooling. In fact, one of the primary purposes of formal schooling is to develop literacy skills among individuals; this frequently occurs by learning and applying a system of print-based rules (e.g., in an alphabetic system, the learner must master the relationship between letters and sounds). Due to the pervasiveness of text in modern society and because written language allows for ideas to be preserved and shared, literacy has significant implications for learning.

Theoretical Background

Great diversity exists among literacy researchers in terms of how they define literacy, the pedagogies they argue should be used to teach literacy, and the significance they attribute to the context in which literacy practices are embedded. Street (1984) has broadly cast these diverse positions into two models. The first theoretical position that Street refers to is called *the autonomous model*. Central to this model is the idea that literacy is a technology, which possesses an exceptional capacity to change human societies and, in fact, is the primary quality that separates so-called developed and underdeveloped nations. According to this model, literate individuals are able to cultivate cognitive abilities, which would otherwise go undeveloped. Unlike ephemeral speech, writing preserves language and allows for reflection that would otherwise be impossible. A writer, unlike a speaker, is not conveying ideas to an immediate listener; rather writing can act *autonomously* of context. It is within this reflective space that human logic is developed. The autonomous model argues that it is this capacity for logic that has enabled the development of today's modern society. Individuals who ascribe to this model propose that literacy is responsible for scientific thought, complex cultural systems (e.g., bureaucracies), and even democratic processes. Typically, pedagogies associated with this theory emphasize the acquisition of print skills through instruction in the rules of the particular print system. Learning, according to this model, is dependent upon mastering basic reading and writing skills. Most government literacy campaigns can reasonably be considered as operating from the *autonomous model*.

In opposition, to the autonomous model, Street identifies a second perspective on literacy – *the ideological model*. Critical to this theoretical position is the notion that literacy practices are always embedded within a larger set of ideologies. In other words, literacy is not elevated as an autonomous technology, which results in advanced forms cognitive processing; rather it is one of many ways to access learning. The ideological model does not position societies along a linear trajectory with "modern" culture in advance of oral traditions and developing nations. Instead, the ideological model accounts for differences between the literacy practices of societies on the basis of social forces. Shifts in the use of language may be initiated by political, economical, or structural conditions within a group of people that serve to change that way in which members of a society communicate. In other words, it cannot be literacy itself that produces change, but rather preexisting social conditions that serve to change the nature of communication within societies. Pedagogies, which are informed by this perspective, emphasize an awareness of larger sociocultural patterns and tend to be more inclusive of practices that are considered part of the literacy construct.

Important Scientific Research and Open Questions

Data from international research efforts have linked literacy skills to a variety of positive outcomes including: personal empowerment, increased access to medical treatments, economic development, increases in civic participation, and improved self-esteem. Most of these data have come from large data collection efforts, as part of census research or self-report surveys. As a result, there is evidence that suggests a relationship exists between literacy and quality of life indicators, but it is not known precisely how literacy results in these outcomes, nor the conditions under which these changes occur. Future research would do much to clarify how literacy learning shifts the ways in which individuals engage in their local environments.

Another area requiring significant investigation is related to what have been called the "new literacies" or "multiliteracies." Within the last few decades, several literacy researchers have argued for a broader view of literacy. Most notably, the New London Group (1996) has suggested that research and practice acknowledge multiple literacies. They argue that individuals "read" the world and make sense of information by means other than traditional reading and writing. These multiliteracies include linguistic, visual,

audio, spatial, and gestural ways of meaning-making (Cazden et al. 1996). Central to the concept of multiliteracies is the belief that individuals in a modern society need to learn how to construct knowledge from multiple sources and modes of representation. Defenders of the "new literacies" are quick to point out that much research still needs to be done to establish new literacy pedagogies, which are aligned with these multimodal ways of creating meaning. Currently, several educational researchers either have proposed or are currently studying the effects of incorporating digital media, hypertext, video games, and touch screen technology into literacy instruction (Jewitt 2008). Other literacy researchers remain skeptical, however, and argue that not enough is understood about multiliteracies to know if traditional reading and writing and new literacies make cognitively equivalent demands on the learner. In fact, some literacy researchers would suggest that the "new literacies" are most accessible to individuals who have already mastered traditional literacy skills. Additional research will be needed to clarify the relationship of traditional literacy learning to the new literacies.

Cross-References

► At-risk Learners
► Content Area Learning
► General Literacy in a Digital World

References

Cazden, C., Cope, B., Fairclough, N., Gee, J., Kalantzis, M., Kress, G., et al. (1996). A pedagogy of multiliteracies: Designing social futures. *Harvard Educational Review, 66*(1), 60–92.

Jewitt, C. (2008). Multimodality and literacy in school classrooms. *Review of Research in Education, 32*(1), 241–267.

Street, B. V. (1984). *Literacy in theory and practice*. Cambridge: Cambridge University Press.

LMS

► Learning Management System

Local Imitation

► Naïve Learning in Networks

Locke, John (1632–1704)

MICHAEL JACKSON
Department of Government and International Relations, University of Sydney, Sydney, NSW, Australia

Life Dates

John Locke (29 August, 1632–28 October, 1704) was born near Bristol in western England, and schooled in Latin at Westminister School and Oxford University, where he remained for some years. He lived in the turbulent times of the English Civil War, the Cromwell Republic and Protectorate, and the Restoration, as well as several foreign wars. At times, Oxford University was in the front lines of these conflicts. A polymath, Locke had a lifelong interest in medicine and introduced himself as "Dr. Locke." He moved to London as a tutor, physician, and advisor to the Earl of Shaftsbury, a statesman of influence, and followed that family into political exile to Holland where he wrote and published many of his most noteworthy books.

Theoretical Background

Three of his many works live on the shelf: *A Letter Concerning Toleration* (1689), *Two Treatises of Government* (1689), and *An Essay Concerning Human Understanding* (1690). In addition, his most important work on education started as letters of advice and became *Some Thoughts Concerning Education* (1690). His entire collected works, published and unpublished, run to nearly 5,000 pages. He was a recurrent and tireless reviser, leaving a thirteenth edition of the *Two Treatises* as a codicil to his will. Religious toleration, limited government, and empiricism were the three constants in his thought. While a student he was described as "man of turbulent spirit, clamorous, and never contented" and so he remained. Accordingly, many critics find these books and others of his works inconsistent, incomplete, and contradictory.

Contribution(s) to the Field of Learning

An Essay Concerning Human Understanding opens with praise for the great scientists of the day, including Isaac Newton, to whom Locke contrasts himself as a modest

under-laborer clearing the brush. Disarming modesty aside, later thinkers have crowned Locke as a founder of empiricism. What is human understanding for Locke? Its essential starting point is that nothing is innate. Whatever we are, whatever we become we learn through experience. We see; we hear; we touch; we smell. He was described as a man who had to see things for himself and – better – to touch them. We start with crude perceptions based on simple and direct sense data. To move from these direct experiences to concepts leads Locke into some technical discussions of perception. Our perceptions do not penetrate to the essence of the external world, but rather receive signals from it.

