Concept Mapping: A Neuro-Scientific Approach

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Abstract

Rarely if ever are the boundaries of any scholarly body of knowledge or theory integrated in an inter-disciplinary collaboration, yet there are arguably some situations where just such a symbiotic relationship is quite compelling. One such example was recognized in the remarkable similarities that exist between complex high-tech design and the logical function and design of the human brain. An even better example exists involving the processes of learning and the potential implication for collaboration between neuroscience and adult education.

Introduction

Recent research in neuroscience has determined that complex designs and inventions particularly in the high technology field are remarkably similar to the design and function of the human brain. Goldberg (2001) demonstrated that human beings tend to invent, create, and design complex mechanisms such as computers in a fashion that is consistent with the integral design of the human brain. The question that beckons is whether this is an indication that there is some invariant law of evolution at work, or is it a demonstrative manifestation of the unconscious recapitalization of the human brain's own design?

Smith (1982) posits that the individual who has learned "how to learn" achieves a most significant activity in life by continuing his or her education. Novak and Gowin (1984) in their text on the same topic use the construct of a concept map as a graphical depiction of understanding how one learns through a "change in the meaning of experience" (p. xi). Interestingly enough the technique of concept mapping is very similar to a macro view of the physiology of the neocortex and perhaps another example of the possible recapitalization of the brain's design and the process of learning.

Relevance of Research to Practice (R2P)

The synergies and similarities of learning how to learn (LHTL) theory in adult education and current knowledge and research in neuroscience offer a unique opportunity to enhance and expand LHTL theory and application. The timing for such an initiative could not be better given the desire of adult educators to re-establish roots in the theory to practice arena. The current demand and interest by popular culture in issues of learning and knowledge development are no more evident than in the fields of technology development and self fulfillment. Hawkins (2004), inventor of the Palm Pilot technology, describes in his book *On Intelligence* his commitment to develop a truly intelligent computer for commercial purposes that is modeled on the brain. Gladwell (2005), in his current best seller *Blink*, describes the phenomenon of implicit, seemingly unconscious learning, again with a fascination on the process of learning within the brain. This context offers a unique opportunity for adult educators to reach an attentive global audience with valid learning theory. Gladwell's approach further enhances LHTL theory with the importance of implicit learning when connecting concepts from intuitive predictions.

Literature Review

Smith (1982) provides a very concise description of learning theory which is substantively consistent with the functionality of the brain gleaned from neuroscience:

> Learning has been variously described as a transformation that occurs in the brain; problem-solving; an internal process that leads to behavioral change; the construction and exchange of personally relevant and viable meanings; a retained change in disposition or capability that is not simply ascribable to growth; and a process of changing insights, outlooks, expectations, or thought patterns. (p. 34)

Other scholars have offered supporting theoretical contributions. Knowles (1973) offers "learning is a process by which behavior is changed, shaped, or controlled." Knowles (1980) also contributed his *andragogy* theory, which is defined as "the art and science of helping adults learn" (p. 43). This theory is based upon five behavioral assumptions. Adults are self-directed, retain experiential knowledge, acquire developmental responsibilities, are problem centered, and are internally motivated to learn. Mezirow (1996) contributed a theory of *perspective transformation* which is a process defined as "any meaning- making activity" (p. 162). This process of achieving transformation is based on three components, experience, critical reflection, and development. Lindeman (1961) described the chief purpose of learning as discovering the meaning of our experience (intelligence) and noted that "the person who knows what he wants to do and why is intelligent" (p. 17).

Mountcastle (1998) in *Perceptual Neuroscience: The Cerebral Cortex,* identifies the following goal as a priority in neuroscience research, "to determine the relations between the material order of the world around us and the sensory-perceptual order of our experience; and, to discover the central neural mechanisms of these transformations" (p. 362). Mountcastle is referring to understanding the process that causes the perceptual transformations of memory associated with experiences. Several years earlier, Novak and Gowin (1984), evaluating research and behavior in a totally different discipline recognized that LHTL involves realizing and understanding changes in the meaning of one's experience. The common ground from both theory bases is the focus on experience and the changes and/or transformations that occur in the context of learning. Combining the research and theory of these disciplines to better understand learning could be a powerful example of commensalism within disciplines and a significant contribution to each.

Synergies between concept mapping theory and the actual function within the thinking brain (neocortex). The primary area of the human brain that is engaged in the process of learning is called the neocortex or thinking brain, which is the top layer of the brain (the convoluted ridge pattern that is most distinctive in drawings and images). This membrane has six layers each the approximate thickness of a business card and each layer is patterned from a similar algorithm of cell structure. This latter factor is significant since although certain processing activity (vision, hearing, etc.) have preferred sections within the neocortex, the cell structure is such that they could theoretically be processed anywhere in an equally efficient fashion.

