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Handbook of Research on Educational Communications and Technology (3rd Ed) Some Reflections (1):

On a Deeper Understanding of the Constructivist Learning Principles and Constructivist Instructional Design

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Abstract:*Compiled by the Association of Educational Communications and Technology (AECT) in the US, the Handbook of Research on Educational Communications and Technology has impacted the field of educational technology in many important ways, since the 1990s. The third edition, published in 2008, in particular, provides the reader with more innovative content due to the collected efforts of its co-editors and a large team of contributing scholars. This article will focus on the third edition of the handbook by first outlining its overall structure and contents, and directing the reader to those arguments that stimulate the field most. It will then concentrate on a more in-depth discussion of a re-appraisal of the following two issues: the constructivist learning principles and the relationship between constructivist and engineering instructional design. The former is considered, in the third edition, as one of the two most important research discoveries, while the later is deemed as one of the four important developments in educational communications and technology in the past five years.*

Keywords: Association for Educational Communications and Technology (AECT), Constructivist learning principles, Constructivist instructional design, engineering instructional design, minimally guided instruction, discovery learning

1. Introduction

Since the 1990s, the Association of Educational Communications and Technology (AECT) in the United States (US) has mobilized scholars in the field for the compilation and publication of the *Handbook of Research on Educational Communications and Technology* (hereafter the Handbook). This handbook has generated significant global impact on the field of educational technology. The third edition is the latest edition. The first two editions, published in 1996 and 2004 respectively, were both edited by David Jonassen who was a professor at Columbia University in the US and a contemporary representative of radical constructivism. The third edition was launched in 2008 and edited by a group of well-established scholars in the field, consisting of J. Michael Spector, M. David Merrill, Jeroen van Merrienboer, and Marcy P. Driscoll.

There are 42 chapters in seven major parts in the first edition (Jonassen, 1996): (a) Foundations for Research in Educational Communications and Technology; (b) Hard Technologies: Media-related Research;

(c). Soft Technologies: Instructional and informational Design Research; (d) Instructional Message Design Research; (e) Instructional Strategies Research; (f) Issues of Organization and Change in Educational Communications Technology; and (g) Research Methodologies in Educational Communications and Technology.

The second edition retains the structure and overall framework of the first edition (Jonassen, 2004). It only revised and updated the content of each chapter to reflect the new developments in the theory and practice of educational technology since the first edition, focusing on the developments made at the start of the 21st century.

The third edition was significantly transformed. The *Handbook* was redesigned to include 56 chapters in six major parts relating to (a) foundations, (b) strategies, (c) technologies, (d) models, (e) design and development, and (f) methodological issues (Spector, Merrill, Jeroen & Marcy, 2008). In addition, the book was edited by four co-editors instead of one. Each of the four co-editors was in charge of one part and supported by another co-editor and a team of editorial members. There is also a change in the composition of editorial members between the third edition and the first and second editions. All authors in the first and second editions were well-known experts and scholars in the US, while most of the chapters in the third edition were collaborative contributions of much acclaimed experts and scholars in the field, as well as young scholars who were not well known at the time. Furthermore, 20% of the authors and one co-editor in the third edition were not from the US. Precisely because of this change in its team of authors, the third edition, in contrast to the first and second, appears to be refreshingly open, international, and diverse in perspective. It also predicts the future developments of educational technology. What is worth mentioning here is the publication of the Chinese translation of over one million words *Handbook* in September 2012 after five years of collective efforts from a translation team led by Ren Youqun, Jiao Jianli, Liu Meifeng, and Wang Qiong.

2. The Overall Framework and Key Contents of the Handbook (3rd Ed)

The third edition of the *Handbook* comprises six major parts: (1) foundations, (2) strategies, (3) technologies, (4) models, (5) design and development, and (6) methodological issues. The four parts from Part II to Part V (i.e., strategies, technologies, models, design and development) each outlines and discusses the historical development, research evolution, new developments, and future trends of its own research theme. These four parts focus on the use of information and communications technology to support teaching and learning, therefore forming the core contents of the *Handbook*. Part I, foundations, and Part VI, methodological issues, concentrate on research foundations and methodology, promoting a deeper understanding of the theoretical foundations, relevant hypotheses, and methodological issues in this field. These two parts provide useful guidance to the reader on the effective application of educational communications technology in practice.

