Learning Sciences Perspective on Engineering of Distance Learning. Part 2

Mourat A. Tchoshanov – PhD, Prof. of Mathematical Education at the Division of STEM Education, mouratt@utep.edu
University of Texas at El Paso, El Paso, Texas, USA
Address: EDU612, 500 W. University Avenue, El Paso, TX 79968, United States

Abstract. There is an on-going debate in the literature on theoretical underpinnings of distance learning. Scholars consider different theoretical perspectives including but not limited to theory of independence and autonomy, theory of industrialization, and theory of interaction and communication through the lens of a traditional Learning Theory approach. There is a lack of discussion on a potential role of a newly emerging field of Learning Sciences in framing the theory of distance learning. Thus, in this paper we provide a theoretical analysis of the Learning Sciences as a new approach to understand distance learning in the era of Information and Communication Technology (ICT). Learning Sciences is an interdisciplinary field that studies teaching and learning. This emerging innovative field includes but is not limited to multiple disciplines such as cognitive science, educational psychology, anthropology, computer science, to name a few. The Learning Sciences' major objective is to understand and design effective learning environments, including distance learning, based on the latest findings about the processes involved in human learning.

Keywords: distance learning, Learning Sciences, constructivism, constructionism, connectivism, "engineering of learning" paradigm

Дистанционное обучение с позиции наук об учении. Часть 2

Чошанов Мурат Аширович – PhD, проф., кафедра высшей математики и кафедра подготовки учителей, mouratt@utep.edu

Техасский университет в Эль Пасо, Эль Пасо, Техас, США

Адрес: EDU612, 500 W. University Avenue, El Paso, TX 79968, United States

Аннотация. *В литературе продолжаются дискуссии о концептуальных основаниях дистанционного обучения. Учёные рассматривают различные теоретические точки зрения, включая, помимо прочего, теорию независимости и автономии, теорию индустриализации и теорию взаимодействия и коммуникации, через призму традиционного подхода к теории обучения. Отсутствует обсуждение потенциальной роли недавно появившейся области – науки об учении (Learning Sciences) – в формировании теории дистанционного обучения. Таким образом, в этой статье мы предлагаем теоретический анализ направления наук об учении как нового подхода к пониманию дистанционного обучения в эпоху информационных и коммуникационных технологий (ИКТ). Эта инновационная область, изучающая преподавание и учение, включает, среди прочих, несколько дисциплин, таких как когнитивная наука, педагогическая психология, антропология, информатика и многие другие. Основная цель Learning Sciences – изучение и разработка эффективной обучающей среды, включая дистанционное обучение, на основе последних данных о процессах, связанных с тем, как человек познаёт и учится.*

Ключевые слова: *дистанционное обучение, науки об учении, конструктивизм, конструкционизм, коннективизм, инженерия учения*

Introduction

The world is transitioning through unprecedented changes due to the intensive implementation of distance education caused by the global pandemic. The field of distance education rapidly responds to the new challenges. Under these circumstances, the use of the traditional Learning Theory does not provide an in-depth understanding of learning and teaching in digital environment. Moreover, the phenomenon of distance learning itself is a relatively new landscape which requires a solid theoretical foundation. Analyzing theoretical underpinnings of distance learning, scholars claim that the following approaches, namely cognitive behaviourism, social constructivism and connectivism closely influenced understanding the phenomenon of distance learning. Whereas cognitive-behaviorist approach attempts to explain the first generation of individualized distance learning (e.g. correspondence education), social-constructivism and connectivism aim at understanding learning as a socially enacted process. The difference between the social-constructivism and connectivism is in understanding how learning takes place: connectivism claims that learning can reside outside of an individual (e.g., within a social network) through connection to specialized information sets which enables an individual to advance his/her current state of knowing.

In last two decades, scholars intensively seek for a theoretical underpinning of the distance learning. However, there is a lack of discussion in literature on a potential role of a newly emerging field of Learning Sciences in framing the theory of distance learning. The Learning Sciences deserves a theoretical discourse as an emerging approach to understand distance learning in the ICT era based on the advancement in cognitive science, educational psychology, anthropology, computer science, didactics, etc. The Learning Sciences' major objective is to understand and

design effective learning environments in different settings, contexts, and formats.

The paper is a continuation of the discussion on the Learning Sciences and its major theoretical pillars[1]. Thus, we discuss recent developments in two leading theories of the Learning Sciences: Constructivism and Constructionism as well as an emerging branch of Constructivism – Connectivism. We also illustrate Social Constructivism in action via engineering of distance learning activity. Finally, we conclude the paper with discussion.

Constructivism

In this section, we provide an overview of the key ideas of constructivism, its basic principles in the context of a learning process, and briefly discuss its advantages and disadvantages.

The key idea of constructivism is that ***knowledge cannot be simply transmitted*** to a student. One can only create pedagogical conditions for successful construction of knowledge and understanding. From a philosophical standpoint, constructivism reflects a fairly simple fact: each of us constructs his/her own understanding of the world. Thus, each of us has a unique vision of the world, belief, and viewpoint.

Constructivism is a pedagogical theory that gives priority to a learner's point of view no matter how idiosyncratic it might be. According to Jean-Jacques Piaget, student's opinion is a starting position for construction of new knowledge by overcoming the cognitive conflict between the existing internal structure (schema) and external unknown reality. Eliminating this conflict restores the so-called *cognitive equilibrium* (balance) characterized by the processes of *assimilation* of new knowledge into the existing schema and *accommodation* (e.g., change, modification, replacement) of previous schema based on newly learned knowledge and understanding. Another prominent scholar –

Lev Vygotsky – added an important social dimension to constructivism by emphasizing *co-construction* of knowledge and understanding. Vygotsky's claim that a learner develops new knowledge and understanding through interaction with others expands the theory toward *social constructivism.*

Constructivism values the process more than the result. Piaget argues that scientific knowledge is not a static phenomenon; it is a process, more specifically, the process of continuous construction and reorganization.

