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A Quest of Design Principles of Cognitive Artifacts through Case Analysis in e-Learning: A Learner-Centered Perspective

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Learners are often posited in a paradoxical situation where they are not fully involved in decision making processes on how to learn, in designing their tools. Cognitive artifacts in e-learning are supposed to effectively support learner-centered e-learning. The purpose of the study is to analyze cases of cognitive artifacts and to inquire those design principles for facilitating the learner-centered e-learning. Four research questions are suggested: First, it will be analyzed the characteristics of learners with respect to design of cognitive artifacts for supporting the learner-centered e-learning. Second, characteristics of four cases to design cognitive artifacts in learner-centered e-learning environment are analyzed. Third, it will be suggested the appropriate design principles of cognitive artifacts to facilitating learner-centered learning in e-learning environment. Four cases of cognitive artifacts design in learner-centered e-learning was identified as follows: Wiki software as cognitive artifacts in computer-supported collaborative learning; 'Play Around Network (PAN)' as cognitive artifact to monitor learning activities in knowledge community; Knowledge Forum System (KFS) as a cognitive artifact in knowledge building; cognitive artifacts in Courses-as-seeds applied meta-design.

Five design principles are concluded as follows: Promoting externalization of cognitive artifacts to private media; Helping learners to initiate their learning processes; Encouraging learners to make connections with other learners' knowledge building and their cognitive artifacts; Promoting monitoring of participants' contributions in collaborative knowledge building; Supporting learners to design their cognitive artifacts.

Keywords : cognitive artifacts, cognitive artifacts design, learner-centered design (LCD)

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Introduction

Recent technological developments make researchers, instructors and learners explore the use of computers, network technologies, and related technologies to support a variety of innovative teaching and learning approaches. Contemporary theories on human learning such as constructivism, situated cognition, and knowledge building emphasize the role of learners to understanding what they experience about their learning environment. Learner is viewed as an active constructor of knowledge. Accordingly, the needs for learning technologies which empower learners through learner-centered learning such as self-directed or self-regulated learning have emerged.

Although many researchers have recently paid attention to learner-centered learning strategies, learners are usually posited in a paradoxical situation in which they have insufficient knowledge, inefficient skills, and lower level of controllability of learning technologies. Even though learner is responsible for accessing, selecting, organizing, and analyzing information according to their unique needs in learner-centered learning environment (Hannafin, Land, & Oliver, 1999; Jonassen & Grabinger, 1990), learners are usually provided with a limited amount of resources for solving the given problems. Learners are often ill-equipped cognitively to navigate vast information networks, to identify and select appropriate resources and to interpret learning materials. Few studies have been conducted to investigate and identify what paradoxical situations learners are in learner-centered learning environment. In addition, few insights exist when it comes to dealing with learners' controllability of learner-centered e-learning technologies in which learners dynamically construct and evolve intuitive theories using learner-centered e-learning. Problem-based learning (PBL), for example, is one of the most popular learner-centered instructional models. Even though most PBL cases are claimed to be learner-centered learning strategy, they are actually not learner-centered learning strategy because the learners are not fully involved in decision-making processes in

solving problems.

PBL often capitalizes on technological tools for analyzing, presenting, and communicating results. PBL also capitalizes on technological capabilities to provide opportunities to represent and manipulate complex, and often abstract, concepts in tangible, concrete ways (Morrison & Lowther, 2005). Cognitive artifact as a technological tool in PBL can support the cognitive structure construction. However, many programs of PBL in e-learning are actually not learner-centered because technological tool can not be redesigned, modified by learners (Fischer, 2003, 2007).

Learners can use learning technologies to collaborative with others via network, to gather data, to graph and analyze data, to produce multimedia artifacts (Scardamalia & Bereiter, 2006; Stahl, Koschmann, & Suthers, 2006). Further, when learners publish what they solve the problems, the artifacts that learners develop make their understandings visible to others. If artifacts are concretely and explicitly externalized, they allow learners to share and have their artifacts reviewed by instructors, learners, parents, and members of community (Scardamalia & Bereiter, 2006).

Cognitive artifacts refer to man-made things that seem to support or enhance learner's cognitive abilities. Norman (1991) defined that cognitive artifacts are artificial devices to maintain, display, or operate upon information in order to serve a representational function and that affect human cognitive performance. On the other hand, Scardamalia and Bereiter (2006) mentioned epistemic artifacts which can refer to something that are created by learners and serve for Knowledge building. According to Scardamalia and Bereiter's perspectives, epistemic artifacts are main values created in situation that learners are engaged in the deliberate creation and knowledge improvement which are valued for a community (Scardamalia & Bereiter, 2003, 2006).