Locke stressed the great and powerful influence of languages on our minds. The highly charged political world in which he moved was rent by ideological language that led to bloodshed. At other times, fragile religious toleration rested as much on mutual silence as agreement. More often than not, it was best to be careful about what one said. He arrived at the conclusion that we think in words, and by implication, that we cannot think without words. If there is no word for a phenomenon then we can hardly think about it.

Much of our knowledge comes through language. We join together our perceptions with the reports of others, and we generalize from them, sometimes mistakenly. The meanings of words are established by convention and maintained by use. All in all, knowledge is hard to get and difficult to test. Consequently, the best approach is careful, limited, tentative, and liable to correction. *An Essay* ends with a stress on our ignorance.

Born blank like white paper, we are written into existence by perceptions and experience. Though he does not use the term *Tabula rasa*, it has since been applied to his theory. If so, then systematic education is crucial. Guiding the perceptions and experience of children from the very first is the best way to bring them up. Association is one of the most important ways children learn. In this way, we form constructive habits and screen out destructive influences. The babe in arms carried to church services to hear the uplifting emotion of hymns will learn to love God. Character is built not inherited with a title. That experience forms character inspired many subsequent reformers to change social conditions to improve humanity. If criminals are made by social conditions, then they can be reformed through changed social conditions, went the argument.

Some Thoughts Concerning Education focuses on the upbringing of a gentleman, and has a contemporary ring to it. Locke wanted children to be treated as children, not as small, uncomprehending adults. He recommended repeatedly that learning, be it Latin or geometry, be made fun. He preached positive reinforcement, long before B. F. Skinner, and inveighed at length against the common practice of corporal punishment, which had been applied to him as a schoolboy. The curriculum he proposed was lengthy, including geography, arithmetic, astronomy, chronology, history, rhetoric, logic, and natural philosophy. To which he added music, fencing, painting, and gardening. This program anticipated much of what became the broad education first for gentlemen and then the upper classes more generally in Great Britain. He himself practiced and recommended a form of shorthand for note-taking. At the end of *Thoughts* he suggested travel to broaden the mind.

It has been said that Locke's greatest contribution to knowledge in *An Essay* was in the identification of crucial questions more than in the answer he gave to them. For instance, how do we link perceptions under concepts? Does perception depend on agreement? What do we perceive? What is the relationship, if any, between a word and the phenomenon it names? His persistent revision of his own works suggests the tentative nature of knowledge. The emphasis on epistemology in *An Essay* anticipates the research program of both English analytic philosophy and continental post-modernism. Jean-Jacques Rousseau was much influenced by Locke.

Cross-References

▶ Associationism
▶ Plato (429–347 BC)
▶ Rousseau, Jean-Jacques (1712–1778)

References

Chappell, V. (Ed.). (1994). *The Cambridge companion to Locke*. Cambridge: Cambridge University Press.

Cranston, M. (1957). *John Locke: A biography*. London: Longmans.

Locke, J. (1968). *The educational writings*. Cambridge: Cambridge University Press.

Newman, L. (Ed.). (2007). *The Cambridge companion to Locke's "essay concerning human understanding"*. Cambridge: Cambridge University Press.

Yolton, J. (Ed.). (1997). *Collected works of John Locke*. London: Taylor & Francis.

Locus of Control

Locus of control is the framework of Rotter's (1954) social learning theory of personality. It refers to the extent to which individuals believe that they can control events that affect them. A basic distinction has been made between internal and external locus of control.

Cross-References

► Attribution Theory of Motivation

References

Rotter, J. B. (1954). *Social learning and clinical psychology.* New York: Prentice-Hall.

Locus of Instructional Control

► Learner Control

Logical Argument

► Argumentation and Learning in Science Education

Logical Reasoning

► Conditional Reasoning by Nonhuman Animals

Logical Reasoning and Learning

Terezinha Nunes
Department of Education, University of Oxford, Oxford, Oxfordshire, UK

Synonyms

Logical thinking

Definition

Logical reasoning is a form of thinking in which premises and relations between premises are used in a rigorous manner to infer conclusions that are entailed (or implied) by the premises and the relations. Different forms of logical reasoning are recognized in philosophy of science and artificial intelligence. *Deductive reasoning*, considered typical of mathematics, starts with premises and relations, which lead to a conclusion. For example, if A = B and B = C (the premises), the inevitable conclusion is that A = C because equality is a transitive relation. Note that if A $\neq$ B and B $\neq$ C, it is not possible to draw the conclusion that A $\neq$ C because inequality is not a transitive relation. *Inductive reasoning*, necessary in empirical sciences, uses observations to arrive at premises as well as relations between premises, which are then used to arrive at conclusions. Inductive reasoning cannot convey the certainty of deductive reasoning: Even if the patterns of observations that led to the premises are true, inductive reasoning carries the uncertainty of going from a limited number of observations, however large, to a general premise. Induction was considered by the British philosopher John Stuart Mill (1806–1873) as a necessary practice in the search for knowledge, though fallible. Neyman (1957) prefers to use the term "inductive behavior" rather than "reasoning" to convey the idea that, when scientists use induction, they decide to take a "calculated risk" and "to behave in the future (perhaps until new experiments are performed) in a particular manner, conforming with the outcome of the experiment." *Abductive reasoning* starts from consequences and relations and seeks to identify a premise from which the consequence could be derived. Similarly to inductive reasoning, abductive reasoning involves inferences that are uncertain, and proceeds by attempts to eliminate alternative explanations that could lead to the same consequence. The reasoning used in diagnoses is seen as a typical example of abductive reasoning: A symptom, such as nausea, could result from a variety of causes, so in the diagnostic process a pattern is sought to describe the nausea (e.g., Is it constant or dependent on circumstances? Which circumstances favor its appearance? Which treatments are effective and for how long?) in order to identify the premise that explains its emergence. Although these three forms of reasoning differ, they have in common the use of premises and relations used to make inferences in a norm-governed way. Inductive and abductive reasoning do not convey the certainty of deductive reasoning but they are

a norm-governed practice to the extent that inter-subjective agreement can be reached concerning the application of the relevant norms. This distinguishes reasoning from beliefs, intentions, and behavior resulting from emotions or instinct.

Theoretical Background

Learning involves a (conscious or implicit) reading of the person's own experience, so it might be asked in what ways logical reasoning participates in this reading of the person's experience. The answer to this question was the same in two rather different approaches to learning, behaviorist learning theories (proposed by Watson, Thorndike, and Skinner, for example) and Gestalt psychology (proposed by Wertheimer, Köhler, and Duncker). Logical reasoning played no role in behaviorist learning theories because learning was conceived as the non-mediated connection between a stimulus and a response. The S-R schema was either the result of an association between a stimulus and biologically established connection, in classical conditioning, or the result of reinforcement of a behavior in the presence of a stimulus, in operant conditioning. Gestalt psychology conceived of two ways in which behavior changed through experience: through trial and error, which was seen as unintelligent, random behavior selected for repetition by its consequences, and through insights, which were sudden changes in the way a person saw the situation, resulting from brain functions that regulated perception. Perception was seen as holistic and the brain automatically produced a restructuring of how a situation was perceived after exposure to different perspectives of the situation. In these theories, logical reasoning did not play a role in learning.

