Constructionism: A New Way to Teach and Learn in the Fourth Industrial Revolution Age

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Abstract: The purpose of this study was to introduce the concept of a new instructional theory called 'constructionism', that was proposed by Papert. For this purpose, the definition and characteristics of constructionism were sought in comparison with constructivism. Constructionism is a new educational paradigm that Papert founded, based on the study of Piaget's constructivism in response to the new era of the industrial revolution. It emphasizes learning activities to produce specific outcomes in the educational values of constructionism through individual or collaborative activities of learners, such as 'building', 'making', and 'creating.' Papert describes constructionism as "learning by making", and the "making" process can be interpretable as both physical and non-physical components. Physical making refers to the creation of physical objects as a result of learning. Rather, non-physical making is the process of thinking that results in specific outcomes. Constructionism is characterized by class activities, such as creating, organizing, and expressing knowledge, and emphasizing the performance of learning activities. Constructionism shares the core elements of the learning process with constructivism. Concretely, constructionism can be realized in the classroom in a way that teachers and learners perform specific instructional activities such as project-based learning and resource-based learning. In addition, constructionism, as developed from constructivism, can emphasize collaborative learning via using communities of practice for collective intelligence. These construction-based learning activities extend from traditional children's play to recently highlighted activities including coding education, 3D printing in education and maker education. In conclusion, constructionism is expected to play an important role to support theoretical background in future learning environments. Recent studies will be the foundation of new learning environments that need to support educational activities in the fourth industrial revolution age.

Keywords: Constructionism, Constructivism, 4th industrial revolution, learning theory, instruction

INTRODUCTION

Intellectual resources such as creativity and problem solving ability have been emphasized in the 21st century with the emergence of the fourth industrial revolution age. Accordingly, a new approach and learning competency are required in education.. For a long time, some experts have emphasized the importance of "learning by doing" so that learners could learn from their own experiences in the real world. Also, there are arguments that learning should go with education designing, making and creating objects. In this regard, Seymour Papert is referring to the founder of constructionism that was further developed based on constructivist theory.

Papert's constructionism evolved from Piaget's constructivism, and furthermore he wished to establish an optimal theory that could correspond to the advanced sotiety with computer-based learning environments. Papert's ideas on "learning by making" now get to interest again, as a new era of technological disruption. Although Papert's work on Logo began more than 50 years ago, his core ideas are as important and pertinent today as ever before. It is evident that constructionism includes a lot of possibilities to cultivate learners' competency required in the 21st century. Constructionism-based education consists of remodeling, creating, improving, and sharing with peers or outsiders using a variety of tools (3D printers, application software, tools, etc.). This process can enhance learners' capacity as autonomous and collaborative learning activities are supposed to happen, which are also directly to be linked with real lives.

In this paper, we will examine concepts, uses and future developments of constructionism.

THEORETICAL BASIS

Constructionism

Constructionism is a theory founded by Seymour Papert, a mathematician and computer scientist.. Papert has been influenced by both Piaget as a scholar, and constructivism as a theory (Papert, 1991). Papert developed constructionism further based on the framework of constructivism to establish the optimal theory corresponding to his main field of study -

computer-based learning environments. In other words, constructionism adopts the physical activities, such as “building”, “making”, and “creating,” in which learners generate concrete results through individual or collaborative activities.

Papert explained constructionism as "learning by making" (Papert, 1991). Making as mentioned above refers to not only a physical activity composed of visible elements but also non-physical and cognitive one. Physical activity is related to the creation of a physical object as a result of learning. Non-physical on is the result of specific thought process that may not appear as tangible. In this process, computers play a major role in contributing to learning by enhancing creativity, expressiveness, and motivation (Falbel, 1991).

Classroom activities to implement constructionism include building and constructing learners’ own knowledge (Harel & Papert, 1991). Noss and Clayson (2015) systematically developed the classroom activity process in constructionism, highlighting the role of constructionism as a thinking frame for learners to learn in the most effective way: 1. Building a model, 2. Reflecting on the model, 3. Debugging the model, 4. Sharing the model.