In some perspectives of cognitive artifacts, Norman (1991) focused on artificial device or perspective while Scardamalia and Bereiter (2006) focused on student-

generated products from his perspective of epistemic artifacts. Until now, it is really hard to find out the clear definition of cognitive artifacts in learner-centered e-learning environment, although most of the scholars who are interested in this field, tried to define the cognitive artifacts on cognitive science view points. In this study, cognitive artifacts is operationally defined not only as a tool that serve a representation and presentation function and affect learners' cognitive performance but also as a product such as ideas, theories, models, solutions that can be physically generated, articulated, circulated by learners and instructors in e-learning.

Tools as cognitive artifacts play important roles in e-learning as learner-centered learning environment (Land & Hannafin, 1996) in which problems are framed in authentic and meaningful contexts, learners are engaged in problems using multiple resources and tools, and knowledge construction is facilitated using technology as well as human scaffolds (Hannafin et al., 1999). In order to reduce an unexpected cognitive load of the learners and to enhance learners' controllability in learner-centered learning, it needs to examine how cognitive artifacts that aid in learner-centered learning environment can support to enhance learners' controllability of learner-centered learning environment.

The major purpose of this study is to analyze the cases of cognitive artifacts and to inquire the cognitive artifacts design principles for facilitating the learner-centered e-learning and to point out the necessity of systematically analyzing the potential of cognitive artifacts as tools to support learner-centered e-learning. More specifically, to achieve this research purpose, the research questions are suggested as follows: First, it will be analyzed the characteristics of learners with respect to design of cognitive artifacts for supporting the learner-centered e-learning. Second, characteristics of four cases to design cognitive artifacts in learner-centered e-learning environment are analyzed. Third, it will be suggested five design principles to design the cognitive artifacts to facilitating learner-centered learning in e-learning environment.

Learners' Characteristics for Learner-Centered Cognitive Artifacts Design

Recent technological developments over the last two decades, such as personal computers, the Internet, wireless network, and web based multimedia technology have emerged and those developments gave us tools to support a variety of innovative and transformative teaching and learning approaches. However, many cases for supporting effective learning are not likely to succeed. Cuban (1986) noted two reasons why previous technologies before 1980s have failed in educational field: First, previous technologies could not be modified along with the needs of learners. Second, previous technologies could not be effectively integrated all the educational contexts, learning activities and goals. Therefore, if cognitive artifacts have to effectively support learning, they seems to be designed to focus on learner's goals, needs, activities, and educational contexts (Quintana, Shin, Norris, & Soloway, 2006). There are critical issues to consider not only software usability but also nature of learners (Quintana, Soloway, & Krajcik, 2003).

Quintana et al. (2006) introduce two software design approaches such as learner-centered design (LCD) as a new software design methodology and user-centered design (UCD) as a typical software design approach. They analyzed what the differences between two approaches are. In UCD approaches, software designers try to make their software easy for people to use since learners are novice users, but in LCD approaches, software designers seems to consider the nature of learners and instructors could not be considered as the only professional users as well (Quintana et al., 2006).

In order to design learner-centered cognitive artifacts, it should be considered the two reasons of previous technologies failure pointed out by Cuban (1986) and LCD/UCD approaches for software designs analyzed by Quintana et al. (2006). It is necessary for identifying the differences between learners' characteristics and instructors' characteristics with respect to the design of learner-centered cognitive

artifacts. Accordingly, it could be summarized with four cognitive artifact design aspects such as expertise aspect, growth in skill aspect, motivation aspect, community aspect and two user dimensions such as instructors' characteristics and learners' characteristics. It could be really hard to get the support from teachers' expertise since there may not be elements to substitute teachers' role as experts in e-learning environment. In this sense, the cognitive artifacts to substitute teachers' role as experts is necessary for learner-centered e-learning environment. Here is precisely described the differences with respect to four aspects as follows.

Expertise aspect: Learners may be assumed not to have expertise or to have lower expertise. In other words, learners may have insufficient or incomplete know-how information of the activities, tools, and practices in given tasks. On the other hand, it may be assumed that instructors have already expertise such as domain knowledge and problem solving skills in given tasks.