Two psychologists, William James (1842–1910) and Alfred Binet (1857–1911), challenged these conceptions of irrational learning. William James in his "Principles of Psychology" (1890) broke the rigidity of the S-R schema, when he described a person's ability to select means that are appropriate to ends as the hallmark of intelligence. Thus a response in a learning experience was no longer seen as a result of a non-mediated bond to the stimulus but as mediated by the person's intelligent goal-directed behavior. Alfred Binet, in an article about the amendment of visual illusions, argued that reasoning opposes simple perception when people are able to recognize, by means of

measurement operations, that a visual illusion is an illusion, even though the perception has not changed. If two same-sized circles A and B are surrounded by circles of different sizes, the one which is surrounded by smaller circles is seen as larger than the second, surrounded by larger circles. If A and B are measured or compared directly by superposition, it is possible to know that they are the same size, although they are still perceived as different. Binet attributes this ability to amend illusions ultimately to the use of the Aristotelian logical principle of noncontradiction: The two circles cannot be at the same time of the same and of different sizes. Binet's interest in logical reasoning also led him to study children's understanding of transitive relations, of the sort if $A > B$ and $B > C$, then $A > C$.

These early theoretical developments in psychology placed intelligence and reasoning at the center of problem solving and learning.

Important Scientific Research and Open Questions

Among the earliest studies of the relationship between logical reasoning and learning is a study by Piaget and Gréco (1959), which addressed the connection between logical reasoning and learning in the context of children's understanding of relations in space. If a rod with three tacks, each of a different color (say black, white, and red), is inserted into an opaque tube and drawn from the other side, the order of appearance of the tacks can be predicted, even though the movement of the rod inside the tube cannot be seen. The order of appearance of the tacks is the same in which they went in. If the tube is rotated 180°, the order in which the tacks emerge from the tube is inverted. If two rotations of 180° are performed, the order of appearance of the tacks is not inverted, because one rotation cancels out the other. Thus the results of these different events, distinguished by the number of 180° rotations (from 0 to 2), are not always the same.

Piaget and Gréco suggested that learning to predict the outcomes of such events is not a simple reading of the experience; if a child observes 0–2 rotations and is asked to predict the result of three rotations, the child cannot make the prediction from readings of previous experience. Correct predictions must be based on logical inferences regarding the conditions under which the different outcomes, direct or inverse order, take place. When children draw inferences about the

outcomes from their understanding of relations in space, the predictions that they make have the certainty of deduction. When the children simply try to memorize the events and their outcomes from a set of observations, they do not attribute certainty to their predictions and sometimes offer interpretations that are supported by imagination rather than deduction. One child for example, who predicted that the order of appearance would be the same order of entrance after a 180° rotation and observed the inverse order, suggested that the object that came out first was faster than the others and overtook them while inside the tube, overlooking the fact that the tacks were pinned on the rod and did not have independent movement.

Piaget and Gréco noted the role of logic in learning to predict the outcomes of these events in two ways. First, the children who started the experiment with a better understanding of relations in space were more successful in achieving systematically correct predictions; thus, the children's initial level of reasoning was an important condition for learning. Second, they noted that some conditions of learning afforded the construction of a system of relations in space better than others; during the learning phase, the children who represented the changes of positions of the tacks through drawings after 0–2 rotations of the tube, were successful in learning how to make predictions. The measure of success was not the speed in decline of number of errors but the children's success in making correct predictions for events that they had not observed: for example, predictions for the outcome of three rotations of 180° after they had observed events with 0–2 successive rotations. The more successful teaching condition was one in which the order of events (defined in terms of number of 180° rotations, from 0 to 2) was entirely random, and thus did not favor attempts to solve the task by memorizing the outcome of each event.

The role of logical reasoning in learning has also been explored in other domains and using rather different research methods. In mathematics learning, there has been great interest in knowing whether knowledge of numbers or logical mathematical reasoning is more important for learning mathematics. When children solve at least some mathematical problems, logical mathematical reasoning may be crucial. If a problem is about an addition story (e.g., "Joe brought some marbles to school and won four in a game during play break. At the end of the day he had seven marbles. How many did he start the day with?") but the easiest way to solve it is by subtraction, the children are more likely to succeed if they understand the inverse relation between addition and subtraction. Nunes et al. (2007) used a longitudinal study to test the role of logical mathematical reasoning in mathematics learning. They assessed children's knowledge of numbers as well their logical mathematical reasoning when the children were in their first year in school. The assessment of knowledge of numbers included the children's ability to read and write numbers and knowledge of number facts. The children's logical mathematical reasoning included questions about the inverse relation between addition and subtraction as well as other aspects (e.g., the children's ability to make inferences using one-to-one and one-to-many correspondences). The children's mathematical learning was assessed completely independently of the researchers by means of state-designed tests delivered by the schools when the children were in the second year of school, approximately 14 months after they had been assessed by the researchers. Using regression analyses, Nunes et al. (2007) showed that the measures of the children's mathematical reasoning and of their knowledge of numbers made separate contributions to the prediction of their mathematical achievement; the contribution of reasoning was the more important of the two.

There is still ongoing discussion of the role of reasoning in learning and in action in general. In the domain of number, for example, there are three alternative theories about how children come to understand cardinal and ordinal numbers. Gelman and Gallistel (1978) and Dehaene (1992) favor a neurological view, which places the meaning of numbers in the coordination of innate perceptual systems of numerosity and innate counting systems and therefore does not involve logical reasoning. Carey (2004) attempts to explain children's knowledge of ordinal numbers as the result of induction, based on perceptual discriminations of 1, 2, and 3 objects, and learning that the count words one, two, and three follow each other in this fixed order. From these two, unrelated facts, they form the rule that each number in a counting sequence is one more than the previous number. Piaget (1952) and other contemporary researchers, such as the French psychologist Gérard Vergnaud (2009), propose that the origin

of children's understanding of number is in their schemes of action and the understanding of the logic of quantities.

Cross-References

References

Carey, S. (2004). Bootstrapping and the origins of concepts. *Daedalus, 133*, 59–68.

Dehaene, S. (1992). Varieties of numerical abilities. *Cognition, 44*, 1–42.

Gelman, R., & Gallistel, C. R. (1978). *The child's understanding of number*. Cambridge, MA: Harvard University Press.

Neyman, J. (1957). "Inductive behavior" as a basic concept of philosophy of science. *Revue de l'Institut International de Statistique/Review of the International Statistical Institute, 25*, 7–22.

Nunes, T., Bryant, P., Evans, D., Bell, D., Gardner, S., Gardner, A., et al. (2007). The contribution of logical reasoning to the learning of mathematics in primary school. *British Journal of Developmental Psychology, 25*, 147–166.

Piaget, J. (1952). *The child's conception of number*. London: Routledge & Kegan Paul.

Piaget, J., & Gréco, P. (1959). *Apprentissage et connaissance*. Paris: Presses Universitaires de France.

Vergnaud, G. (2009). The theory of conceptual fields. *Human Development, 52*, 83–94.