“Central to any notion of constructionism, and its first defining characteristic, must of course be the idea of modelling; that is, by creating external building blocks by a process of building, reflecting and debugging, learners can develop relevant internal knowledge structures. Modelling, approached in this way, promotes the learning of powerful ideas through use, in contrast to the conventional way of much teaching (Papert’s 1996 “Power Principle”). This last characteristic points to collaboration, which is worthy of a separate defining characteristic of a constructionist agenda, not least as we are seeing rapid developments in the ways that it is possible for students to share resources and ideas and to collaborate through technological devices, both in the same physical space and at a distance.” (Noss & Clayson 2015: 287-288)

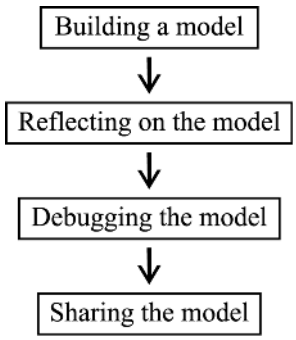

Figure 1.Noss and Clayson thinking process phase.

Constructionism follows general principles of constructivism, however, constructionism could be understood as a principle that emphasizes the process of the learner physically or psychologically embodying objects. At this point, the learner is engaged in learning activities in a very active way. This involves a variety of activities to explore, ask, and solve learning problems and content. Therefore, learning based on constructionism has a strong attribute for “playful learning.” (Resnick, 2004).

Constructivism vs Constructionism

Constructionism shares the key learning process elements with those of constructivism in terms of pursuing knowledge construction for oneself. By the way, constructionism can be distinguished from constructivism by emphasizing learner participation in the process of creating physical objects (Papert, 1991). More specifically, constructivism and constructionism are compared as follows.

First, constructivism emphasizes the construction of cognitive knowledge, whereas constructionism is interested in making learning results based on constructed knowledge.. Constructivism assumes that the results are to be expressed in a cognitive form when constructing knowledge. This characteristic can be found in most of the constructivist theories such as the cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1992), and the cognitive apprenticeship (Collins, & Brown, & Newman, 1989). On the other hand, constructionism is more interested in actual output of learning. Examples of the philosophy include block construction through LEGO, movement generation of objects through logo programming, and production of results through making procedure.

Second, constructivism emphasizes the context of individual knowledge construction. The knowledge constituted by individual contexts and experiences may be different, which is the core of knowledge construction results. In contrast, constructionism emphasizes the process of constructing playful and imaginative knowledge process (Resnick & Robinson, 2017). This philosophy of constructionism is a learning criterion that goes through a series of processes that produce learning outcomes.

Third, constructivism is interested in achieving collective intelligence based on collaboration through Community of Practice (CoP). In contrast, constructionism emphasizes the creation of individual learning outcomes through creative thinking (Resnick & Robinson, 2017). In sum, constructionism shares the basic philosophy with that of constructivism, but constructionism has its own unique learning orientation.

Similar theories

It is worth considering Rousseau's naturalism and Dewey's progressive education theory as it goes back to finding theories that are educational philosophical backgrounds of constructivism and constructionism.

Brubacher divides naturalism into Pragmatic naturalism represented by Dewey and Romantic naturalism represented by Rousseau Pragmatism has borrowed these naturalistic philosophies. Thus, progressivism can also be regarded as an educational movement influenced by naturalism.

Jean-Jacques Rousseau's Naturalism education

Rousseau's theory represents a naturalistic education that sees the realization of nature born. Rousseau recognized the natural state of human beings as worthwhile, and found the purpose, content, and method of "nature-based" education.

Rousseau's "Emile(1762)" is a full-length educational novel composed of five parts. In this novel, Rousseau divides the growth process from newborn to adolescence into five stages and discusses the developmental process of each stage and argues appropriate education. Rousseau's educational philosophy is the claim of the human nature, and He calls the goal of education a natural goal. Nature education aims for a natural human being. A natural human being is a person who interacts directly with the environment through direct experience. What is required to realize is the principle of "Negative education." Negative education is not an active education in which the teacher takes precedence in the metaphorical sense, but rather an education that catches the object of interest appropriate to the developmental level of the child and pushes the child's spontaneous growth from behind. This is an education that helps children experience, feel, and realize through their activities. At this time, the child's learning should be done through direct sensory experience with the child's surroundings rather than by linguistic activities such as lectures, preaching, and books. Providing the child with all the procedures and answers makes the child receptive to the experience of others. Therefore, naturalists view active self-activity as a desirable learning that solves the problem through the senses in active interaction with the environment. This principle of learning through the senses has a great influence on the "progressive education" represented by Dewey in the 20th century. It is also an education that promotes the growth from the inside of the child, not from the outside mold that transforms the child according to the framework that the teacher or the parent creates. The role of the teacher in negative education is an assistant to promote the growth by observing the process of growth and change of the child and giving necessary help. In other words, the education that Rousseau advocates is to create, assist, and promote the active participation of the learner, which is in line with the position of constructivism. The role of the instructor is the same as that of the constructivist teacher, as seen as a facilitator and a guide, not as a person who communicates knowledge as an authority to learners.