Growth in Skill aspect: Learners' goals are to develop subject domain knowledge and learning skills for example, problem solving skills. In accordance with learners' gradual advancement in learning processes, cognitive artifacts can support learning activities to construct cognitive structure by modifying itself along with learner's growth simultaneously. On the other hand, instructors usually start to teach every subject with expertise. Thus, it may not be necessary for instructors to show their growth in knowledge and skills. Therefore, in teacher-centered instruction, cognitive artifacts can be designed without any consideration of cognitive artifacts' modification with respect to any growth in instructors' knowledge and skills.

Motivation aspect: Learners are usually considered not to be highly motivated in new learning situations. In learner-centered e-learning environment, it is necessary to design cognitive artifacts which can support to motivate learners' engagement. On the other hand, it can be assumed that instructors are deeply involved and motivated in their activities. That is why it is not much necessary to provide something for motivating instructors in teacher-centered instruction. Cognitive artifact designers can assume that instructors have the sufficient motivation to be

engaged in their work.

Community aspect: Learners are generally belonged to heterogeneous group because of their different level of prior knowledge and skills. Therefore, it is necessary that diverse individual characteristics have to be considered for developing the cognitive artifacts. On the other hand, instructor as a single person is considered to be an expert. It is not so much considered instructors' characteristics for developing cognitive artifacts in e-learning.

Analyzing the Characteristics of Cognitive Artifacts through Four Cases Analysis

Learner-centered e-learning generally attempts to provide learners with liberation over and responsibility for what is learned. Especially, PBL encourages learners to explore and examine a variety of problems and resources to construct personal strategies for handling these problems, as well as negotiate and share solutions (Barrows & Tamblyn, 1980; Bransford, Zech, Schwartz, Barron, & Vye, 2000). PBL provides learners with learner-centered learning processes rather than direct instruction for transmitting concepts and knowledge.

Recent researchers (eg., Bereiter & Scardamalia, 2003; Land & Hannafin, 1996; Scardamalia & Bereiter, 2006) have emphasized activities that facilitate higher-order cognitive skills in technological environments. Four cases are reviewed as applications of cognitive artifacts to facilitate problem solving, creative problem solving, and metacognitive analysis in learner-centered e-learning environment.

Characteristics of Wiki software (Wikipedia) as cognitive artifacts in computer-supported collaborative learning

Collaborative activities in Wiki service give rise to, for example, the production

of the world's largest online encyclopedias such as Wikipedia since every internet user is allowed to participate in this undertaking (Korfiatis, Poulos, & Bokos, 2006). The Wikipedia example will be applied in this article in order to figure out the design principles of cognitive artifacts for learner-centered e-learning more concrete. In Wiki software, people work jointly on one artifact and a multitude of people around the world are able to participate in collaboratively working process anywhere and at anytime. After a user externalize his or her knowledge in a Wiki, the Wiki exists independently from the individual person's knowledge. The individual person's knowledge can serve as a resource for other peoples' learning (Kafai, 2006; Scardamalia & Bereiter, 1994). Contributing to an article does not only allow the creation of an artifact, it can also lead to individual learning processes in the contributors.

Wikis' potential as a cognitive artifact for learner-centered e-learning lies in their ability to allow to facilitate shaping of knowledge according to learners' needs (Reinhold, 2006). Strengths of Wiki software as cognitive tools are to support learner-centered e-learning due to their ability to facilitate collaboration (Notari, 2006), to allow for design-based learning (Rick & Guzdial, 2006), and to support inquiry learning and the co-construction of knowledge (Yukawa, 2006). Overall, Wiki can be generally considered to support social constructivist learning (Bruns & Humphreys, 2005).

Wiki software as a cognitive artifact implies not only to support monitoring peer's participating processes to learner's products as cognitive artifacts (eg., 'Discussion' or 'edit' page in Wikipedia) but also to view their ideas as useful communal cognitive artifacts for navigating knowledge community.

Characteristics of the structure and functions of 'Play Around Network(PAN)' as cognitive artifact to monitor learning activities in knowledge community

Play Around Network (PAN) (see Figure 1) as a cognitive artifact developed by Youn & Lim (2008) shows nodes and links based on e-learning system database.