Logical Thinking

Logic-Based Reasoning

Logic-Based Relational Machine Learning

Long-Distance Dependencies

Longitudinal Learning Research on Changes in Learning of University Students

BEVERLEY JACKLING
School of Accounting and Finance, Victoria University, Melbourne, VIC, Australia

Synonyms

Cross-sectional research; Crosswise research; Lengthwise research; Longitudinal research

Definitions

Longitudinal research: Longitudinal research is research in which data are collected for each item or variable for two or more distinct time periods and the subjects or cases analyzed are the same or at least comparable from one period to the next and the analysis involves comparison of data between or among periods (Menard 1991).

Measurement of Change: Longitudinal studies typically measure change over time, in a variety of forms, including differences in perceptions, processes, and events. *Longitudinal quantitative data analysis* is typically viewed as numerical data representing various types of change over time.

Longitudinal qualitative data analysis includes a range of techniques that may include case studies, interviews, focus groups, and archival work that is conducted over a period of time.

Change through time may involve qualitative data being examined chronologically, categorically, and thematically in a longitudinal study.

Theoretical Background

Longitudinal data have been collected over many centuries but only more recently has the use of longitudinal research methods become popular in education research. ▶ Longitudinal research has become increasingly valued because it has been professed to be a means of measuring change and making strong causal interpretations. For example, studies linked to learning have been viewed as having the potential to inform educators using both ▶ longitudinal quantitative data analysis and longitudinal ▶ qualitative data analysis techniques. While longitudinal research is more frequently linked with quantitative data analysis, Saldana (2003) discusses qualitative approaches for seeking, identifying, and describing the qualitative dynamics of the processes associated with longitudinal studies of change through time. The seminal work of Miles and Huberman (1994) provides a number of techniques that bring together both quantitative and qualitative methodologies that are useful to researchers combining both research methods. In the next section, longitudinal studies are illustrated by reference to the literature around approaches to learning. In this educational research context, the use of longitudinal research methods demonstrates how students respond to teaching and learning practices and interventions in different units/courses of study over time.

Important Scientific Research and Open Questions

There is some suggestion that approaches to learning change over the duration of a university course of study. In some instances, the differences have been attributed to the characteristics of the individual (personological factors such as student sex, age, prior experiences, and intrinsic motivation) and in other instances have related to contextual factors identified with perceptions of the requirements of and responses to the learning environment.

Studies using longitudinal studies have more recently shown an increase in meaningful and deep approaches to learning linked to the context of learning. As students progress through their university studies and perceive that the teaching is good and perceive that the workload is appropriate they are more likely to adopt deep approach to learning (e.g., Jackling 2005).

The relationship between changes in learning approach over time and the nature of the learning context (in the form of teaching and learning environment) have been a feature of numerous studies. There is some evidence that suggests students use a deep approach to learning in the first year of their university studies, while in the final year they are more inclined to use a surface approach to avoid "hard" thinking. More specifically, some early research found that students responded to the learning environment in such a way that they increased their "course-wiseness" by reproducing what they perceived the examiner wanted or was likely to accept. Some longitudinal studies show that students are more inclined to use a surface approach to learning as they progress through their university studies.

Longitudinal studies in various discipline areas have, however, produced mixed results in terms of attempts to understand approaches to learning over the duration of a university course of study. For example, a longitudinal study of science students found that the university experience did not encourage students to engage in deep approaches to learning. The study supported the view that student perceptions of the study tasks, workload, and assessment procedures have an impact on the general approach to study in terms of the study strategies adopted.

Studies of the teaching methods used in medical school courses have highlighted the impact different teaching methods have on the stability of learning approaches over time. For example, Newble and Clarke (1986) demonstrated that a deep approach to learning has been shown to typically decline in a traditional medical school course, but increase in a medical school using a problem-based teaching approach. This type of finding supports the view that there can be an institutional and or departmental contextual effect on student learning. Additionally, different types of teaching may produce differences in learning approaches over time.

Learning approaches may change during a university course of study due not only to the nature of the discipline but also the students' perceptions of the learning context. For example, teaching and assessment in differing units throughout an undergraduate degree may result in varying degrees of emphasis in deep and surface approaches to learning. Assessment can be a powerful force in influencing the learning approach adopted by students. Prior research (Entwisle and Ramsden 1983) suggests that subject units within an

undergraduate degree that were perceived to have excessive assessment and syllabus demands would, by their nature, encourage students to adopt surface approaches to their learning.

The stability of the learning approach of students may be disturbed both by changes in the levels of student motivation and the effect of changes in the context of the learning environment, specifically related to the task demands of course work. The impact of the context of learning on changes in learning approaches over time is addressed below.

The task demands have been identified with both the departmental policies within universities and student perceptions of different course requirements in units of study. For example, learning approaches may be influenced by the effects of teaching at both an individual lecturer level and at a more general course level.

Longitudinal research of learning has been particularly important in studies that have addressed the impact of interventions to foster deep approaches to learning. For example, English et al. (2004) aimed to establish the effectiveness of a series of interventions designed to facilitate the development of critical thinking and writing skills, while at the same time encouraging a deep approach to learning.

The results showed that when compared at the beginning and end of the first year course, students exposed to the intervention scored significantly higher on deep approaches to learning than students attending classes where the intervention was not administered. Similarly, in the business discipline area, Hall et al. (2003) reported on an intervention centered on the introduction of group learning activities designed to improve the quality of students' learning outcomes. They reported a statistically significant increase in deep approach attributed to the group learning intervention. In contrast, Ballantine et al. (2008) undertook a longitudinal study which aimed to encourage a deep approach to learning over the duration of a unit of study at university. In this instance, the intervention was the use of case studies method designed to foster a deep approach to learning. However, the study reported a statistically significant increase in the surface approach to learning contrary to the aims of the intervention. The authors suggest that this finding may serve to demonstrate that by the final year of university study students' approaches to learning may be "less

dynamic and amenable to change." This is consistent with the early research that suggests that students may become "course-wise" as they progress through their university studies.

The above examples of interventions in the learning situation demonstrate that longitudinal research methods can have an important role to play in improving the quality of learning in the university setting. Longitudinal research although having some distinct advantages as a research method, has offsetting costs and difficulties. For example, panel attrition is typically a problem for longitudinal studies where a study attempts to collect data from the same group of respondents over time. Individuals who are no longer part of the study may differ systematically from the rest of the population. Similarly, the effect of panel conditioning can be problematic in longitudinal studies particularly where repeated testing may encounter problems of recall by respondents. Additionally, repeated cross-sectional designs may encounter problems where there are relatively minor differences in sampling procedures that may present serious problems for replication. In summary, longitudinal research may be expensive for researchers given the time commitment and the intensity required in following up on respondents. These costs need to be addressed in light of the distinct benefits that longitudinal research offers as a means of academic inquiry.

Cross-References

▶ Assessment in Learning
▶ Complex Learning
▶ Deep Approaches to Learning in Higher Education
▶ Independent Learning
▶ Learning Criteria, Learning Outcomes and Assessment Criteria
▶ Learning Environments
▶ Learning Strategies
▶ Perceptions of the Learning Context and Learning Outcomes
▶ Problem-Based Learning
▶ Qualitative Learning Research

References

Ballantine, J. A., Duff, A., & Larres, P. (2008). Accounting and business students' approaches to learning: A longitudinal study. *Journal of Accounting Education, 26*, 188–201.