Six review articles on the third edition of the *Handbook* were written by the translation team headed by Ren Youqun, Jiao Jianli, Liu Meifeng, and Wang Qiong, and were published in volumes 1-6 of China's Journal of Distance Education in 2010 (Zheng & Ren, 2010; Wang, 2010; Zhao, 2010; Jiao, He &

Zhan, 2010; Kang, Ma, Ju & Liu, 2010; Jiao, Zhan & He, 2010). These articles discuss and analyse the contents of the six parts in detail. To help the reader understand the key points of the *Handbook* accurately, the contents of the six parts will be outlined below.

Part I, foundations, covers three main themes (Ren, Jiao, Liu & Wang, 2011; Zheng & Ren, 2010): historical foundations, theoretical foundations, and authentic learning related theoretical positions. The "historical foundations" section reviews milestone events and paradigm shifts in the history of educational communications technology. The "theoretical foundations" covers the theoretical foundations for research in educational communications and technology such as the psychology of learning and its philosophical foundation, empirical perspectives on memory and motivation, communications theory, human-computer interaction, and instructional design and development. When discussing authentic learning theories, the handbook addressed complexity theory, experiential, and situativity theory. This section ends with a brief discussion of the characteristics of the research foundations in educational communications technology.

Part II, strategies, also includes three main themes (Ren, Jiao, Liu & Wang, 2011; Wang, 2010): learning theories, teaching models and instructional design principles in educational communications and technology. In terms of "learning theories," the *Handbook* focuses its review on technology-supported learning psychology and generative learning theories.

The section on "teaching" models outlines nine currently prevalent empirical models that have impacted teaching significantly. It also discusses the four focal points in technology-supported inquiry learning. When discussing instructional design principles in educational communications and technology, it introduces first principles of instructional design and the prescriptive principles for knowledge formation and teaching feedback.

Part III of the *Handbook*, technology, consists of four themes. First, while introducing the 16 chapters in this part, it also traces the developmental stages of different technologies by exploring their research development and future trends. Second, through a comparison with the contents in the technology part in the second edition, the third edition also captures the extension and changes in the themes of technology research. Third, from the perspectives of "hard technology," "soft technology," and "design technology," it evaluates the development of educational technology. Finally, it illustrates that the key feature of the development of contemporary educational technology is the further blending of teaching and information technology.

Part IV of the *Handbook*, models, is also composed of four themes. First, human cognitive architecture and technology-based teaching are examined that outlines the basis for human cognitive evolution and various instructional principles generated by cognitive load theory. Second, the nine general models directed toward learning in and outside schools are addressed that analyse the nine general models in educational communications and technology. Third, the application of models focusing on learning in specific domains discusses the application of various learning models to five disciplinary areas such as reading, mathematics, science, law and medicine. Finally, the summary, discussion, and outlook are presented that summarizes cognitive psychology-based models and the relationship between these models and explores the future applications of these models in different domains.

Part V of the *Handbook*, design and development, pertains to four areas of discussion. First, the chapter titled "Competencies for the New-Age Instructional Designer" points out the challenges facing new-age instructional designers, followed by the "Design and Development of Research Content and Practice" that introduces cognitive task analysis, tools for design and development of online instruction, design language, user-centred design and development, artefacts as tools in the design process, and the social consequences of design and development teams. Third, the evaluation reviews examine evaluation models and methodologies and discusses in detail the validation of technology-based performance assessments. Finally, the systems design for change in education and training illustrates the responsibilities of change agents, and introduces current research on systems design for systematic change in the fields of education and training.

Part VI of the *Handbook*, methodological issues in educational communications and technology, also has four components. First, research and theory development systematically discusses the four perspectives relating to theoretical statements, two theories, and the theory developments in educational communications and technology. Second, research approaches and four research designs analyses instructional strategies, educational technologies, instructional design models, and instructional design and development. This is followed by data collection and analysis that discusses methods of data collection and analysis for evaluating learning process and complex performance. Finally, a review and outlook of research summarizes the most significant developments and research findings in educational communications and technology in the last five years, and explores the possible development and the most significant research issues in the next five years in the field. This section also discusses, summarizes, and forecasts research methodologies in educational communications and technology.