Every node and link in PAN can be simultaneously changed in response to information of learners, problems, projects, products and their interrelationship generated in database. Learners can navigate whole information in e-learning system and monitor learning activities of community level and explore peers' products and their interrelationships by using PAN as cognitive artifacts. If learner chooses a node, then that node is located in center of PAN and also that node is surrounded by another node with related information. PAN as a cognitive artifact is operated to incrementally enlarge the network with nodes and links as shown in Figure 1.

Figure 1. Screenshots of Play Around Network (PAN) (Youn & Lim, 2008)

PAN provides several ways to connect among learners as well as between learners' products and ideas. Using this PAN, learners can see, at a glance, not only anyone who is linked with many peers and who is isolated with peers, but also which ideas are highly connected and isolated. Instructors, in this case, encourage learners to take up peer's ideas and products, and also extend them through online activity.

Analyzing the case of PAN, the goals of PAN as cognitive artifacts imply not only to encourage collaboration and efficient distribution of information resources, but also for learners to view their ideas as useful communal cognitive artifacts like communal navigation tools.

Incrementally enlarge T

Characteristics of Knowledge Forum System (KFS) as a cognitive artifact in knowledge building

Scardamalia and Bereiter (2003, 2006) stressed differences between Knowledge building and learning. Knowledge building can be defined to be creating or modifying public knowledge. Knowledge building is a phenomenon that lives 'in the world', and is available to be worked on and used by other learners. In contrast, learning can be defined as an internal unobservable process that results in changes of beliefs, attitudes, or skills.

The theory of knowledge building encompasses the fundamental learning, sub skills, and socio-cognitive dynamics pursued in other approaches, along with the additional benefit of movement along the trajectory to mature education (Scardamalia & Bereiter, 2003). Knowledge building refers to the process of creating new cognitive artifacts as a result of common goals, group discussions, and synthesis of ideas. These pursuits should advance the current understanding of individual within a group, at a level beyond their initial knowledge level, and should be directed towards advancing the understanding of what is known about that topic or idea.

'Knowledge Forum system (KFS)' as an example of cognitive artifact for effective knowledge building, which was developed by Scardamalia and Bereiter (2003), is designed to facilitate metacognitive thinking through the use of prompts to generate questions, hypotheses, or theories. KFS is a multimedia database which is designed to maximize the ability of a community of users to create and improve both its content and organization (Scardamalia & Bereiter, 2006).

Cognitive artifact like KFS strongly implies to support learners to individually or collectively control the whole range of components of knowledge building which include goals, strategies, resources, evaluation of results, and so on. In KFS, learners can create their views and have responsibility for different views.

Characteristics of cognitive artifacts in case of Courses-as-seeds

Courses-as-seeds is a kind of instructional model that explores meta-design and social creativity in the context of universities (dePaula, Fischer, & Ostwald, 2001). It's goal is to create a culture of informed participation that is situated in the context of university courses of semester-based classes (Fischer & Ostwald, 2005). The content of a course such as lectures, readings, and assignments is traditionally defined by the resources provided by instructors. Making learners involve as active contributors, courses itself do not have to rely only on the intellectual knowledge provided by the instructors. In case of courses-as-seeds, courses can be explained a kind of cognitive artifacts that the instructor provides the initial seed rather than a finished product, according to the SER model (Seeding, Evolutionary growth, Re-seeding model) (Fischer, 2003; Fischer & Ostwald, 2002).

In case of Courses-as-seeds, learners are identified as active contributors, who are engaged in not only the assignments but also the design of the courses themselves. Learners choose their projects and form teams based on individual interests and share their work in courses-as-seeds.

Courses-as-seeds implies that learners are able to examine how current cognitive artifacts are limited; to analyze and create specifically additional cognitive artifacts; to explore different interactive modes including face-to-face activities, synchronous, asynchronous with the cognitive artifacts; and to utilize new paradigms such as meta-design for developing the open/extensible cognitive artifacts (Fischer, 2007).

Five Principles Suggested for Cognitive Artifacts Design to Facilitate Learner-Centered e-Learning

Based on learner's characteristics and cognitive artifacts characteristics from four cases analysis, it can be suggested five principles of cognitive artifacts design to

facilitate learner-centered e-learning as follows.

Promoting externalization of cognitive artifacts to private media

Cognitive artifacts can support externalizing individual products and providing a situation to be engaged in public knowledge building process through solving a knowledge-related problem or task. Kafai (2006), Scardamalia and Bereiter (1994), and Krajcik and Blumenfeld (2006) stressed that learners learn more effectively when they develop artifacts and external representations of their constructed knowledge. Especially in problem solving based learning, cognitive artifact developed by learner results from learners' investigation into the driving question (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palinscar, 1991).