Implementation of constructivism in the classroom requires rethinking of traditional instructional practices. For instance, learning objectives and learning outcomes should be designed around the key position of constructivism: knowledge cannot be transmitted to a student; it could be self-constructed by a student or co-constructed in the process of student's interaction with others. That is why constructivists try to avoid the "imposing" terminology in the design of the learning objectives and outcomes, for example, teacher-directed actions such as "teach", "cover", "tell", "show", etc. Instead, constructivism encourages using student-centered language in the design of learning objectives and outcomes: "construct", "engage", "understand", "justify", "reason", "reflect", etc.

Student motivation should be driven by real life exploratory activities, which include but are not limited to searching, investigating, and solving sound socially relevant problems, especially those arising at school, in the neighborhood, within a community (e.g., environmental, economic, social, etc.). These types of problems and activities engage students in data collection, analysis, and problem solving that contribute to the well-being of their immediate environment.

Congruently, the content should be developed around those concepts and ideas that support students' understanding, stimulate students' reasoning, encourage students to share their assumptions, hypotheses and conjectures, motivate speaking out, involve students into meaningful dialogue and exchange of diverse viewpoints. Therefore, the classroom culture and environ-

---

[1] Tchoshanov, M.A. (2021). Learning Sciences Perspective on Engineering of Distance Learning. Part 1. *Vysshee obrazovanie v Rossii = Higher Education in Russia.* Vol. 30, no. 2, pp. 33-49, doi: 10.31992/0869-3617-2021-30-2-33-49

ment should be built with an emphasis on student learning, student intellectual needs, student collaboration, and student success.

This type of student-centered environment is supported by the work of scholars. For example, the framework of the "5e" instructional model (Bybee et al.) [1] describes a social constructivist learning cycle, which helps students to build new understandings and draw ideas from prior experiences through the following five stages: engage, explore, explain, extend, and evaluate. The "5e" model could be effectively used for engineering of learning in different formats: face-to-face, blended/hybrid, and distance learning.

The main objective of the "*engage* stage" is to engineer student learning via building their intrinsic motivation and involving students in the activity along with conducting pre-assessment of their prior knowledge and understanding. During this stage, students make connections between past, present and new learning experiences. At the "*explore* stage" students are directly involved in an inquiry-based activity. This stage allows students to work collaboratively in teams, sharing and communicating their understanding through testing hypotheses, making predictions, and drawing conclusions. The major goal of the "*explain* stage" is to engineer student communication using individual and group presentations of what they have learned through the process of reflective thinking. The "*extend* stage" allows students to expand on the concepts, make connections and generalize the concepts. The purpose of the final "e" in the cycle – the "*evaluation* stage" – is to engineer ongoing diagnostic process that allows both the teacher and the student to assess whether the desired level of understanding has been attained through implementation of well-designed rubrics, observation, interviews, peer-assessment, portfolios, and inquiry-based learning products/ artifacts. This stage also addresses students' misconceptions and common mistakes.

Considering the key position of constructivism, the next question is how to become a constructivist teacher/instructor? First of all, a constructivist teacher is not just a teacher in a traditional sense; she/he is a facilitator, organizer, and coordinator of the problem-based student learning. Constructivist teacher by his/her very nature is a teacher-engineer. A constructivist teacher ensures favorable classroom environment for co-construction of students' new knowledge and understanding and encourages student initiative and collaboration. In turn, students become co-designers of the instructional process sharing the responsibilities for achieving learning objectives and outcomes with the teacher.

In curriculum planning, a constructivist teacher prefers to consider real life problems including the context and data from practical situations and original sources. Moreover, a constructivist teacher provides opportunities for students to collect such data by observing real life situations, searching related information on the web, surveying participants, etc. Figuratively speaking, a constructivist teacher should engage both hands and brains of students.

Concepts, theories, algorithms, and theorems are abstractions that human beings create as a result of discovery. Theory is a retrospection. Accordingly, in the learning process an abstraction should be a destination rather than a starting point. Therefore, constructivism suggests focusing on exploration first, understanding main concepts and major ideas, and only then memorization of algorithms, rules, and theorems. Moreover, a constructivist teacher designs learning objectives using the cognitive terminology to emphasize understanding: classify, justify, analyze, synthesize, predict, evaluate, etc.

A constructivist teacher allows students to take over teaching of some fragments of the lesson, change the direction of the classroom discourse, offer ideas on improving teaching and learning. Obviously, constructivist teaching requires not only easy content handling but also profound pedagogical knowledge. Knowing-to-act at the moment (Mason and Spence) [2] becomes a key ability for a constructivist teacher. This will allow a teacher to depart from the rigid structure of a lesson and transfer the

Table 1

Comparative characteristics of traditional and constructivist approaches to teaching and learning

Characteristic	Traditional Approach	Constructivist Approach
Curriculum	Curriculum emphasis is on basic knowledge and skills.	Curriculum emphasis is on major ideas and concepts.
Teaching and learning	Teaching and learning is predetermined by the strict implementation of the curriculum.	Learning and teaching process is flexible with an opportunity to modify the curriculum.
Resources	Teaching and learning is completely based on the recommended textbook.	Textbook is not a dominant source of information.
Student positioning	Student is an object of the learning process. Knowledge is transmitted to a student.	Student is a subject of the learning process. Knowledge is constructed by a student.
Teacher positioning	Teacher imposes knowledge, understanding and his/her point of view on students.	Teacher is a facilitator of student learning and understanding.
Assessment of learning outcomes	Teacher evaluates the effectiveness of student learning by the number of correct answers.	Teacher values student reasoning (even if it is not correct).
Criteria for student success	Test and exam results are the only source of information about the level of student knowledge and skills. Learning objectives, teaching, and assessment are usually considered in isolation.	Student learning is assessed not only by test results but also by the efforts made by a student to achieve progress. Learning objectives, teaching, and assessment are closely connected.