The brain is a hierarchical memory driven system that uses the five senses and the perception of time, space, and consciousness to make predictions which form the basis of learning and knowledge creation. These hierarchical memory cell clusters enhance and grow throughout life and generate predictive feedback that can be graphically depicted in the concept map. The concept map (Novak & Gowin, 1984) graphically depicts ideas and relationships that result in the acquisition and construction of knowledge. Concepts (contained in an oval figure) are linked by neutral or directional lines in a hierarchical fashion to form key propositions. This ability to predict, gives humans an evolutionary advantage. Humans can place themselves in the future, within the confines of our minds, and alter our present behavior.

Consider concepts such as multiple intelligences (Gardner, 1983), social management, and emotional intelligence (Goleman, 1995; Bar-On, 2000), Hawkins explains that this memory driven system allows one to predict how an individual or group (society) is likely to react to a certain stimulus. This allows one to control or at least somewhat anticipate an outcome, overcome differences, manage emotions, etc. Predictions or propositions are not always valid or true, and erroneous propositions add information to this metaphorical pyramid of hierarchal memory as well as do the accurate predictions – hence the process of learning. The true value and major contribution of the concept map and VEE (or other) heuristic is most evident in the process of validating knowledge. This is a simple graphic in which the event or object is listed at the point of the "V" symbol. The "thinking" components (theory, concepts, principles, philosophies, etc.) are listed on the left and the "doing" components or methodologies including the results and records are listed on the right. The focus question describing the interaction between the conceptual and methodological is listed in the center of the "V". The brain functions in a manner that associates concepts, but it is not capable of validating the outcome anatomically.

The concept of memory is most important to the process of learning. Memory essentially represents the building blocks of learning. The neuron is the basic cell within the brain and it is estimated that we have approximately thirty billion (30,000,000,000) neurons in the neocortex. There are many types of neurons in the neocortex but the predominant cell is called the pyramidal cell based upon its shape. According to Feldman (1984), in mammals these cells constitute seventy to eighty percent of the total neurons in the neocortex. Each of the pyramidal cells has several thousand synapses. These connect with the synapses of other cells following sensory input and form bits of memory that are associated with assemblies of cells and their respective synapses. In order to present a perspective of memory capacity, note that if each pyramidal cell had only one thousand synapses the neocortex would contain approximately thirty trillion (30,000,000,000,000) synapses (potential memory bits) which is more capacity than necessary for any lifelong learner. In fact, some anatomists believe the number of synapses per pyramidal cell is closer to ten thousand, which equates to an incomprehensible number. Vernon Mountcastle (1998) a neuroscientist at John Hopkins University, noted "Two central themes in neurobiology are that synaptic relations between neurons are plastic--they can be changed by experience--and that long-term changes in synaptic strength are important brain mechanisms for learning and long term memory" (p. 137). The thousands of synapses associated with each neuron are densely packed at varying distances from the neuron cell. The closer the synapse is to the actual cell, the stronger the connection and the intensity of the feedback. As the neocortex receives sensory input it is constantly associating that input with existing memory and updating or refining each representation that exists in varying stages of learning and knowledge development. This quality of plasticity and the reciprocal changes in and by experience credibly support the theory posited by Novak and Gowin (1984). It is valuable to compare how fundamentally different the perfect fidelity of stored computer memory is from that formed and found in the neocortex. Hawkins identifies four significant differences: "the neocortex stores sequences of patterns, the neocortex recalls patterns auto-associatively, the neocortex stores patterns in invariant form, and the neocortex stores patterns in a hierarchy" (p. 70). A brief description of each of these attributes is appropriate, and helps one to visualize the mechanism behind the mental output that stimulates the physical process of concept mapping.

The neocortex stores sequences of patterns and we recall memory in the same way. We do not recall an entire story, song, movie or even the alphabet at once. We recall sequences in the order in which they were stored. I personally learned the alphabet in the sequence ABCDEFG, HIJKLMNOP, QRS, TUV, WX, Y and Z. I automatically recall the alphabet the same way every time. If asked to start in the middle of a sequence I pause to find my place. If I am asked to say it backwards I completely stumble because that is not the sequence I learned. This is true of memorized speeches, songs, or anything we learn in sequence.

The neocortex recalls patterns auto-associatively. Patterns and associations include related input that is garnered from all of the senses. This is quite phenomenal in and of itself. We can often see or otherwise sense a small portion of an object, person or thing and completely identify it by filling in the rest. The concept map depicts recalled associations in the form of key propositions.

The neocortex stores patterns in invariant form (objects) or invariant representations (persons). This particular attribute is dramatically different from memory stored in a computer. A computer stores every bit of information in perfect fidelity. Memory stored in the neocortex is based upon dynamic associated relationships. The best example may be the face of a person we are familiar with. We can observe this person from different angles, at different times, in various contexts and still have no difficulty in recognizing him/her. The internal representation empowering the recognition of that person is invariant within the brain. Conversely, the computer can only confirm recognition if the input representation is near identical to one of the stored complete images. This is the weakness of visual identification surveillance systems and the reason positive matches are so infrequent. The neocortex can receive input consisting of a minute glimpse (the equivalent of a few pixels) of a nose and immediately fill in the entire face.