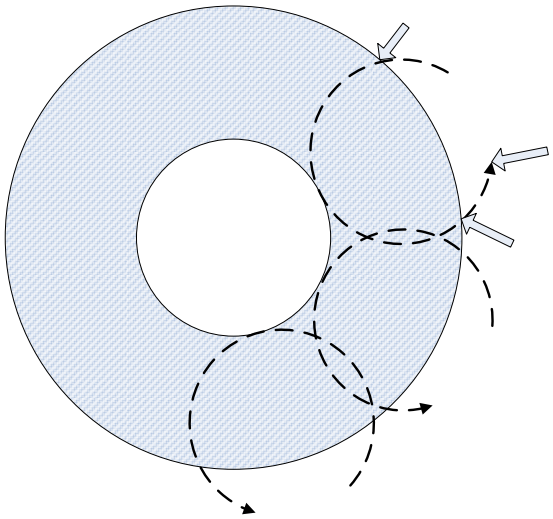

Figure 2. Externalizing learner's cognitive artifacts and engaging public knowledge building

Learners can use not only Wikipedia as a public space but also blog as a private media for their products. Learners can participate to public knowledge building area

through their learning trajectory from questioning to product and they are interrelated with each other (refer to Figure 2). By using their blog as a private media in social networking web site as a public space, learners can create or modify public knowledge while learners are actively engaging in learning environment.

As shown in [Figure 2], it represents conceptual model that learners produce a solution of knowledge-related problem and private experience-related problem as a cognitive artifact. If a learner externalizes his or her products, then other learners can use these products as learning materials and other learners can interconnect their products to other's. In this regards, Scardamalia and Bereiter (2006) suggest that when learning is decontextualized, knowledge and skills may become inert, or unable to transfer from one context to another.

Helping learners to initiate their learning processes

PBL as a learner-centered instruction, approaches usually limit learners' involvement to problem solving processes itself (Kim, 2006). In PBL, learners can learn about problem-related subject domain knowledge and problem solving skills in authentic situation. Also, cognitive artifacts must not only support the acquisition of the problem solving skills but also be adoptable, changeable in respond to change of learners' problem solving skills and problem solving processes as individual cognitive structure (Greeno, 2006). In accordance with learners' gradual enhancement of competencies in learning processes, cognitive artifacts can support learning activities to construct cognitive structure by modifying cognitive artifacts along with learner's enhancement of competencies (Quintana et al., 2006).

Although learners are involved in learner-centered PBL in e-learning environment, it seems not to be exactly learner-centered e-learning since learners are not fully involved in critical decision making processes on how to solve problems. In authentic learner-centered PBL, learners can completely control over not only their problem solving processes but also the contents, use of tools and

supports, and so forth (Kim, 2006). In collaborative learning environment, although the process-oriented nature of collaborative learning in traditional teaching-learning situations is indisputable, both E-Learning in general and collaborative E-Learning in particular commonly neglect this fact (Helic, 2006). Morrison and Lowther (2005) capitalized on technological capabilities of tools to provide opportunities which can represent and manipulate complex and abstract know-how knowledge in tangible ways. Cognitive artifact as a technological tool in PBL can support the cognitive structure construction such as problem solving processes. If learner-centered e-learning could be effective, learners seem to be able to decide, plan, monitor, and evaluate their learning processes by themselves.

Encouraging learners to make connections with other learners' knowledge building and their cognitive artifacts

Learners generally study in heterogeneous group in a regular classroom and they have different levels of prior knowledge and skills (Quintana et al., 2006). As a connectionist model, knowledge is stored in connections that modulate the transfer of activity from one unit to the next (Schneider & Graham, 1992). Learning always involves modifying the connection weights. Multiple processing occurs simultaneously because information is stored in the strengths between the connections instead of static form (Gredler, 2004).

Learners have few opportunities to take up other's work and build on it in conventional offline classrooms. A great emphasis cognitive artifacts in learner-centered e-learning focuses on making connections with other learners and between their products. As mentioned before, Wiki software as a cognitive artifact can support not only monitoring peer's participating processes to learner's products but also to make connections with other students' knowledge. Also, PAN as a cognitive artifact can be a tool to effectively and efficiently observe other's behaviors and to enable for constructing individual learner's problem solving process model and for

monitoring other's results of decision-making, and for changing their behavior model.