"reins of power" of leading the lesson to students while focusing on achieving learning objectives of the lesson. A constructivist teacher never reports his/her view first. Instead, she/he listens to students' viewpoints, explanations and justifications, involves students in a meaningful discussion, addresses and synthesizes diverse students' views and only then offers his/ her view on the issue as one of the possible views among others.

A constructivist teacher encourages the development of students' critical thinking by considering opposing points of view, setting counterexamples, offering contradictions in order to promote a productive classroom discourse. She/he values good questions more than good answers. A constructivist teacher appreciates substantive, good, and 'smart' student questions. Moreover, a constructivist teacher often uses "waiting time" after asking a question: she/he leaves students enough time to think about an answer, make connections, and come up with analogies, images, and metaphors to provide a substantiated response. A constructivist teacher does not accept weak and short answers and always asks students to elaborate on their responses.

A constructivist teacher provokes students' curiosity by asking challenging questions and using heuristics to support student learning.

She/he refrains from using low level teaching strategies to support student learning such as lecturing (providing information) and demonstration (showing how to do). A constructivist teacher would rather use advanced heuristics to support student learning such as demanding explanation and justification, providing hints (e.g., organize your data into a table), criticizing and posing counterexamples, sustaining high cognitive demand questioning (e.g., why, what if), and focusing on action (e.g., how did you do it). Table 1 highlights differences between constructivist and traditional approaches to teaching and learning.

As with any innovation, constructivism has some obvious flaws. At the current stage of its development, constructivism is more an educational philosophy than a learning technology, which causes some difficulties in the practical implementation of constructivism in the classroom. Some opponents accuse constructivism for undermining the foundations of organized teaching and learning. The main argument of opponents is fuzziness and lack of determination in teaching and learning (Anderson, Reder, and Simon) [3].

Despite the opponents' arguments, constructivism gets supporters among the teaching community, which is taking concrete steps

to introduce the theory into practice. There is a shift from the old theories of behaviorism toward constructivism that takes place at different educational levels (e.g., schools, colleges, and universities). Most of the teacher training curricula are revised to include the principles of constructivism. Instead of studying the works of E. Thorndike, B. Skinner and other representatives of behaviorism, pre-service teachers study the works of J. Piaget, J. Dewey, L. Vygotsky and other constructivist scholars.

Constructionism

Constructionism is the theory of teaching, learning, and design advanced by Seymour Papert. Constructionism argues in favor of a more active participatory learning through social interaction and production of tangible learning outcomes. Learning, according to Papert, is "building relationships between old and new knowledge, in interactions with others, while *creating artifacts of social relevance*" (cited in Kafai) [4, p. 35].

Constructionism is closely related to the Piagetian constructivism theory. But they are not identical: constructivism places a primacy on the development of individual and isolated knowledge structures, whereas constructionism focuses on the connected nature of knowledge with its personal and social dimensions (Kafai) [4, p. 36]. In this sense, the Papertian constructionism shows resemblance with the Vygotskian social constructivism. In his original studies, Papert extensively used the programming language Logo to provide children with the opportunity to learn programming and to study Mathematics and Science through the manipulation of digital objects (e.g., Logo turtle), in interaction with others, and reflection on their own thinking and learning (e.g., metacognition).

In order to address the key ideas of constructionism, let us first consider the major distinction between two opposing approaches: innovative constructionism and traditional instructionism. Constructionism advances the idea of learning by constructing (e.g., knowledge, learning artifacts) whereas instructionism is associated with the traditional approach to teaching by transmitting knowledge. According to Mooney, Piaget "claimed that children construct their own knowledge by giving meaning to people, places, and things in their world. He was fond of the expression "*construction is superior to instruction*" [5, p. 61]. From this perspective, constructionism is strongly rooted in constructivism. In his pioneering publication "*Mindstorms*", Seymour Papert tried to define constructionism by contrast with constructivism:

"Constructionism – the N word as opposed to the V word – shares constructivism's connotation to learning as building knowledge structures irrespective of the circumstances of learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity whether it is a sand castle on the beach or a theory of the universe" [6, p. 1].

According to this definition, active engagement in learning through construction of 'a public entity' is the central aspect of constructionism. Moreover, the context and environment are critical in stimulating learning and construction of knowledge. Technology plays a key role in the constructionist classroom because it enables students to create 'public entities' and develop both cognitive and affective skills while acting as the agents of learning. According to constructionism, manipulation of objects facilitates the connection between the old knowledge and a new concept. The Papertian constructionism builds on the similar constructivist idea and proposes the term "objects-to-think-with". This process of mental identification with the object supports the mechanism of appropriation and is called *syntonic* learning. Papert used the Logo Microworlds as an example of the computer-based 'objects-to-think-with' approach that provided students with the opportunity to construct artifacts through designing their own programs and construct their knowledge and understanding at the same time.

To clarify the difference between constructivism and constructionism, Kafai explains that, though both theories involve the mechanisms of

assimilation and accommodation, constructionism goes beyond these essentially cognitive processes placing high emphasis on *appropriation,* a social interactive process, which suggests that "learners make knowledge their own and begin to identify with it" [4, p. 39]. In other words, appropriation is an essential final stage of the learning process: students are expected to construct knowledge and design their own artifacts by applying the concepts they have gained to new situations.