3. What are the Most Stimulating Discussions in the Handbook (3rd Ed)

After careful reading of the translated third edition of the *Handbook* and reflecting on years of research and practice in educational communications and technology, the author has been provided with much insight into the significance of the *Handbook*. The author believes that the following five issues discussed in the *Handbook* are most the impressive and thought-provoking:

1. Constructivist learning principles and constructivist instructional design.

2. Complexity theory and technology-supported complex learning.

3. Situativity theory and situativity instructional model and strategies.

4. First principles of instruction and the four-component instructional design model (4C/ID model).

5. The arguments concerning the future of educational technology that are triggered by changes in the trends of the technology research.

In relation to the first issue, "the limitations of constructivist learning principles" is considered by the *Handbook* to be one of the two most important research findings in educational communications and technology in the last five years. The other most important finding relates to a deeper understanding of expertise reversal effect as one can see in Chapter 56, *Foundations for the Future*. Closely related to this issue is the "significant reduction in the gap and tension between constructivist and engineering models of instructional design," which is perceived in the *Handbook* as one of the four important developments in the last five years in educational communications and technology (see Chapter 56). The author believes that the analysis and evaluation of constructivist learning principles and constructivist instructional design reflect reality and are accurate.

The other four issues mentioned above (i.e., complexity theory, situativity instructional strategies, first principles of instruction and the 4C/ID model, and arguments on the future of educational technology triggered by changes in the trends of the technology research) are also focal components of educational communications and technology. They are innovative theories and applications that have had great impact on education and training.

At the same time, the author has also found that the *Handbook* contains differences and even bias in academic standpoints due to its large team of authors of different backgrounds. Some discussions are one-sided or even contain obvious mistakes. To avoid misleading and having adverse effects on the development of educational technology in China, this author would like to express personal views on the shortcomings of this *Handbook*, which will add to the five issues mentioned above to form the sixth issue: Analysing the Main Shortcomings of the 3rd edition of *Handbook of Research on Educational Communications and Technology.*

Thus, the author's reflections on the *Handbook* will focus on the six issues mentioned above. The next section will analyse the first issue: constructivist learning principles and constructivist instructional design. Discussions on the remaining five issues will be published in two separate articles at a later time.

4. A Deeper Understanding of "Constructivist Learning Principles"

In regard to a deeper understanding of constructivist learning principles, after quoting the research by Kirschner et al. (2006), the last chapter (Chapter 56) of the *Handbook* points out that "the limitations of constructivist learning principles, such as discovery methods and inquiry learning, are becoming more clear" (p. 810). As this new finding has practical implications to education and training, the *Handbook* discusses it as the first of two most important findings in educational communications and technology in the last five years.

Since the 1990s, along with the rapid development in information technology which features multimedia computers and network communications (especially the Internet), e-learning (i.e., digital or Web-based learning) supported by such technology has spread worldwide. The interactivity offered by multimedia computers promotes learners' interest in learning and places learners at the centre of their cognitive learning process. In addition, the various valuable features of network communications promote students' creative and collaborative spirit and skills. For example, the abundant online resources facilitate learners' self-learning, self-inquiry, and self-discovery, and support anywhere, anytime collaboration and sharing on a large scale. Ever since the 1990s, E-learning, an unprecedented way of learning, has been regarded as an optimal learning mode. Constructivist learning principles (e.g., discovery methods and inquiry learning), which provide a theoretical basis for this mode of learning, are naturally becoming the most highly advocated learning principles in the field of educational technology, and more broadly, in global education.

However, Kirschner et al. (2006), based on evidence from empirical studies in education and training over the years, postulate that constructivist learning principles are not a panacea to be administered in every situation, despite its certain facilitating effects on self-learning, self-inquiry, and self-discovery. This is because these learning principles advocate minimally guided instruction and require learners to learn science through doing science. The obvious adverse effect of these learning principles has been proven in practice. So have the limitations of these principles (including constructivist instructional paradigms based on these principles). The following three limitations are discussed by Kirschner et al. (2006).