John Dewey's Progressive education

Dewey is a leading thinker of progressive education from the United States. Progressive educationalists actively inherited the naturalist education traditions formed in Europe in the 18th century, while accepting Pragmatism to form the theory of progressive education. The most prominent feature of Pragmatism is the philosophy of "change." According to the Pragmatic perspective, the ultimate essence of this world is constantly changing. Thus, with Pragmatism, value is seen as contextual rather than absolute or universal. At this time, the fact that knowledge is contextual is one of the basic assumptions of constructivism, which is linked to the provision of constructivist learning principles, as well as contextual and situational knowledge.

Dewey's education theory is well known as "learning by doing." Dewey emphasizes the subjective practice of learning through experimental education. For Dewey, education is a process in which an organism lives in an environment and is constantly reconstructing experiences. Dewey redefined the content of education from the viewpoint of 'experience' as the subject in which the experience occurred to the child. Here, according to Dewey, the meaning of the experience does not mean to try, but rather to experience. There is "continuity" in which experience is constantly linked to later experiences, and it is an educational experience when "environment-organism interaction" occurs. In doing so, the task of educators is to empirically construct and reconstruct a curriculum that starts from the student's current interests and concerns and ensures continuous development into new, extensive experiences. Therefore, rather than focusing on the existing curriculum, the curriculum should incorporate existing curriculum or include elements related to actual life so as to enable the child to experience it. In short, progressive education emphasizes that the subject should be related and taught to the child's life experience, rather than claiming a separate curriculum consisting of the child's experience with a "Subject-centered curriculum." In this way, from the point of view of the child's experience, the curriculum in progressive education is called the "Experience-centered curriculum." This is consistent with the content of various learning models of constructivism as follows. For instance, cognitive apprenticeship allows students to experience changes in their knowledge state while observing and practicing professional tasks in real life. Additionally, situated learning helps improve the problem solving ability and the transfer effect of learning by providing available knowledge in a real situation. Lastly, the cognitive flexibility theory emphasizes the need for a theme-based flexible learning environment to develop adaptive coping abilities for rapidly changing situational needs. In sum, all of these learning models are deeply related to constructivism. On the other hand, the results of constructionism are not only a product of

concrete learning, but can be evaluated as a useful teaching method in terms of practical understanding of educational ideas and by being applied or utilized in connection with real life. This experiential education is enriched through cooperation and collaboration among learners, while teachers maintain close communication with learners.

CONSTRUCTIONISM-BASED EDUCATION TRENDS

LEGO/Logo

The Logo is a practical software that connects the logo from the representative toy block LEGO to the programming language. The learners freely assemble the LEGO blocks and perform learning through play. By adding gears, motors, sensors, etc., it is possible to move static LEGO blocks. Now the LEGO block is connected to the computer and the learner uses the Logo program to move the object using the LEGO block. Thus, LEGO/Logo provides an environment that allows learners to perform very rich constructionism activities. This will continue to develop into a "programmable brick" and "intelligent brick." In 3D printing education, experts have to observe a process of development of LEGO/Logo. Especially software needs advanced to learning age, devices that are constantly evolving and the trend of results. The LEGO/Logo project started with the creation of structures, but it evolved to understand future mechanisms and to change the behavior to enable robot-like behaviors (Resnick, 1993).

Programming education

Programming education or coding education uses software to develop thinking, reconstruction, and development of the learning product.

Learning through educational programming developed from Logo is available from the elementary level called "Scratch" to various degrees of difficulty and depth such as JAVA, C ++, etc. Pellas and Peroutseas (2016) analyzed the effects of programming education using a 3D online virtual environment. In the study, students learned Scratch programming in a collaborative learning environment using real-time and non-real-time communication tools through “Secondlife” webpages. As a result, students actively learned through the online collaborative learning environment, anywhere at any time. Also, teacher feedback was effectively implemented on the virtual reality enhancing the learning effect.