As the emphasis on appropriation is one of the main distinctions between constructivism and constructionism, it will be discussed further after a brief explanation of assimilation and accommodation mechanisms. Assimilation and accommodation are complementary processes that can be best understood by the comparison with principles of learning suggested by Donovan and Bransford [7]. Assimilation corresponds to the first principle of learning – it involves drawing on prior knowledge (e.g., already existent cognitive schema) to understand the new information. Accommodation refers to the second principle of learning presented by Donovan and Bransford [7] – the relation between factual knowledge and conceptual framework to support understanding. In other words, conceptual understanding helps to create a new schema that helps to accommodate the factual knowledge acquired. Appropriation is an inherent aspect of learning highly emphasized in constructionist classrooms. As appropriation implies ownership of knowledge, it requires that a learner develops strong self-monitoring and metacognitive strategies, which Donovan and Bransford [7] identify as the third principle of learning. Metacognition is critical in the knowledge appropriation because it "includes an awareness of the need to ask how new knowledge relates to or challenges what one already knows – questions that stimulate additional inquiry that helps guide further learning" [7, p. 11]. Here lies the value of technology as "objects-to-think-with", which helps students to develop cognitive and affective skills, as well as metacognitive competence as they engage in both individual and collective activities

involving designing 'public entity' (e.g., a computer program) and constructing understanding.

Kafai's argument [4] that technology facilitates the knowledge appropriation in constructionist classes seems very plausible as she provides examples of the research projects that corroborate this point. In one of the studies, older students were required to design instructional software to teach fractions to younger learners. The project provided substantial evidence to conclude that younger students highly benefited from the software whereas student-designers greatly improved their programming skills and conceptual knowledge of fractions in addition to developing metacognitive competence. Another revealing research evidence substantiating the cognitive, metacognitive, and affective gains of using technology as facilitator of learning is a study on the involvement of ten-year-old students in designing and programming their own computer games. The project provided students with an opportunity to design games according to their interests, which is very important as the knowledge appropriation process requires that learners should be engaged in activities that are interesting, relevant, and meaningful to them (Donovan & Bransford) [7].

The Papertian constructionism also distinguishes from the Piagetian constructivism with regard to cognitive development, and emphasizes the role of social interactions in influencing learning. This is a bridging point that constructionism builds between Piagetian and Vygotskian views on constructivism. Vygotsky [8] considers learning as a result of collaboration and socialization. Furthermore, Vygotsky emphasized the role of language in facilitating the learning process. Vygotsky also stressed the role of the teacher as a dynamic and effective contributor to the learning process by providing the needed scaffolding to learners until they are able to execute the task independently [8].

Yet, the apparent major distinction between constructionism and constructivism, regardless of its Piagetian or Vygotskian interpretation, is the emphasis that constructionism places on the production of an artifact that can be shared and

Comparison of the Piagetian Constructivism and the Papertian Constructionism

Parameter	The Piagetian Constructivism	The Papertian Constructionism
Theoretical focus	The theory of knowledge development	The theory of learning and teaching
Primary dimensions in knowledge development	Places primacy on the development of individual and isolated knowledge structures	Focuses on the connected nature of knowledge with its personal and social dimensions
View on learning	Views learning as building relationship between old and new knowledge	Views learning as building relationship between old and new knowledge in interaction with others
View on knowledge construction	Views knowledge construction as an individual act	Articulates a more distributed view of knowledge construction
Aspects of learning	Concerned primarily with cognitive aspect of learning	Concerned with combination of cognitive and emotional aspects of learning to address "knowledge as desire" phenomenon
Primary learning outcome	Building a cognitive schema	Creating an artifact of social relevance
Cognitive mechanism of knowledge construction	Builds on the mechanisms of assimilation and accommodation	Extends the mechanisms of assimilation and accommodation to the process of appropriation
Role of technology in knowledge construction	Technology is not a primary focus in knowledge construction	Knowledge co-construction and appropriation is facilitated by interactive activities involving technology
Relationship between concrete and abstract	Distinguishes between concrete and abstract thinking and considers the latter as more advanced	Equally valuing concrete and abstract: "concrete thought could be just as advanced as abstract thought" (Kafai) [4]
Learning culture	Concerned primarily with individual learning and development irrespective of other circumstances of learning	Emphasizes the importance of learning cultures with focus on apprenticeship models
Learning environment	Authentic learning is not a primary consideration	Values learning environments, which promote authentic and syntonic (e.g., responsive and adaptive) knowledge construction

reflected upon with others in addition to being personally meaningful. Perhaps, this distinction may have resulted from the evolution of technologies, which lead to advancing constructivism toward constructionism.

Papert also strongly emphasized the role of learning culture in knowledge co-construction and claimed that "…this suggests a strategy to facilitate learning by improving the connectivity in the learning environment, by actions on cultures rather than on individuals" (cited in Kafai) [4, p. 39]. To emphasize the influential role of learning cultures, Papert describes how learning is facilitated among the members of the Brazilian samba schools where the group participants of different age learn from each other. Another difference refers to the equal value of concrete and abstract thinking in construction-

ism. Papert and Turkle discovered that "the top-down or planning approach was not always superior to a more improvised, more bricoleur-like approach" [9, p. 30]. *Table 2* summarizes major differences between the Piagetian constructivism and the Papertian constructionism via multiple lenses.

Regardless of the differences between constructivism and constructionism as depicted by Table 2, these theories play a significant role in providing a solid foundation for framing and interpreting emerging learning phenomenon in the digital age.

Connectivism as an Emerging Branch of Constructivism

With growing ICT integration in teaching and learning, there are new theoretical models

branching out of constructivism. One of these emerging branches is connectivism.

Downes identifies the core proposition shared between social constructivism and connectivism as the knowledge 'not being acquired, as though it were a thing' [10]. Connectivism is a theoretical framework for understanding learning through the process of connecting to and feeding information into a learning community (Kop and Hill) [11]. Siemens further clarifies, "A community is the clustering of similar areas of interest that allows for interaction, sharing, dialoguing, and thinking together" [12]. Within the connectivist framework, "a learning community is described as a *node*, which is always a part of a larger network. Nodes arise out of the connection points that are found on a network" [11] and *knowledge is distributed across the network* and "rests in diversity of opinions" (Siemens) [13]. This leads connectivists to propose the following definition of learning: "learning is the network" and, therefore, learning can reside outside of ourselves (within a network or a database).