Cognitive artifacts in learner-centered e-learning should provide functions for monitoring and viewing other students' knowledge building processes and their products. By using PAN as a cognitive artifact, learners can take advantage of their peers' knowledge productions they have to know that those productions exist and they can find out their model in the cognitive artifacts. PAN provides a graphical overview of the group's products. It includes a function that allows an individual to see at a glance which products have already been produced by themselves as well as others' and a function that allows an individual to connect, explore toward that product (refer to Figure 1).

Promoting monitoring of participants' contributions in collaborative knowledge building

One of the fundamental changes is the new opportunities of collaborative learning in which all learners can act as active contributors in personally meaningful problems or topics. Innovative information technology allows researchers and also learners to monitor the real collaborative learning process of myself and other learners. However, it is usually neglected collaborative learning process in collaborative e-learning situations (Helic, 2006). Wiki software as a cognitive artifact provides new opportunities for learning and collaborative knowledge building as well as for understanding these processes and how learning and collaborative knowledge building take place (Cress, & Kimmerle, 2008). In a wiki, people work jointly on one common artifact. And a multitude of people around the world are able to participate in this process anywhere and at anytime. Like a wiki, if cognitive artifacts should support learner-centered e-learning in collaborative situation, cognitive artifacts can serve a function to monitor how people make use of others' knowledge through collaborative knowledge building with artifacts (Bruckman, 2006; Norman, 1991).

In PBL for learner-centered e-learning, learners rarely have a chance to monitor other's problem solving processes and sub-products throughout the processes. This may unintentionally convey the irrelevant notion that student's problem solving processes is not a useful information resource and that they are not important producers of Knowledge. However, learners' products in a wiki can be considered as other learners' cognitive artifacts to facilitate and mediate their learner-centered e-learning.

Supporting learners to design their cognitive artifacts

Supporting learners to design their cognitive artifacts is to create learner-centered e-learning environment that empower learners to engage in learning process rather than learning environment restricted to the use of existing cognitive tools. Fischer and Scharff (2000) introduced the strategy of *Meta-design* that extends the traditional notion of system design beyond the original development of a system to include an ongoing process in which stakeholders become *co-designers*. Rather than presenting users with closed systems, Meta-design provides them with opportunities, tools, and social reward structures to extend the system to fit their needs. Meta-design has shifted the control from designers to users and empowered users to create and contribute their visions and objectives. Wright, Marlino, and Sumner (2002) asserted that Meta-design is a useful method for projects where 'designing the design process' is a first-class activity, meaning that creating the technical and social conditions for broad participation in design activities is as important as creating the artifact itself.

Courses-as-seeds (dePaula et al., 2002) as one case that was applied meta-design is introduced in chapter III earlier. In Courses-as-seeds case, learners act as active contributors and they are also active in the design of the courses themselves. In Creative Problem Solving (CPS) support system (Lim & Jang, 2008) as an another case of designing cognitive artifacts by themselves, learners can design their

problem solving process model and creative thinking tools in accordance with their growth of problem solving competencies. If cognitive artifacts in e-learning should effectively support the learner-centered e-learning, cognitive artifacts might be redesigned by learners rather than simply use of them given by others.

Conclusion

Analyzing learners' characteristics and four cases of cognitive artifacts, it is confirmed that cognitive artifacts can effectively support monitoring and reflection of learner's interaction with others, enhance learners' controllability of learner-centered e-learning environment, and empower learners' ownership of decision-making and their design or redesign the cognitive artifacts by their needs in their learning processes.

If cognitive artifacts in e-learning be effectively support the learner-centered e-learning, the cognitive artifacts might be designed to focus on learner's goals, needs, activities, educational contexts. More importantly, designers have to consider learner's controllability of their cognitive artifacts in e-learning environment. When cognitive artifacts are designed for learners, there are critical issues to consider not only usability but also nature of learners and their activities. Five principles of cognitive artifacts design to facilitate learner-centered e-learning inquired in this study and the results can be summarized as follows.

First, designing the cognitive artifacts is always considered to promote the externalization of learners' product to private media in public space. Therefore, learners externalize their products, then other learners can use their product as learning materials and other learners can interconnect between their products and other's product. Cognitive artifacts have to be designed to be externalized to public space and private space and to be interconnected with other cognitive artifacts.