L

English, L., Luckett, P. Mladenovic, R. (2004). Encouraging a deep approach to learning through curriculum design. *Accounting Education: an International Journal 13*(4), 461–487.

Entwisle, N., & Ramsden, P. (1983). *Understanding student learning.* London: Croom Helm.

Hall, M., Ramsay, A., & Raven, J. (2003). *Changing the learning environment to promote deep learning approaches in first year accounting students.* Paper presented at the Discipline of Accounting and Business Law Seminar Series, University of Sydney, Sydney.

Jackling, B. (2005). Analysis of the learning context, perceptions of the learning environment and approaches to learning accounting: A longitudinal study. *Accounting & Finance, 45*(4), 597–612.

Menard, S. (1991). *Longitudinal research series: Quantitative applications in the social sciences, 76.* Newbury Park: Sage.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis*, (2nd ed.). Thousand Oaks, CA: Sage Publications.

Newble, D. I., & Clarke, R. M. (1986). The approaches to learning of students in a traditional and in an innovative problem based medical school. *Medical Education, 20*, 267–273.

Ramsden, P. (2003). *Learning to teach in higher education* (2nd ed.). London/New York: Routledge Falmer.

Saldana, J. (2003). *Longitudinal qualitative research: Analyzing change through time.* Walnut Creek: AltaMira.

Longitudinal Research

▶ Longitudinal Learning Research on Changes in Learning of University Students

Long-Term Depression

A decrease in the efficiency of synaptic communication resulting from a number of factors including, for example, uncorrelated pre- and postsynaptic stimulation. In some cases, the absence of a neurotransmitter is also sufficient. For example, long-term depression in the basal ganglia is observed in the presence of repeated stimulation of a postsynaptic neuron by a presynaptic neuron if the neurotransmitter dopamine is absent.

Long-Term Expertise Development

▶ Long-Term Learning in Soar

Long-Term Expertise Development in Complex Domains and Individual Differences

ROBERT W. HOWARD
School of Education, University of New South Wales, Sydney, Australia

Synonyms

Long-term skill learning

Definition

Different learners typically acquire ▶ expertise at different rates and may reach quite different asymptotic performance levels. Complex knowledge domains are those which may greatly tax working memory and attention, examples being high-level chess play and scientific research. Various patterns of performance differences between individuals may occur over extended periods of time and/or practice in such domains. For instance, extended training may magnify individual differences in performance. One obtained pattern of individual differences consists of relatively small initial performance differences which progressively widen and then stay large and constant.

Figure 1 gives an example from international chess. This domain is often used to study expertise development because it has longitudinal performance data, no glass ceiling, and has a numerical performance rating system with skill measured on a scale running from about 1200 to 3000 (Howard 2009). The figure compares players in the international domain for at least 20 years who played at least 750 rated games by July 2010. It compares players who eventually made the top ten in the rating list (n = 10), other grandmasters who had never reached the top ten by July 2010 (n = 183), and non-grandmasters (n = 164). Point 1 gives their mean performance rating at domain entry, point 2 on the next list 6 months later, and so on. Differences between all pairs of groups are relatively small at domain entry, progressively widen over time, reach approximate asymptote, and then remain large and roughly constant.

Baltes and Kliegl (1992) found an analogous pattern when comparing word recall of younger and older

Long-Term Expertise Development in Complex Domains and Individual Differences. Fig. 1 Illustration of individual differences in chess expertise development over 20 years from entry into the international domain at point 1. The pattern is relatively small initial group differences which progressively widen and then stay large and constant. Even after 20 years, the non-grandmasters have not reached the performance level at which eventual top ten players started

participants after extensive practice in use of a mnemonic device – the Method of Loci. Differences in number of words recalled between younger and older groups were small initially but then widened. In mathematics learning, as the difficulty of the material increases, initial differences in the skill of performing calculations may widen as material becomes progressively more difficult to understand (Ackerman 2007). In scientific research, there is anecdotal evidence that productivity differences occurring at career start between eventual top performers and other scientists may progressively widen and then remain large and constant.

In less complex domains which make lesser demands on working memory and attention, different patterns of individual differences may occur. Initial wide performance differences may diminish with time and practice as skill components are automated and the demands on working memory and attention lessen even further. This pattern is well known in job performance. IQ score is a good predictor of performance mainly in the early stages of job performance. Differences between individuals then may be sizeable but as training progresses and tacit knowledge increases, performance differences may start to converge.

Theoretical Background

What causes these individual differences in performance? Researchers have long considered that differences in partly innate psychometric abilities such as general intelligence and visuospatial ability are largely responsible. Francis Galton in 1869 held that innate talent differences affect expertise development and constrain ultimate performance level. Galton argued that training can only improve performance to a particular level set by ability and then "*level of maximum performance becomes a rigidly determinant quantity; there is an immutable limit on performance where he cannot by any education or exertion overpass*".

Charles Spearman in 1904 proposed the existence of a general factor of intelligence (denoted g), which aids performance in all intellectual tasks. It should therefore be a factor in creating individual differences in expertise development in complex intellectual domains. Individuals with higher IQ scores, IQ being a measure of g, should acquire expertise faster and more readily, and should reach higher ultimate performance levels. Indeed, research suggests that IQ score is the best single predictor of performance in the workplace and on various intellectual tasks (Gottfredson 1997), at least initially.

However, around 1990, some researchers argued for an opposing view. They argued that high-level performance in intellectual domains reflects only extensive and/or appropriate practice (Ericsson 2006). Top performers do not necessarily have higher IQ scores or other abilities, they just had more practice, and almost any individual can reach elite performance levels by starting early enough and practicing extensively

(Ericsson 2006). The theory now most associated with this view, expert performance theory, has been applied in several domains.

Important Scientific Research and Open Questions

Several important issues concern researchers. These issues have proved difficult to resolve empirically because controlled experiments studying expertise development over more than a few hours or days of practice can be impractical, and researchers often must use the vocational and sports domains and correlational studies. Then, practice and performance levels can be difficult to measure, and dropouts and gatekeeper influences can make results more difficult to interpret. A common methodological problem of some studies is that participants with widely varying degrees of training are compared and the results may be hard to interpret. Ideally, participants in any study of individual differences should be compared only at performance asymptotes.

One particularly controversial issue concerns the existence of and importance of "innate talent" in developing expertise in a given domain, related to the ability issue mentioned above. Simonton (2008) defined innate talent as any feature of natural endowment that has one or both of the following effects. First, talent enhances training by allowing a talented person to attain a higher level of expertise for a given unit of training or by allowing mastery of the skill in less training time than average. Second, talent enhances performance. Talented individuals with a given amount of accumulated practice will exhibit a higher level of output than the less talented with the same level of accumulated practice. Natural talent in a given domain might consist of several ability and personality factors. Simonton (2008, p. 31), discussing possible natural talent for scientific research, noted: "It is extremely unlikely that endowment constitutes a homogeneous psychological capacity . . .. Instead the natural endowment most likely consists of a weighted composite of numerous and highly specific intellectual and personality characteristics."