Downes and Siemens attempt to locate the construction of distributed-knowledge among other epistemological frameworks such as objectivism, pragmatism, and interpretivism. Objectivism claims that reality is external to mind, and knowledge is experientially acquired whereas pragmatism positions knowledge as a negotiation between reflection and experience. Interpretivism persuades that knowledge is an internal construction through socialization and cultural cues (Driscoll) [14]. Siemens further argues that "the concept of emergent, connected, and adaptive knowledge provides the epistemological framework for connectivism…" [13, p. 10] and suggests the following alignment between epistemologies and learning theories: objectivism → behaviorism; pragmatism → cognitivism; interpretivism → constructivism; distributed knowledge → connectivism.

As any emerging framework, connectivism has its weak points that are criticized by opponents. Thus, Kerr [15] suggests that the basic ideas of connectivism had already been pro-posed by Clark [16] in his theory of embodied active cognition built on the Papert's constructionism. Sharan [17] cannot distil any new principles from connectivism that are not already present in other existing learning theories. Critics also argue that recent widespread attention to the work of connectivism is mainly due to the high visibility of networks in the digital age. Moreover, critics including the author of the book are not convinced that learning can reside in non-human appliances (Kop and Hill) [11].

Social Constructivism in Distance Learning

Implementation of the social constructivist approach in the auditorium/classroom requires knowledge of specific teaching methods and techniques. One of the wide accepted methods is the cooperative learning. When the author asked his graduate students to define what was a cooperative learning, one of them wrote "… social constructivism in action". There is a sustained interest to use cooperative learning in both face-to-face, hybrid, and online classes. Modifications of cooperative learning include but are not limited to the team-based learning, collaborative learning, learning in small groups. In this section, we will focus on a number of specific issues related to the implementation of cooperative learning such as: what constitutes a cooperative learning, what is an optimal size of a small group in cooperative learning, how to implement specific cooperative learning techniques in distance education using breakout rooms options in widely used videoconferencing platforms such as Zoom, Google meet, Microsoft teams, etc.

The theoretical basis of cooperative learning pedagogy is grounded in the works of Vygotsky and other scholars who emphasized the critical role of social interaction and interpersonal communication in learning and intellectual development. Studies showed that communication in the process of cooperative learning had a positive effect on the development of students' language, thinking and intelligence. Moreover, well-organized cooperative learning contribut-

ed to higher learning outcomes than traditional forms of teaching. Even the most dynamic and informative lecture, in general, was less efficient than learning in small groups with a skillfully constructed communication among students.

The major research on the topic of cooperative learning took place in the 1980-ies. During this period, a number of studies on the benefits of social learning in small groups were conducted by Davidson [18], Webb [19] and cooperative learning – by D. Johnson and R. Johnson [20], Slavin [21], and others. Let us consider the following main practical issues related to the implementation of cooperative learning in the learning process: formation of small groups; cooperative learning techniques; methods of cooperative learning; assessment of group achievement. We will start the review of cooperative learning by asking a question: is any learning in small groups considered cooperative? The quick answer is "no". According to the above mentioned studies, in order to ensure that learning in small groups is cooperative, it should meet the following basic requirements: the majority of classroom and extra-curricular activities should be carried out in small groups (3–5 people in each group); each small group must possess a collective spirit – the team spirit; each team member should be responsible for themselves, for others and for the members of the team as a whole; it is preferable that a student's membership in a team is stable and permanent within the class and across different classes; and, last but not least, the collective student work should be considered as student achievement in the course of progress assessment (Davidson) [18], (D. Johnson and R. Johnson) [20].

The basic starting positions in planning cooperative learning are related to the composition, size, structure and the "lifespan" of a small group. First, the principle of heterogeneity (diversity) in the formation of small groups should be taken into account. Studies show that homogeneous (uniform in terms of learning) groups are not effective: the strong groups become stronger and the weak – even weaker. On the other hand, studies on the heterogeneous composition of small groups show that it significantly improves learning and achievement of weak and mid-performing students and, at the same time, stimulates the academic progress of advanced students. In addition, small groups should be formed using the following criteria: variety of educational interests, social and psychological characteristics and psychological compatibility of group members; diversity of learning styles and preferences, etc.

The second issue is related to defining the optimal size of a small group. Some educators feel that the most appropriate size of a small group is three students per group. Others suggest five students in a group. The option – two students per group is not considered as a learning team. Observations show that the optimal size of a small group – four students per group. It is also reported that this size of a small group has the highest degree of efficiency and productivity as well as the most suitable for intra-group communication (Reynolds) [22]. There are also some other advantages for this particular composition: it could be easily rearranged into two subgroups of two students (it is convenient to work in pairs). This is also the most ideal combination for heterogeneity in terms of academic performance (one strong, two medium and one weak student per group) and in terms of gender (two males and two females). It should be noted that the formation of a small group is rather complicated process if you do not carefully consider the factor of group dynamics. If the group dynamics is not addressed, a group can work productively for a while and then quickly disintegrate. On the other hand, a carefully formed group will consistently and effectively operate over a long period of time.

The principles of cooperative learning should be applied at various stages of a class/lesson planning: starting at the exploration stage and ending at the evaluation stage. The main goal of cooperative learning at the exploration stage is to link the prior collective knowledge of group members to the new knowledge through collaborative project. Let us consider an example of a collaborative project for the topic of

trigonometry in college level PreCalculus class "Trigonometric relationships between the sine and cosine of the numeric argument" using social-contsructivist techniques in the Zoom-based distance learning environment. The class is divided into groups of 3–5 students in each using breakout rooms. Each group of students receives a description of the project and graphing calculators. The groups are asked to record their observations of function behavior and write conclusions for further discussion in the zoom whole classroom setting.

• Using a graphing calculator, plot graphs of functions f, g and $f + g$, where $f(x) = \sin^2 x$ and $g(x) = \cos^2 x$. Observe the behavior of the function $f + g$.