In particular, from the viewpoint of constructionism, computational thinking plays a major role in organizing and managing the learning content through a collaborative problem solving process. Programming or 3D printer-based education extend learning areas to various learning activities. Using these learning elements, learning goals should aim at promoting social, cognitive, and high-order thinking ability through the participation in activities of learners.

Maker education

According to Dougherty (2012), the creator of the maker movement, "Makers collectively refer to those who perform various activities that produce various products, and this process is usually represented by playing with technology-related activities." In other words, making means the 'maker uses various tools to create creative outputs, and activities to share and communicate with others. Making is the activity of making something necessary for itself or the society, sharing knowledge with other makers with cooperative activities. In recent years, with the development of science and technology, such as 3D printers, we have come to an era in which individuals can produce specific objects or products directly from consumer objects of mass production, which are more active, creative, and independent producing activities. In the field of education, under the influence of the maker's movement, it is expected the effect of not only achieving learning goals through various creative activities within the school curriculum, but also expanding the abilities of learners in the learning process. More specifically, as a tool to help students perform STEM-related subjects through a ‘Maker movement,’ learners can participate in more vivid and appropriate ways to achieve learning goals (Maker culture, n.d.). Kafai et al., who branded maker education on the basis of Papert's constructionism and named it "Makeology," described the results they found in their observations in a learning camp (Peppler, Halverson & Kafai, 2016).

According to the maker movement concept, the learners produce their own learning content through their thinking. This goes beyond traditional thinking process that educational producers and consumers are separated from each other. In other words, if the government, the educational institution, the school, and the teacher are educational producers who define what students should learn, the learner is an educational consumer who accepts the generated content. However, through the maker movement, the learner breaks the linear structure of consumption in production by acting as a producer of content. In this respect, the maker movement is innovative in terms of being achievable through disruptive technology, and it is expected that the effect will be enhanced as it is applied to education.

3D printing in education

Although 3D printers are not necessarily designed for educational use, they have the characteristics to promote educational activities for students when used in educational scenes.

The objective of using 3D printers in learning can be twofold. First, it is necessary to understand the

concept of a 3D printer, understanding of design, and basic understanding of the idea generation process and method. Second, we need to understand, apply, and utilize 3D printer software, 3D printer output, and technologies in practice. it is required to achieve the learning objectives with proper instructional strategies such as STEAM and design-thinking using 3D printers.

Classes using 3D printers, as well as using programming, LEGO/Logo are experience-oriented learning. In particular, 3D printers experience hands-on results that produce tangible objects rather than experiencing them in a virtual or on-line. This type of learning builds itself into the process of producing concrete outcomes, and continues to develop itself through challenges and failures to produce successful outcomes.

General learning environments using 3D printers are to be set with learner-centered. The advantage of this participatory learning is that the motivation of the learner is enhanced and the level of participation in the class is high. It is also advantageous for memory and retention because learners acquire knowledge for themselves from the context. Although the physical participation of learners is an essential process, participant learning can be facilitated when learners engage in active activities with high motivation and engaging learning activities.

In this learning process, learners should be asked to utilize metacognitive skills to think, criticize, revise, and supplement themselves, which ultimately leads to creative learning activities.

CONCLUSION

Rapid technological changes and advances are always controversial because it gives people hope and fear at the same time. However, technology is developing faster whether we want it to or not. Therefore, it is not appropriate to accept or criticize technologies indiscriminately.

Careful consideration and research should be required to properly use technology where it is needed and to achieve the desired effect. The same is true in education. Recent trends of social change, represented by the fourth industrial revolution age, has also increased the anxiety about current education and has changed the way of education. The capacity required for growing students in the changed educational environment is also changing and becoming more diverse. Golinkoff and Hirsh-Pasek (2018), who have studied science for decades in how children learn, emphasize that '6C' is a necessary skills for future generations. ‘6C’ is an abbreviation of Collaboration, Communication, Contents, Critical Thinking, Creative Innovation, and Confidence. It covers both hard and soft skills. As the necessity of soft skills education emerges from the classroom where the existing hard skill improvement was central, instructional methods would be applied variously. When using the ideas of Rousseau to Dewey and other scholars, it is essential to consider the thoughts of many philosophers who have been constantly contemplating learner-centered education and apply it to instructional methods of the new age.

To this end, further research on constructionism, which is an advancement from the existing constructivism, is required. Additionally, rich experiences using the ideal of constructionism will be helpful for adopting practical use of constructionism-based learning environments.t.

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