4.1. The Constructivist Instructional Approach Characterized by "Minimally Guided Instruction" hasFailed.

Kirschner et al. (2006) argue that those instructional paradigms based on constructivist learning principles can neither be successfully applied in classroom teaching, nor can they provide an accurate understanding of human cognitive architecture. The human cognitive architecture emphasized here by Kirschner et al. (2006) is based on the theory of information processing. This theory maintains that human working memory is limited and serves as a gateway to information stored in long-term memory. With this understanding of the information processing theory, Kirschner et al. (2006) believe that learners, especially novice learners, due to the limitation of working memory, cannot effectively process information. As a result, their learning can be affected. They further point out that minimally guided instruction can overload the working memory of novice learners because "minimally guided instruction appears to proceed with no reference to the characteristics of working memory, long-term memory, or the intricate relations between them" (p.76). On the basis of their analysis of teaching and research case studies, they conclude that the failure of constructivist learning principles lies precisely in the paradigm of minimally guided instruction to novice learners.

4.2. Learners do not Possess the Knowledge and Skill Base for Learning Science through Scientists' "doing Science"

When discussing discovery learning principles in constructivism (especially the emphasis on learning science through "doing science"), Kirschner et al. (2006) postulate that children are different from adult experts in many ways. For example, children are not cognitively as powerful as adult experts, and they do not possess sufficient content and situated knowledge. According to Kirschner et al, situated knowledge refers to knowledge relating to conditions for the application of certain procedures or conditions for fast tracking certain knowledge. If children are required to learn science as scientists do, they must possess all the knowledge and capabilities. Without the knowledge and capabilities, they would be learning under a deficit model that will lead to failure.

4.3. Under Certain Circumstances, Conventional Direct Instruction can be Superior to Constructivist Instruction

Kirschner et al. (2006) regard learning as the change of long-term memory. Consequently, they assert that the architecture of long-term memory "provides us with the ultimate justification for instruction" (p.77). This was followed by a theoretical justification of the facilitation of long-term memory through conventional direct instruction based on a systems theory. They argue that such facilitation is superior to constructivist instruction.

5. A Re-appraisal of the Relationship between Constructivist and Engineering Instructional Design

As discussed above, "significant reduction in the gap and tension between constructivist and engineering models of instructional design" was held as one of the four important developments in educational communications and technology in the last five years. This is because constructivist learning principles (e.g., discovery and inquiry learning) has long been regarded as incompatible to conventional instruction based on a systems approach (also known as "direct instruction"). They often oppose each other in design and learning support. The other three are major changes in instructional strategies and learning technologies in e-learning, advances in using technology to optimize affective responses, and the shift from instructional model building to instructional model testing.

However, in recent years, research and practice in instructional models and instructional system design and development have demonstrated that instructional design based on constructive learning principles (e.g., constructivist instructional design) and conventional instructional design based on systems theories do not necessarily contradict each other. On the contrary, they can be very well-aligned to each other, so as to complement one another and maximize the advantages of each. This would help achieve the most effective integration between information technology and curriculum in e-learning. The following three classical case studies and their outstanding achievements best exemplify the results of the vigorous debates, the open dialogues, and mutual absorption between the two opposing viewpoints.

5.1. The Debates on "Minimal Instructional Guidance" and the Consensus Reached

Kirschner et al. (2006) contend that our understanding of human cognitive structure is based on the information processing theory that postulates that human working memory is limited, and that "minimally guided instruction appears to proceed with no reference to the characteristics of working memory, long-term memory, or the intricate relations between them" (p.76). Jonassen (2004), an advocate of contemporary radical constructivism, commented on these two contentions by saying that the cognitive structure discussed by Kirschner et al. only focused on working memory and long-term memory, while ignoring other aspects of cognitive structure. In fact, human cognitive structure should take into account the learning context, the learner, and the cognitive process (social cognitive process) in order to interpret and predict cognitive activities.

In the same line, Wise and O'Neill (2009) further argue that experimental studies on how to control the quantity of guidance cannot provide a valid basis for making assumptions about the fundamental merits of constructivist teaching. Although there are numerous debates on more-versus-less or high-versus-low guidance to learners, through the investigation of relevant research, especially instructional case studies, they have discovered that the quantity of guidance is just one dimension to achieve learning goals. Further, this dimension should be considered together with other dimensions to effectively achieve learning goals. For example, the context and timing of guidance are two other dimensions that should receive attention.