Expert performance theory holds that practice alone is crucial, or at least that evidence for the value of natural talent in complex domains such as chess is lacking. Certainly extensive practice can greatly improve performance but whether practice alone is the key factor in expertise development is unclear.

Most supporting studies for this view are correlational. Howard (2009) instead found much indirect evidence for the existence of a natural talent factor for chess, which constrained ultimate performance level.

Another issue concerns the relative importance of different types of practice in expertise development. Traditional skills researchers defined "practice" as actually performing a task – batting a ball, playing chess, or carrying out scientific research. It is a truism that people learn best by doing. Expert performance theory holds that "deliberate practice" is the main determinant of expertise level. Deliberate practice can be defined as a training activity aimed at reaching a level just beyond the currently attainable level of performance by engaging in full concentration, analysis after feedback, and repetitions with refinement. An example might be practicing a tennis serve on the court repeatedly, and getting feedback on performance from coaches and a video setup. Deliberate practice is distinguished from competition (competing in the Olympics) and from play (playing offhand chess for fun).

But exactly what activities constitute deliberate practice in complex intellectual domains such as chess is unclear. Furthermore, deliberate practice may be less important in complex domains with continual demands on working memory and attention (Howard 2009).

Another important issue is what precise form expertise development over time and practice takes and how the form might be affected by various variables. The power law of practice holds that the relationship between performance and amount of practice follows a power function. Improvement is most rapid in the early stages of training and then improvements progressively diminish as performance approaches asymptote. A power function implies a learning process in which some mechanism is slowing down the rate of learning, that learners eventually approach performance levels which they cannot get beyond. The curves for top ten players and other grandmasters in Fig. 1 are good fits to power and logarithmic functions. But some researchers have suggested repealing the power law, proposing that a better fit is an exponential function.

Cross-References

▶ Ability Determinants of Complex Skill Acquisition
▶ Expertise
▶ Expertise and Learning
▶ Individual Differences and Learning

References

Ackerman, P. L. (2007). New developments in understanding skilled performance. *Current Directions in Psychological Science, 16*, 235–239.

Baltes, P. B., & Kliegl, R. (1992). Further testing of limits of cognitive plasticity: Negative age differences in a mnemonic skill are robust. *Developmental Psychology, 28*, 121–125.

Ericsson, K. A. (2006). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 683–703). New York: Cambridge University Press.

Gottfredson, L. S. (1997). Why g matters: The complexity of everyday life. *Intelligence, 24*, 79–132.

Howard, R. W. (2009). Individual differences in expertise development over decades in a complex intellectual domain. *Memory & Cognition, 37*, 194–209.

Simonton, D. K. (2008). Scientific talent, training and performance: Intellect, personality, and genetic endowment. *Review of General Psychology, 12*, 28–46.

Long-Term Learning in Soar

William G. Kennedy
Krasnow Institute for Advanced Study, George Mason University, Fairfax, VA, USA

Synonyms

Expertise; Expertise development; Long-term expertise development

Definition

Long-term learning in Soar is the process of accumulating procedural knowledge throughout the existence of an intelligent, learning agent. In Soar, such knowledge is in the form of IF-THEN productions, or rules, called "chunks." The learned chunks are new rules capturing the results of resolving obstacles in the reasoning process. This long-term knowledge is maintained by the system with the expectation that it will be useful during the existence of the agent. Declarative memory is not part of Soar's long-term memory.

Theoretical Background

Allen Newell, through his book, "Unified Theories of Cognition" (Newell 1990), proposed many partial theories of cognition, both abstract and human, and offered the Soar architecture as a candidate-unified theory of cognition. He defined a unified theory of cognition as "a single set of mechanisms for all of cognitive behavior." Three parts of his theory are applicable to long-term learning in Soar: symbols, memory, and learning. First, Newell, with Herbert A. Simon, theorized that humans were symbol-processing systems and that symbols were representations of knowledge that are useful in the process of storing and retrieving that knowledge. Next, the consensus was and still is that there are two separable kinds of memory. The first is declarative memory, which is the collection of the facts including processing status used in problem solving. The collection of this information forms the working memory of the system and Newell proposed this knowledge was the system's short-term memory. The other accepted form of memory is procedural memory, which is made up of the IF-THEN rules or productions that use the declarative knowledge to develop additional declarative knowledge and to take actions to solve the overall problem. Then, as part of the theoretical basis of Soar, Newell proposed that long-term procedural memory could be considered as a single production system. Although he acknowledged that episodic and semantic memories were the next most commonly proposed separate memory structures, he proposed "trying to live with" the single representational system.

Newell also proposed one form of learning, called chunking. The implications of the chunking theory of learning were twofold. The Soar qualitative theory of learning included the premise that learning occurs at an approximately constant rate and that the productions, which make up the long-term memory, are maintained permanently. He proposed no mechanism to remove learned knowledge, i.e., forgetting. Therefore, Soar, as a unified theory of cognition, includes a monotonically increasing long-term memory associated with its constant learning process, when learning employed. However, many models using Soar do not employ learning and meet their performance goals using only productions that are initially loaded into the system.

Constantly increasing long-term memory results in performance problems, both theoretical and practical, and there are other important research questions. For practical purposes, the most common

approach by Soar users is to pre-load the system with all the rules necessary to solve the intended scope of presented problems and to not have the agent learn at all.

Important Scientific Research and Open Questions

Long-term learning in Soar, as well as other symbolic learning and monotonically increasing systems, led to performance problems associated with the maintenance, retrieval, and use of the knowledge. This situation was identified as the "utility problem" (Minton 1990). Approaches to address this problem initially include restricting or stopping the learning process and improving the matching of current conditions to memory. They proved to be somewhat successful, but did not resolve the theoretical basis of the problem. Even restricting the expressiveness of the rule language was not successful because it necessitated a large increase in the number of rules necessary to represent the same amount of knowledge (Tambe et al. 1990). Another approach is to begin with learning but to later stop learning. The conditions for which this approach is appropriate have not been explored for the Soar system specifically. Improvements in the matching process have extended practical performance of Soar to beyond 100,000 rules (Doorenbos 1993), but because there is still growth in the match costs with additional chunks, it does not resolve the theoretical side of the problem.

Removal of previously learned knowledge, i.e., forgetting, appears to be necessary to address the theoretical basis of the utility problem. Forgetting based on the lack of recent use has been explored in Soar (Kennedy and De Jong 2003) and in both Soar and ACT-R, the other important cognitive architecture (Kennedy and Trafton 2007). Forgetting based on other characteristics of the long-term memory, the agent's goals, or environment, have yet to be explored.

The Soar system continues to be the basis of active research and to be a widely applicable real-world problem. Recent activities have added episodic, semantic, and spatial memories to its architecture (Laird 2008). What the long-term effects are on the theoretical and practical performance of long-term learning in Soar with these new forms of long-term memory are open research questions.

Cross-References

▶ Chunking Mechanisms and Learning
▶ Learning by Chunking
▶ Matching

References

Doorenbos, R. (1993). Matching 100,000 learned rules. *Proceedings of the eleventh national conference on artificial intelligence* (pp. 290–296). Menlo Park, CA: AAAI Press.