• Plot graphs of the following functions: $f(x) = \cos x$ and $g(x) = \sin(x + c)$. By varying the parameter c describe the behavior of the graphs of two functions. Record the values of the parameter, at which the graphs of these functions are the same.

• Conduct the same observation for the following functions: $f(x) = \sin x$ and $g(x) = \cos(x + c)$.

• Plot graphs of the following functions: $f(x) = \cos^2 x$ and $g(x) = \sin^2 x$. How can a graph of the function $g(x)$ be transformed to get the graph of the function $f(x)$?

Students work in small groups at the assigned breakout rooms for 10–15 minutes constructing the appropriate graphs of functions, discussing the results, asking questions, clarifying obscure points in assigned tasks, formulating main conclusions from observations, recording findings on the answer sheet, etc. Each group will be asked to present their major finding. At the same time, each team member must be willing to speak on behalf of the team. During the group work the teacher/instructor monitors the work of teams visiting each of the breakout rooms, asks guiding questions to clarify certain points, provides recommendations to better articulate findings, etc. In other words, the teacher coordinates and directs the group work through breakout rooms option in distance learning environment.

After working in the breakout rooms, students return to the zoom whole classroom setting to present their findings. The group work could be presented through screen sharing feature using whiteboard or other note sharing options (Google docs, OneNote, etc.). During the group presentations, the teacher selects one of the groups to share its results. A speaker presents the findings on behalf of the group. For each session the group appoints its speaker. Each member of the group should get an opportunity to be a speaker. At the same time, the group might decide to present as a team where one of the group members demonstrates the graphics, another member comments on the findings for the first task, the next member reports results for the second task, etc. While the first group presents, the members of other teams listen to the presentation, ask questions through the chat room, offer their findings and conclusions if they disagree with the presented results, and express support if they have the same results. Moreover, the members of other teams and the teacher have the right to address questions or comments to any member of the presenting team. Therefore, it is crucial that each member of the team is able to explain any task and answer questions she/he is asked on behalf of the whole team. During cooperative learning, the teacher and the team members need to maintain friendly atmosphere in the process of discussion with the elements of constructive criticism. The teacher acts as a discussant following the rules and regulating the question-and-answer session but in no way imposing his/her point of view. At the end of the discussion, the teacher briefly summarizes the results obtained by the groups, records major findings on each task, analyzes typical errors and provides a closure to the discussion.

At the stage of learning new material the main purpose of the group work is to provide formal proof for the empirical findings of the group obtained at the exploration stage. The sequence of the group work at this stage is similar to the exploration stage of cooperative distance learning. The third stage of the lesson is application of the newly learned material: at this stage

groups can work collaboratively in breakout rooms on assigned problems. Also, the teacher might administer a test to monitor and evaluate individual students' progress. Moreover, an additional project could be assigned as a collective or individual homework. Thus, the teacher combines group and individual assignments during the cooperating learning. If the homework project is assigned as a group work, in a virtual zoom meeting[2] the team determines the scope and sequence of work as well as the distribution of tasks between the team members. After doing each part of the distributed homework individually, the group meets virtually to discuss solutions, during which each team member has an opportunity to understand solutions presented by the other members through asking questions, discussing results, and correcting solutions if necessary. An important requirement for the virtual group homework is that each member of the group should know how to solve every problem in the assigned homework project and be able to present and justify the solution on behalf of the group. Performance of each group member will impact the final group's grade for the homework project. In the process of grading the group homework, the teacher has a right to selectively invite team members for individual zoom meeting to ask questions and provide comments on the solutions for specific tasks encouraging each member to be responsible for the results of the entire group, which motivates students to work hard on the group homework projects.

There are a variety of cooperative methods and social learning techniques that can be used in cooperative learning: jigsaw method, achievement teams, team contest, team-based individual learning, cooperative team learning, distributed learning technique, coop-coop method, experiment in cooperative learning, inquiry-based team learning, etc. Most of these methods work well in a traditional face-to-face

mode (Webb) [19]. Let us consider some of the methods which work effectively in the distance learning environment.

Jigsaw method is useful while studying a textbook chapter or a course reading and implemented through the following sequence of steps: students are divided into teams of four students and the course material is divided into four parts. Each student is assigned to study one of the parts. Then, members of different teams who have studied the same part are brought together to an assigned breakout room for 10–15 minutes to discuss the new material. After the discussion, the students return to their teams in and each student of the team in turn explains the content of the assigned part to the rest of the team. The student knowledge and understanding of the new material is assessed by individual test or quiz. The winner is the team that gains the highest cumulative team score on the test. The main feature of this method is interdependence of the team members in learning: the team success depends on the individual work of each team member and on the individual contribution of each member to the collective learning and performance.

Method of achievement teams is effective while using a lecture format and implemented as follows: lecture – group work with the text – individual self-study. At the beginning of each class/lesson, a teacher delivers a brief lecture to provide an overview of the new material with an emphasis on the main points, which later will be used to solve problems assigned to each group. The lecture should be sufficiently broad in content and practical application. Next, students get into the assigned breakout rooms and work in teams on lecture notes and help each other to understand its content. While working in groups, the students are involved in the discussion to clarify the main points of the lecture. The students are allowed to ask the teacher only when none of the team members can answer a question. After the group work is done, the students carry out an individual assignment. At this stage, each team member is working on his/her own task without interaction with the other team members. The main focus of this method is

---

[2] At the University of Texas at El Paso each student have an access to the Zoom platform through the Blackboard LMS.

on individual student achievement that will be added up to the team score. The importance of each student effort is enhanced through the following arrangement: an individual student score counts if it is above the student's average score for his/her previous work. The team receiving the highest score is the winner.