At the same time, Gresalfi and Lester (2009) also point out that the difference between constructivism and conventional instruction does not lie in the quantity of guidance but in the types of guidance. They claim to have included in their instructional guidance various types of guidance suitable for the understanding of knowledge points through inquiring, explaining, and testing.

When discussing the misunderstanding of constructivist no-guided instruction or minimally guided instruction, Pea (2004) presents a persuasive account on the characteristics of scaffolding instructional strategy. He maintains that there are two characteristics that distinguish scaffolding from conventional instruction. First, conventional instruction only provides guidance when learners run into learning difficulties and are unable to proceed. In contrast, scaffolding provides learners with support to pursue learning independently. Second, after the learning content and learners are determined, in conventional instruction, the quantity and intensity of guidance remain unchanged, whereas in scaffolding instruction, the quantity and intensity of guidance tend to reduce or even fade, along with learners' increased mastery of knowledge and skills.

Despite the originally opposing views, consensus was reached on the two following aspects, as the result of the debates on minimally guided instruction:

1. In regard to human cognitive structure – In addition to working memory and long-term memory, we should also take into account the learning context and learners' cognitive processes.

2. In regard to the effectiveness of instructional guidance – To effectively achieve learning goals, apart from the quantity dimension of guidance, we need to take into consideration other dimensions such as the context, the amount of time, the types of guidance, and the learners' abilities and needs.

5.2. A Deeper Understanding of the Debates on "Using Scientists' doing Science Approach to Learn Science"

Duschl and Duncan (2009), strong supporters of constructivism, disagree with the contention by Kirschner et al. (2006) that students should not be required to learn science through "doing science." They were not convinced by the argument put forward by Kirschner et al. that "students do not possess the necessary knowledge and cognitive ability" and that "students should not use a deficit model to learn science." They argue that Kirschner et al. do not understand that no age-related developmental stage will prevent students from learning science. They believe that more research should be done in relation to the development of children's cognitive ability. Learning science should not be simply regarded as the accumulation of knowledge in long-term memory. On the contrary, it is a cognitive development process that promotes conceptual changes and re-organization in memory. At the same time, through their own teaching experiences, they also point out that when scientific content becomes extremely abstract or complicated, the carefully designed curriculum using a systems approach and the provision of instructional guidance during discovery learning, will effectively help students to understand abstract scientific concepts, to grasp data models, and to develop and modify interpretations. They can also engage in-depth discussions on conceptual structures. In other words, to Duschl and Duncan (2009), appropriate instructional guidance based on a systems approach and studying science through scientists' doing science (e.g., discovery method) does not necessarily contradict each other. On the contrary, they can complement each other as conventional instructional guidance can help address the inadequacy of constructivist instructional paradigm.

5.3. The Debates on and Comparison between "Direct Instruction" and Constructivist Instruction

Some scholars such as Spiro and DeSchryver (2009) admit that conventional direct instruction can be more effective in well-structured domains such as mathematics and physics, while constructivist instruction (e.g., learning science through doing, discovery and inquiry learning including problem-based inquiry, context-based inquiry, project-based inquiry, resource-based inquiry) can lead to better results in ill-structured domains (e.g., medical diagnosis).

Herman and Gomez (2009) also state that some critics of constructivist instruction ignore some of the critical components of the instructional process such as motivation, the social context of the classroom, and other aspects of the dynamics of instruction. In addition, as argued above by Duschl and Duncan (2009), systems-based conventional instruction and science learning through "doing science" does not necessarily contradict each other. Research and case studies conducted by Gresalfi and Lester (2009) demonstrate that the constructivist instruction that they have advocated, explicitly includes many systems-based conventional instructional paradigms as inquiry, explanation, and testing. These paradigms are considered suitable for promoting learners' understanding of specific knowledge points. This clearly shows that new constructivist instruction does not reject teacher explanations at all. What it opposes is an entire lecture which is completely teacher-controlled. The constructivist paradigm does not oppose "direct instruction" with a systems approach.