Second, when designing the cognitive artifacts, it is necessary to consider the

perspective for helping learners to initiate their learning processes. Cognitive artifacts should be supported present their change or growth of their learning competencies. In accordance with their gradual growth, cognitive artifacts can be modified or redesigned with them. Learners seem to be able to decide, plan, monitor, evaluate and change their learning processes by themselves.

Third, the cognitive artifacts design is required to encourage learners to make connections with other learners' knowledge building and their products. Cognitive artifacts to facilitate learner-centered e-learning should provide functions for monitoring and viewing other learners' knowledge building processes and their products.

Fourth, the designer of cognitive artifacts keeps in mind to promote monitoring of participants' contributions in collaborative knowledge building. Cognitive artifacts not only support monitoring peer's participating processes to learner's products as cognitive artifacts but also viewing their ideas as useful communal cognitive artifacts for navigating knowledge community.

Fifth, designing the cognitive artifacts is always considered to support learners to design their cognitive artifacts. Cognitive artifacts to facilitate learner-centered e-learning should empower learners to engage in learning processes with tools that designed by their hands rather than simply use of existing cognitive artifacts given by others.

In short, e-learning environment designers have to consider the five design principles of cognitive artifacts for designing the effective learner-centered e-learning. In addition, it needs to take empirical study which can validate the effectiveness of five design principles of cognitive artifacts to facilitate learner-centered e-learning.

References

Barrows, H. S., & Tamblyn, R. (1980). *Problem-based learning: An approach to medical education*. New York: Springer.

Bereiter, C., & Scardamalia, M. (2003). Learning to Work Creatively with Knowledge. In E. De Corte, L. Verschaffel, N. Entwistle, & J. van Merriënboer (eds.), *Unravelling Basic Components and Dimensions of Powerful Learning Environments*. EARLI Advances in Learning and Instruction Series.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palinscar, A. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist*, 26 (3&4), 369-398.

Bransford J.D., Zech L., Schwartz D., Barron B., & Vye N. (2000). Designs for environments that invite and sustain mathematical thinking. In P. Cobb (Ed.), *Symbolizing, Communicating, and Mathematizing: Perspectives on Discourse, Tools, and Instructional Design* (pp. 275–324). Hillsdale, NJ: Lawrence Erlbaum.

Bruckman, A. (2006). Learning in online communities. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 461–472). New York: Cambridge University Press.

Bruns, A., & Humphreys, S. (2005). Wikis in teaching and assessment: The M/Cyclopedia project. *WikiSym 2005—Conference Proceedings of the 2005 International Symposium on Wikis*, pp. 25–32.

Cress, U., & Kimmerle, J., (2008). A systemic and cognitive view on collaborative knowledge building with wikis. *International Journal of Computer-Supported Collaborative Learning*, 3, 105-122.

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920*. New York: Teachers College Press.

dePaula, R., Fischer, G., & Ostwald, J. (2001). Courses as Seeds: Expectations and Realities. *Proceedings of the Second European Conference on Computer-Supported Collaborative Learning (Euro-CSCL' 2001)*, Maastricht, Netherlands, pp. 494-501.

Fischer, G. (2003). Meta-Design: Beyond User-Centered and Participatory Design. *Proceedings of HCI International 2003, Julie Jacko and Constantine Stephanidis (eds.),* Crete, Greece, pp. 88-92.

Fischer, G. (2007). Designing Socio-Technical Environments in Support of Meta-Design and Social Creativity. *Proceedings of the Conference on Computer Supported Collaborative Learning (CSCL '2007)*, Rutgers University, 1-10.

Fischer, G., & Ostwald, J. (2002). Seeding, Evolutionary Growth, and Reseeding: Enriching Participatory Design with Informed Participation. *Proceedings of the Participatory Design Conference (PDC'02)*, Malmö University, Sweden, pp. 135-143.

Fischer, G., & Ostwald, J. (2005). Knowledge Communication in Design Communities. In R. Bromme, F. W. Hesse & H. Spada (Eds.), *Barriers and Biases in Computer-Mediated Knowledge Communication* (pp. 213-242). New York, N.Y.: Springer.

Fischer, G., & Scharff, E. (2000). Meta-Design—Design for Designers. *3rd International Conference on Designing Interactive Systems (DIS 2000)*, New York, pp. 396-405.