The final attribute is extremely significant; the neocortex stores patterns in a hierarchy. The term hierarchy often implies a power structure such as that present within an organization in which the most powerful and knowledgeable individuals rise to the top. The term hierarchy, as used in the context of the neocortex refers to the pattern of connectivity within and between the six cellular layers of the neocortex and actually operates by pushing the most highly developed and refined knowledge down the hierarchical structure. When most sensory input enters the neocortex it enters at the lowest level. This sensory input travels upward through the hierarchical levels, as well as laterally searching for associated memory cells. A very important aspect of this process is that feedback or output is simultaneously being generated and sent to various centers within the nervous system whenever any association is made. In fact, when considering the volume of flow, there is a much greater volume of feedback at any given time than there is sensory input. Memory clusters (knowledge packets) of recent or frequent stimulation will domicile in the lowest appropriate layer of the neocortex to enable the quickest feedback to any sensory input. This seems most logical when referring back to the previous facial recognition example. Once we recognize an object or person we continue to recall information from memory related to that object or person until we change our focus. The volume of feedback generated in this recall process greatly exceeds any input.

Prediction. The hierarchical process of the neocortex will push that memory assembly lower and lower within the structure. As soon as the memory association assembly contains a complete image an invariant representation is stored. Experience can alter or revise minute aspects of that representation, but the person or object will be immediately recognized from the slightest sensory input originating from any of the senses (visual, auditory, olfactory, and tactile).

More precisely, an immediate prediction will flow in the form of feedback. As you can probably imagine, a great deal of these minute memory bits are implicitly learned (unconsciously recorded). Similarly, after we know and readily recognize a person or an object, the subtle enhancements to those invariant representations are very often implicitly learned. The rationale for this is very simple, once we can declaratively recognize a person or object we perceive no need to learn how to recognize that person or object again. Yet, by mere exposure to the changing environment or context in which that person or object is present at any given moment, sensory input is continuously generated and associated with all existing memory resulting in a very dynamic change in our experience. A concept map provides a snap shot of the experience based construct of that knowledge. An appropriate metaphor could be a building that is under construction throughout our lifetime. We could take a snap shot at any given point and depending on the quality of the equipment, position and technique we could produce an elaborate reproduction of the development and even form some progress predictions. The VEE heuristic is a graphic investigative tool that enables a clear illustration of the conceptual and methodological inputs that combine in the process of knowledge construction. The concept map depicts hierarchical relationships retrieved from memory feedback to form predictive propositions to transform the meaning of experience and construct knowledge. The VEE heuristic deconstructs systems and theories and evaluates the methodological interactions to validate and record "knowledge". This explicit exercise strengthens the associated memory clusters and the meaning of the affected experiences, our individual knowledge base.

For several decades, learning theory has been based almost exclusively on observed changes in behavior. Much of this theory is valid and consistent with scientific evidence that has emerged from neuroscience and other disciplines. The depth of understanding surrounding behavior modification and root changes in the experience that triggers and guides human behavior can be invaluable resources for enhancing existing theory and identifying avenues for future research through a multi-disciplinary model.

Conclusion

The one undisputed fact shared by the theories, scholars, practitioners, and learners is that learning and understanding how to learn positively influences the process of learning throughout life. The analysis and evaluation of behavior have been significant criteria for the development of the theory of LHTL. Metacognition and the transformation or evolution of meaning has similarly strengthened the understanding and value of learning in adulthood. Technology and biological research focusing on the functionality of the brain have opened the most direct opportunity yet to study and understand the uniquely human process of learning. Existing theory can be interpreted within the process that generates the predictive output which causes the behavior interpreted to create the theory. Mountcastle (1998), in his epilogue refers to a major research program in neuroscience "to determine the relations between the material order of the world around us and the sensory-perceptual order of our experience; and, to discover the central neural mechanisms of these transformations" (p. 362). The evolution, development and transformation of knowledge stored within the associative memory cell clusters of the individual brain can be reconciled and stimulated consistent with the learning style or methodology unique to any individual learner. The validation of knowledge will still require a heuristic such as the VEE, yet the synergies and similarities of LHTL theory in adult education and this current research in neuroscience offer a unique opportunity to enhance and expand LHTL theory. The notoriety and popularity of adult learning and development applications achieved through the efforts of mass communication and technology open the opportunity to reach more adult learners on a global scale than any previous time in history. It is this combination of factors that have driven my personal passion to develop, explain, and understand LHTL theory. As Smith so astutely defined "learning has been variously described as a transformation that occurs in the brain" (p. 34), which has defined and driven the research and practice in refining LHTL and improving adults' retention. Understanding the mechanisms of these transformations represents a new dimension of LHTL theory and practice. One in which I hope to make a significant contribution.

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Presented at the Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education, University of Wisconsin-Milwaukee, Milwaukee, WI, September 28-30, 2005.