Team-based individual learning method aims to provide small groups an opportunity to move through the curriculum at their own pace which is considered one of the effective learning options in distance education. Students work in small groups at the assigned breakout rooms on individually assigned tasks based on the previously learned material and can access each other for advice, help and assistance. The students are also allowed to work with each other in a virtual team to address misconceptions and correct mistakes. The teacher oversees the group work by visiting breakout rooms and explains the new material to those groups who first completed the work on individual tasks. Individual tasks are evaluated by students from different groups appointed as teaching assistants. The teaching assistants are provided with answer sheets which help them to timely assess individual student's performance. Individual scores are added up to compose a team score at the end of each unit (week). It is clear that the implementation of this method requires careful design of individual assignments and tests for each unit on the teacher side. In addition, the teacher must skillfully allocate study time and space to work on the new material with each group separately.

Cooperative team learning method requires constant mutual understanding and support from team members through peer-tutoring and peer-assessment which is another feature that works effectively in distance learning. This method can be used in various forms of study groups: formal (formed according to criteria specific for a particular learning task), informal (formed on the basis of preference or friendship), and basic (formed to address the long-term educational goals).

Distributed learning technique's key feature is to engage teams in collaborative learning of the entire course material. It is a distributed learning model in a sense that the course material is subdivided among teams, so that by the end of the term students learn the entire course. Each team is assigned a special topic. Teams work to prepare the group report on a topic and present it to the whole group. Within each team, the topic is divided into units. Each student is assigned a unit to independently work on. The student prepares his/her part of the report, submits it to the group, and then, the team compiles the group report based on the individual units submitted by the team members. Each team receives a group grade for the project.

Inquiry-based team learning method is aimed to build teams of students for research projects, solving practical problems and/or to implementing applied projects at a high level of complexity and challenge. This method requires a certain level of independency for each group. Therefore, groups may be formed using arbitrary (often informal) criteria. The main goal set for each group is to conduct a mini-research that requires creative approach to identify a problem, to formulate a hypothesis, to gather empirical data, to conduct statistical analysis, to write the research report, and finally, to defend the research results before a special advisory council consisting of teachers/instructors of different disciplines and students.

The above methods do not exhaust the whole arsenal of cooperative learning techniques. Implementation of these methods illustrates a wide range of practical applications of the social constructivist approach in the virtual classroom. Methods can be combined and used in conjunction with the conventional teaching methods. Furthermore, cooperative learning is an open and dynamic system that is continuously improving by teacher initiative and creativity. The social constructivist learning methods and techniques discussed above improve student participation and engagement in distance learning.

Last but not least, the group assessment should be clearly defined in cooperative distance learning. Studies show that the group grades should not exceed 50% of the total grade

for each individual student (Davidson) [18]. One should be careful to ensure that the group assessment does not significantly reduce the strong individual student performance and, at the same time, does not increase the unjustified weak individual student achievement. Therefore, it is critical to clearly assign grade weights for every group and individual assignment. Implementation of cooperative learning requires special training of teachers and instructors, in particular, to overcome challenges that can arise in a virtual classroom. When arranging cooperative learning in distance format, teachers should also be prepared to resolve some irregularities and constraints with regard to the task assignment and completion. It might happen that individual members, who are not supportive of the group work, are lagging behind in completing their portion of team projects, etc. One can expect difficulties related to group dynamics when high achieving students dominate group projects and discussions, refuse to provide assistance to other group members. This is the so-called growth problems and difficulties associated with group dynamics in online learning, formation and development of the group as a team. In each case, a teacher needs to patiently explain the principles of cooperative learning, hold informal meetings with the groups facing problems, emphasize positive qualities of the group and its individual members, and form psychological compatibility among group members. It is also important to emphasize the ability to work in teams in a virtual environment.

Conclusion

In today's world, current revolutionary changes are associated with the intensive use of digital technologies in many spheres of human life, which democratize knowledge and access to open education. The ICT is increasingly implemented in the daily lives of individuals and the society. We are witnessing the formation of a new phenomenon – a global virtual learning community, which today includes more than one billion users. And the numbers continue to grow. Along with this, the market of online edu-

cational services is steadily growing. With the purpose of expanding online services, the leading universities create MOOC consortiums (e.g. Coursera, Udacity, edX, etc.) to initiate special programs for supporting the design and delivery of online courses, as well as the development of new tools for online learning systems. This creates a domino effect: along with the transfer of many university disciplines, including teacher education courses to the online format, there is a need to revisit the training of school teachers. Instead of the traditional teacher training, the focus is shifting toward a new type of training for teachers who can work in the digital age, with high demands on teachers' knowledge and ability to engineer an effective online learning (Tchoshanov) [23]. Moreover, in the digital era a teacher is not just an online tutor, she/he becomes an analyst and manager of informational resources, a designer and a constructor of courses, modules, and lesson fragments using interactive multimedia tools.

In connection with the emerging changes in the role of teachers in the digital age, an important question arises: what kind of a teacher is needed in the digital age? In order to meet the demands of the new era, a teacher in a traditional sense (e.g., someone who teaches) should be replaced by a teacher-engineer (e.g., someone who engineers student learning). This shift comprises integration of teacher knowledge of content, engineering, and didactics. At the same time, the integration implies reconceptualization of the key role of a teacher-engineer in the digital age: traditional teaching transforms into a research-based engineering of student learning. This transformation requires a teacher-engineer to understand the Learning Sciences in order to effectively design the learning objectives, digital content, and assessment, and to connect them.

The 'engineering of learning' paradigm places a critical emphasis on the development of teachers' engineering design thinking. The development of teacher-engineer's design thinking is a complex process based on the advancements of the Learning Sciences. It involves the following key competences:

1) the design of learning objectives: to create outcome-based, technology-enhanced learning environments that enable students to set their own learning objectives, monitor and assess their learning progress;

2) the engineering of content: to develop interactive content and relevant learning experiences through the selection and design of tasks, problems, projects, and activities that incorporate digital tools and ICT resources to promote student learning and creativity;

3) the design of assessment: to select and develop authentic assessments aligned with the learning objectives and content, and to use assessment data to improve teaching and promote student learning.