Kennedy, W. G., & De Jong, K. A. (2003) Characteristics of long-term learning in soar and its application to the utility problem. *Proceedings of the twentieth international conference on machine learning* (pp. 337–344). Menlo Park, CA: AAAI Press.

Kennedy, W. G., & Trafton, J. G. (2007). Long-term symbolic learning. *Cognitive Systems Research, 8*, 237–247.

Laird, J. E. (2008) Extending the soar cognitive architecture. In *Artificial general intelligence 2008: Proceedings of the first AIG conference*. Memphis, TN: ISO Press.

Minton, S. (1990). Quantitative results concerning the utility of explanation-based learning. *Artificial Intelligence, 42*, 363–391.

Newell, A. (1990). *Unified theories of cognition.* Cambridge, MA: Harvard University Press.

Tambe, M., Newell, A., & Rosenbloom, P. S. (1990). The problem of expensive chunks and its solution by restricting expressiveness. *Machine Learning, 5*, 299–348.

Long-Term Memory

Any memory that persists for more than a few seconds and can be accessed at some later point in time.

Cross-References

▶ Memory Persistence

Long-Term Potentiation

An increase in the efficiency of synaptic communication resulting from repeated stimulation of a postsynaptic neuron by a presynaptic neuron. In some cases, the presence of a neurotransmitter is also required. For example, long-term potentiation in the basal ganglia is dependent upon pre- and postsynaptic stimulation as well as the neurotransmitter dopamine.

Long-Term Skill Learning

▶ Long-Term Expertise Development in Complex Domains and Individual Differences

Lorenz, Konrad (1903–1989)

Lee C. Drickamer
Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ, USA

Life Dates

Konrad Zacharias Lorenz was born in Vienna, then part of the Austro-Hungarian Empire, on November 7, 1903. With the exception of a brief stint as a medical student at Colombia University in New York and several years spent in a Russian prisoner-of-war camp during World War II, Lorenz lived his entire life in Austria and Germany. He died in Vienna on February 27, 1989. He was raised in Altenberg with a large family and ample grounds to satisfy his early interest in and love for animals. Through reading, exposure to nature, and maintaining a variety of creatures in captivity, Lorenz became fascinated by the phenomena he observed. His particular fascination with waterfowl and the process of imprinting became a lifelong professional emphasis. At age 10, Lorenz was introduced to ideas concerning evolution, which further stimulated his inquisitiveness about natural history and the nascent development of hypotheses linked to his observations.

Lorenz's father wanted him to be a medical doctor, but Konrad was less inclined to follow this career track. His older brother, Albert, was on a path to success as a surgeon. At the conclusion of high school, Lorenz began the medical school training program At Colombia University in New York and then matriculated at the University of Vienna. He obtained the MD degree in 1928, but remained strongly directed toward studies of animals. Initially, his interest was in paleontology, but events soon changed his emphasis. His first position, as a faculty member in the Institute of Anatomy in Vienna provided new insights concerning evolution and behavior from a comparative perspective. He began studies in zoology and the psychology of behavior, obtaining a second doctorate in 1933, also from the University of Vienna.

Lorenz formed a strong bond with a neighborhood girlfriend, Margarethe (Gretl) Gebhardt, whose father operated a market garden. He followed the customary pursuits with boys in his neighborhood; these eventually lead, in later years, to motorcycles and boats.

He and Gretl were married in 1927 and had three children, a son and two daughters. Gretl was also a physician and a mainstay throughout their life together, holding the home front during Konrad's time in prison camps, and managing the family farm. She died January 16, 1986, 3 years before her husband.

An aspect of Lorenz's life that receives attention in biographies is his association with the Nazis in the early years of World War II and his subsequent 4 years in Russian prison camps. Several of his publications supported Nazi-like ideals or were slanted to be acceptable to the Nazi social plan. This resulted in many years of discussion and though Lorenz later distanced himself from these sentiments, the issue never completely faded even up to and after the Nobel Prize in 1973. Lorenz served in the German army as a physician during World War II and was captured on the Eastern Front. From June 1944 to early in 1948 he was held in several Russian prisoner-of-war camps, serving the medical needs of his fellow captives. He walked home from the last camp, near Moscow, to his home in Altenberg.

Contribution(s) to the Field of Learning

Academic Appointments

During the years that he worked on his second doctorate, Lorenz was employed, as an assistant professor, in the Anatomical Institute in Vienna. For most of the remainder of the 1930s, a very productive period, Lorenz worked at Altenberg, developing and testing many of his most important ideas. In 1939, he was appointed professor of comparative psychology at the University of Konigsberg in Germany. His career was interrupted from 1941 until 1948 by service in World War II and time spent in Russian prisoner-of-war camps. Upon his return, he conducted research at Altenberg for 2 years and then accepted sponsorship from the Max Planck Society until 1957. He served as co-director and director of the Max Planck Institute for behavioral physiology at Seewiesen in Germany. For his last 16 years, from 1973 until his death in 1989, he was the head of a research station at Altenberg working with sponsorship from the Austrian Academy of Sciences.

Publications

Lorenz's first scientific publication, which occurred in 1927 in the *Journal of Ornithology*, was a diary of

a jackdaw, the subject of many hours of recorded observations. During the ensuing 62 years, he published numerous research articles, a selection of books about animal behavior written for a general audience, and several full length scholarly monographs. Many of his important scientific papers are collected in two volumes entitled *Studies in Animal and Human Behaviour* (1970, 1971). His books for a popular audience include *King Solomon's Ring* (1952), *Man Meets Dog* (1956), and *On Aggression* (1966a), all translated from German editions. His monographs include *Evolution and Modification of Behavior* (1966b) and *The Foundations of Ethology* (1981).

Nisbett (1976) wrote a full length biography of Lorenz, and Burkhardt (2005) wrote a combined treatment of the lives of Lorenz and Niko Tinbergen with an emphasis on the founding of ethology. In addition, Lorenz wrote an autobiography for the Nobel Institute publication at the time he became a laureate in 1973 and an essay in the volume edited by Dewsbury (1985) on *Leaders in the Study of Animal Behavior* (Lorenz 1985). Together, these books and essays provide a thorough picture of the complexities of Konrad Lorenz and considerable, useful detail on his ideas and contributions, those with whom he worked and corresponded, and his legacy.

Mentors and Colleagues

Lorenz credits friends, mentors, and colleagues with stimulating his thinking and writing on aspects of behavior, beginning in his youth and continuing throughout his career; only some are noted here. Several lecturers and professors influenced his early thinking, including Karl Buhler a professor of psychology at the University of Vienna. His first major scientific connection was with Oskar Heinroth, whose work stimulated Lorenz's thinking on behavior, particularly of birds. He met Erich von Holst early in his professional career and they formed a lifelong affiliation, sharing many research interests and bringing different perspectives to bear on behavioral questions. Lorenz focused on the external, observable actions of animals, while von Holst was concerned with related internal physiological processes.