Gredler, M. E. (2004). *Learning and Instruction: Theory into Practice.* Pearson Education, Inc., Upper Saddle River, NJ: Prentice Hall.

Greeno, J. G. (2006). Learning in Activity. In R. K. Sawyer (Ed.), *The Cambrige Handbook of the Learning Sciences (pp. 79-96).* Cambridge, New York: Cambridge University Press.

Hannafin, M. J., Land, S., & Oliver, K. (1999). SCLEs. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: Vol. 2. A new paradigm of instructional theory* (pp. 115–140). Mahway, NJ: Erlbaum.

Helic, D., (2006). Technology-Supported Management of Collaborative Learning Processes. *International Journal of Learning and Change*, 1(3), 285-298.

Jonassen, D. H., & Grabinger, R. S. (1990). Problems and issues in designing hypertext/hypermedia for learning. In D. H. Jonassen & H. Mandl (Eds.), *Designing hypermedia for learning* (pp. 3–25). Berlin: Springer.

Kafai, Y. B. (2006). Constructionism. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 35–46). New York: Cambridge University Press.

Kim, A. (2006). Empowerment Learning: True Learner-Centered Learning in Online Environment. In E. Pearson & P. Bohman (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2006* (pp. 1109-1112). Chesapeake, VA: AACE.

Korfiatis, N. T., Poulos, M., & Bokos, G. (2006). Evaluating authoritative sources using social networks: An insight from Wikipedia. *Online Information Review*, 30, 252–262.

Krajcik, J. S., & Blumenfeld, P. C. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317-333). New York: Cambridge University Press.

Land, S. M., & Hannafin, M. J. (1996). A conceptual framework for the development of theories-in-action with open-ended learning environments. *Educational Technology Research and Development*, 44(3), 37-53.

Lim, W. & Jang, S. (2008). Development of Web-based Creative Problem Solving Support System. In *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2008* (pp. 5020-5024). Chesapeake, VA: AACE.

Morrison, G. R., & Lowther, D. L. (2005). *Integrating computer technology into the classroom* (3rd ed.). Columbus, OH: Merrill.

Norman, D. A. (1991). Cognitive artifacts. In: Carroll, J. M. (Eds.) *Designing Interaction: Psychology at the Human-Computer Interface*. Cambridge University Press.

Notari, M. (2006). How to use a Wiki in education: Wiki based effective constructive learning. *Proceedings of WikiSym'06—2006 International Symposium on Wikis 2006*, pp. 131–132.

Quintana, C., Soloway, E., & Krajcik, J. (2003). Issues and approaches for developing learner-centered technology. In M. Zelkowitz (Ed.), *Advances in computers* (Vol. 57, pp. 272-321). San diego, CA: Academic Press.

Quintana, C., Shin, N., Norris, C., & Soloway, E. (2006). Learner-Centered Design. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 119-134). New York: Cambridge University Press.

Reinhold, S. (2006). Wikitrails: Augmenting Wiki structure for collaborative, interdisciplinary learning. *Proceedings of WikiSym'06—2006 International Symposium on Wikis 2006*, pp. 47–57.

Rick, J., & Guzdial, M. (2006). Situating CoWeb: A scholarship of application. *International Journal of Computer-Supported Collaborative Learning*, 1, 89–115.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, 3(3), 265–283.

Scardamalia, M., & Bereiter, C. (2003). Knowledge Building. In J. W. Guthrie (Ed.), *Encyclopedia of Education.* 2nd edition. New York: Macmillan Reference, USA.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York: Cambridge University Press.

Schneider, W., and Graham, D. (1992). Introduction to connectionist modeling in education. *Educational Psychology*. 27, 513–530.

Stahl, G., Koschmann, T., & Suthers, D. D. (2006). Computer-Supported Collaborative Learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 409–426). New York: Cambridge University Press.

Wright, M., Marlino, M., & Sumner, T. (2002). Meta-Design of a Community Digital Library. *DLib Magazine, 8 (5),* Available at http://www.dlib.org/dlib/may02/wright/05wright.html.

Yukawa, J. (2006). Co-reflection in online learning: Collaborative critical thinking as narrative. *International Journal of Computer-Supported Collaborative Learning*, 1, 203–228.

Youn, S. K., & Lim, W. C. (2008). Inquiry on a Model of Management of Learners' Attention in Web-Based Learning Environments. Proceedings of the KERA International Conference 2008, November 27-29, Seoul, Korea, pp. 1027-1036.

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