In order to respond to the challenges of the digital age, the theoretical underpinnings of distance learning itself need to be re-conceptualized. This re-conceptualization has a clearly defined vector – the Learning Sciences. The Learning Science is moving towards strengthening its design and engineering functions. The development of distance learning field in the direction of the Learning Science with its dominating design functions offers new opportunities for further understanding of learning in the digital age and creating effective learning environments in an emerging global learning community.

References

1. Bybee, R., Taylor, J.A., Gardner, A., Van Scotter, P., Carlson, J., Westbrook, A., Landes, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness*. A report prepared for the Office of Science Education, National Institutes of Health. Colorado Springs, CO: BSCS. Available at: http://science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/$FILE/Appendix%20D.pdf

2. Mason, J., Spence, M. (1999). Beyond Mere Knowledge of Mathematics: The Importance of Knowing-to Act in the Moment. *Educational Studies in Mathematics*. Vol. 38, no. 1-3, pp. 135-161, doi: https://doi.org/10.1023/A:1003622804002

3. Anderson, J.R., Reder, L.M., Simon, H. (1998). Radical Constructivism and Cognitive Psychology. In: Ravitch, D. (Ed.) *Brookings Papers on Education Policy*. Washington, DC: Brookings Institute Press, pp. 227-255.

4. Kafai, Y. (2006). Constructionism. In: R.K. Sawyer (Ed.). *The Cambridge Handbook of the Learning Sciences*. Cambridge: University Press, pp. 35-46, doi: 10.1017/CBO9780511816833.004

5. Mooney, C.G. (2002). *Theories of Childhood: An Introduction to Dewey, Montessori, Erikson, Piaget, and Vygotsky*. St. Paul, MN: Redleaf Press, 128 p.

6. Papert, S. (1993). *Mindstorms: Children, Computers, and Powerful Ideas*. 2nd ed. NY: Basic Books, 252 p.

7. Donovan, M., Bransford, J. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. National Research Council Report. Washington, DC: National Academy Press. 336 p.

8. Vygotsky, L.S. (1978) *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press. 176 p.

9. Papert, S., Turkle, S. (1992). Epistemological Pluralism and the Re-Evaluation of the Concrete. *Journal of Mathematical Behavior*. Vol. 11, no. 1, pp. 3-33. Available at: https://web.media.mit.edu/~ascii/papers/turkle_papert_1990.pdf (accessed 05.02.2021).

10. Downes, S. (2007). *What Connectivism Is*. Posted to the Connectivism Conference forum, University of Manitoba. Available at: https://www.downes.ca/post/38653 (accessed 05.02.2021).

11. Kop, R., Hill, A. (2008). Connectivism: Learning Theory of the Future or Vestige of the Past? *The International Review of Research in Open and Distance Learning,* Vol. 9, no. 3, doi: https://doi.org/10.19173/irrodl.v9i3.523

12. Siemens, G. (2005). *Connectivism: Learning as Network Creation*. Available at: http://masters.donntu.org/2010/fknt/lozovoi/library/article4.htm (accessed 05.02.2021).

13. Siemens, G. (2008). Learning and Knowing in Networks: Changing Roles for Educators and Designers. Paper 105. *University of Georgia IT Forum*. Available at: http://it.coe.uga.edu/itforum/Paper105/Siemens.pdf (accessed 05.02.2021).

14. Driscoll, M. (2000). *Psychology of Learning for Instruction*. Needham Heights, MA, Allyn & Bacon, 476 p. ISBN: 0-205-37519-7.

15. Kerr, B. (2007). *A Challenge to Connectivism*. Transcript of Keynote Speech, Online Connectivism Conference. University of Manitoba. Available at: http://ltc.umanitoba.ca/wiki/

index.php?title=Kerr_Presentation (accessed 05.02.2021).

16. Clarke, D.J. (1988). *Assessment Alternatives in Mathematics*. Canberra: Curriculum Development Centre. ISBN 186366 0194.

17. Sharan, S. (Ed.) (1990). *Cooperative Learning: Theory and Research*. N.Y.: Praeger, 328 p., ISBN-10: 027592887X.

18. Davidson, N. (1990). *Cooperative Learning in Mathematics*: A Handbook for Teachers. Menlo Park, CA: Addison-Wesley, 489 p.

19. Webb, N. (1982). Student Interaction and Learning in Small Groups. *Review of Educational Research*. Vol. 52, no. 3, pp. 421-445, doi: https://doi.org/10.3102%2F00346543052003421

20. Johnson, D.W., Johnson, R.T. (2009). An Educational Psychology Success Story: Social Interdependence Theory and Cooperative Learning. *Educational Researcher*. Vol. 38, no. 5, pp. 354-379, doi: https://doi.org/10.3102%2F0013189X09339057

21. Slavin, R. (1983). *Cooperative Learning*. N.Y.: Longman, 147 p., doi: https://doi.org/10.2307/3324014

22. Hagelgans, N.L. (Ed.), Reynolds, B.E., Schwingendorf, K.E., Vidakovic, D., Dubinsky, E., Shahin, M., Wimbish, G.J. (1995). *A Practical Guide to Cooperative Learning in Collegiate Mathematics*. (MAA Notes #37). Washington, DC. 190 p.

23. Tchoshanov, M. (2013). *Engineering of Learning: Conceptualizing e-Didactics*. Moscow: UNESCO IITE. 192 p.

НАУЧНАЯ ЭЛЕКТРОННАЯ БИБЛИОТЕКА
eLIBRARY.RU

Science Index РИНЦ-2019

Вопросы философии	5,471
Вопросы образования	5,214
Социологические исследования	3,145
Психологическая наука и образование	2,540
Интеграция образования	1,968
Образование и наука	1,281
Педагогика	0,876
Эпистемология и философия науки	0,871
Университетское управление: практика и анализ	0,789
Высшее образование в России	**0,759**
Высшее образование сегодня	0,314
Alma Mater	0,283