Lorenz derived some of his ideas and approaches from reading the works of others and through correspondence with key figures studying in similar areas. Among those with whom he corresponded in his early years were Margaret Nice and Wallace Craig both studying ornithology. The works of Charles Otis Whitman, who served as the major professor for Craig, fostered much of Lorenz's interest in conducting his research in natural settings. The ideas of William McDougall aided Lorenz with conceptualizing the psychohydraulic model to explain the motivations underlying observed behavior. Meeting with and reading the works of Julian Huxley influenced Lorenz's understanding of evolutionary concepts and work on bird courtship, which was central to the ideas he was developing.

Lorenz first met Niko Tinbergen at a symposium held at Leiden in the Netherlands in 1936. Their interests were congruent, but here also, each benefited from the variations in overall perspective and approach favored by the other. They visited in each other's research facilities on several occasions, worked together on joint projects and shared discussions at international meetings. The synergy they experienced and fostered lead to the full development of many of the basic ideas that formed the foundations of ethology. In the early 1950s, Lorenz and Daniel Lehrman of the United States engaged in a heated discussion concerning the terminology then used by ethologists to explain animal actions. At the core of these discussions, which involved many who were starting the pursuit of animal behavior that blossomed in the 1960s and beyond, was the question of how much of behavior is "innate" or genetically programmed versus how much is modified by experience during the course of development. In various forms, aspects of this debate continue today, though new techniques and models now available point the way to a synthesis that really involves neither of the original viewpoints, but rather a synthesis with multiple components. Lorenz and Lehrman found, after discussions, great respect for the other and their different viewpoints.

Important Scientific Research and Open Questions

Konrad Lorenz is one of a half dozen individuals credited with the birth of modern ethology (animal behavior). His approach combined physiology, zoology (ecology), and psychology. Lorenz himself held positions related to all three of these major areas that serve as bases for the birthing of ethology. His legacy, as a founder of ethology, includes the following significant contributions.

Defining Ethology

Together, Tinbergen and Lorenz provided definitions of ethology and helped to characterize the emerging field. Lorenz defined ethology as the comparative study of animal behavior; his interest in comparative work began back with his interest in paleontology and work in anatomy. Tinbergen's definition of ethology was the objective study of behavior; he emphasized conducting simple but elegant experiments to test ideas derived from careful observations of animals in natural settings.

Imprinting

His childhood experiences with geese, ducklings, and other birds he raised or observed made Lorenz a great proponent of imprinting, the processes by which young of a species form attachments to their parents. The original scientific examination of this idea is credited to Heinroth, though clearly people had been aware of the phenomenon for centuries. Lorenz expanded the study of imprinting, tying in his findings on this subject with his overall framework for motivation and analysis of behavior.

Innate Releasing Mechanism and Fixed Action Pattern

To explain animal actions, Lorenz proposed and expanded, over many years, his concept of the internal mechanisms that controlled behavior. In his framework, many animal actions were triggered by a sign stimulus, which triggered an innate releasing mechanism, resulting in performance of a fixed action pattern. The centerpiece was this last, the fixed action pattern, which constituted the observable actions of the organism. Much of what Lorenz wrote in his papers and scientific monographs dealt with these concepts. Further, there was an action-specific energy that built up in the animal, resulting in performance of a particular behavior pattern, sometimes without the presence of the stimulus. At the heart of his thinking was a rather fixed pathway following the stimulus-releasing mechanism-fixed action pattern sequence; this was hard wired in his models for behavior. The result was an instinct; a drive that lead to specific, stereotypical behavior patterns. This notion was challenged by Lehrman and others, resulting in many lengthy exchanges, in writing and in oral presentations. At the core is the debate of the nature vs. nurture argument; as noted elsewhere in this entry, this debate is now considered to be resolved by most scientists.

Other Ideas

Lorenz was a key player in the promulgation of various facets of the nascent field of ethology. Among these are comments on both the facilitation and inhibition of actions, often resulting in sequences of behavior. He was a proponent of studying behavior in both the natural setting and in captivity. He helped pioneer the use of homology and analogy in the exploration of behavior. The comparative method leads directly to notions of similar behaviors being either derived from a common ancestor as in the case of courtship displays in a variety of waterfowl, or resulting from similar selection pressures producing a common solution to particular challenges, such as flight behavior evolving independently as a means of locomotion in insects, bats, and birds. Indeed, he championed the idea that behavior could serve as a taxonomic tool, helping to elucidate the evolutionary relationships among a group of animals where a common behavior pattern, such as courtship in waterfowl, exhibited species-specific variation.

Throughout his work, Lorenz exhibited a pattern in his approach. Initial observation was followed by attempts to measure what was seen and that, in turn, lead to derivation of possible explanations for the original observations. He was a master at applying this simple paradigm to many phenomena in the animal world. He was, from the perspective of many scientists of the next generation or two, unable to come to grips with changes that occur in the knowledge base and underlying theories that occur when any emerging discipline is maturing. His unwillingness to "follow the flow" s the field he helped found progressed to new levels has occasioned much criticism of his work. When one steps back and examines Lorenz's work in its temporal and scientific context, he was a true pioneer with regard to putting the study of animal behavior into a framework. Whereas some of his basic tenets have withstood the test of time and serve as part of the basic framework for understanding behavior today (e.g., use of the comparative method), much of his structure for ethology is now replaced by new ways of testing and thinking about behavior.

Konrad Lorenz was distinguished in appearance, a commanding presence, and possessed both a driving

curiosity about everything in the natural world and a large ego. His contributions to the early development of modern animal behavior are unquestioned and his general approach to the study of behavior remains an integral part of work in this field today. Lorenz, along with his colleague and friend Niko Tinbergen, shared the 1973 Nobel Prize for Physiology or Medicine.

Cross-References

▶ Comparative Psychology and Ethology
▶ Habit Learning in Animals
▶ Tinbergen, Nikolaas

References

Burkhardt, R. W., Jr. (2005). *Patterns of behavior: Konrad Lorenz, Niko Tinbergen, and the founding of ethology.* Chicago: University of Chicago Press.

Evans, R. I. (1975). *Konrad Lorenz: The man and his ideas.* New York: Harcourt Brace Jovanovich.

Lorenz, K. (1952). *King Solomon's ring.* London: Methuen.

Lorenz, K. (1956). *Man meets dog.* London: Methuen.

Lorenz, K. (1966a). *On aggression.* London: Methuen.

Lorenz, K. (1966b). *Evolution and modification of behavior.* Chicago: University of Chicago Press.

Lorenz, K. (1970). *Studies in Animal and Human Behavior* (Vols. 2) (trans: Martin, R.). Cambridge, MA: Harvard University Press.

Lorenz, K. (1974). Autobiography. In W. Odelberg (Ed.), *Les Prix Nobel/Nobel lectures.* Stockholm: Nobel Foundation.

Lorenz, K. (1981). *The foundations of ethology.* New York: Springer.

Lorenz, K. (1985). My family and other animals. In D. A. Dewsbury (Ed.), *Leaders in the study of animal behavior.* Chicago: University of Chicago Press.

Nisbett, A. (1976). *Konrad Lorenz.* New York: Harcourt Brace Jovanovich.

Low Involvement Learning

▶ Incidental Learning

Ludic Behavior

▶ Play, Exploration, and Learning

Ludology

▶ Learning at Play