6. Concluding Remarks

In the 21st century, especially since 2004, there have been intense debates and open dialogues in regard to the two opposing views discussed above in the field of educational communications and technology in the US. They have advanced understanding in the following two aspects:

1. Constructivist learning principles characterized by discovery and inquiry learning do possess their own uniqueness and unreplaceable advantages, but they are not perfectly optimal learning principles as shown by the three limitations critiqued by Kirschner et al. (2006).

2. Instructional design based on constructivist learning principles (e.g., constructivist instructional design) and conventional instruction based on a systems approach (e.g., engineering instructional design) are not in complete opposition. On the contrary, in many cases, they can be effectively brought together in a complementary manner to maximise their respective advantages. This has been convincingly testified by the intense debates on minimally guided instruction, the approach of learning science through doing science, direct instruction, and constructivist instruction, which have led to mutual absorption, acceptance, and valuable consensus.

In view of the above understanding, the *Handbook* lists understanding of the limitations of constructivist learning principles as first of two important findings in educational communications and technology in the last five years. For the same reason, the "significant reduction in the gap and tension between constructivist and engineering models of instructional design," was also deemed by the *Handbook* as one of the four important developments in educational communications and technology in the last five years. The author believes that such analysis, judgement, and evaluation in the *Handbook* reflect reality and are also appropriate, and will provide significant guidance to the development of theory and practice in educational communications and technology worldwide (i.e., in the field of international educational technology).

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The Potential of a First LEGO League Robotics Program in Teaching 21st Century Skills: An Exploratory Study

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Abstract: *Business and political leaders in the US call for schools to teach 21st century skills. In the meantime, researchers call for more research to develop curriculum that teach 21st century skills. In this study, the authors examine the experience of a First LEGO League (FLL) robotics team to explore the potential of FLL for teaching 21st century skills. We found that the program provided opportunities for learning many 21st century skills such as systems thinking, decision making, problem solving, teamwork, conflict resolution, flexibility, perseverance, and self-management. We also found that instructional strategies such as modeling, coaching, scaffolding, examples and case studies were important in providing successful experience to children. For children to retain and transfer these 21st century skills, articulation and reflection are critical.*

Keywords: robotics, 21st century skills, engineering design, non-routine problem solving, project-based learning

1. Motivation for the Study

Business and political leaders in the United States (US) call for schools to teach 21st century skills because of the decline of jobs that involve routine tasks and the growth of jobs that require complex communication and non-routine problem-solving competencies (Partnership for 21st Century Skills, 2013). In a National Research Council (2012) report, "21st century competencies" refer to a blend of knowledge and skills, including "content knowledge in a domain and knowledge of how, why, and when to apply this knowledge to answer questions and solve problems." (p. 6). The 21st century competencies are knowledge that can be transferred to other situations.

In the meantime, there is an increased interest in teaching engineering design problem solving in American K-12 schools. The Next Generation Science Standards (NGSS) (Achieve, 2013) raise engineering design to the same level as scientific inquiry. Both engineering design and scientific inquiry will be taught in all grades from kindergarten to 12th grade. There is significant overlap between the new science standards and 21st century skills, especially in the cognitive domains. For example, 21st century skills such as critical thinking, nonroutine problem solving, constructing and evaluating evidence-based arguments, systems thinking, and complex communication are strongly supported by NGSS (Achieve, 2013).

Researchers call for more research and development on educational programs and curriculum that teach 21st century skills and engineer design problem solving (National Research Council, 2012). The First LEGO League (FLL) (U.S. First, 2013a) is a worldwide robotics program for children 9 to 16 year old (9 to 14 in the US). It challenges participants to design, build, and program a robot to complete a robotics challenge. A survey of 188 FLL teams (Melchior, Cutter, & Cohen, 2004) shows that students, parents, and coaches believe that participants acquired life and workplace-related skills such as teamwork, time and project management, problem solving, and communications skills. It seems that FLL robotics would be a good candidate for teaching 21st century skills and engineering design. However, from anecdotal evidence such as the authors' personal experience in coaching FLL and discussions in FLL online forum, we know that coaches vary in their ability and experience that reflect upon participants' experience in FLL also. In spite of rapid growth of robotics programs such as FLL, there is lack of research-based knowledge on the best practice of coaching FLL and other robotics programs. In this article, the authors examine the experience of a FLL robotics team to explore the potential of FLL for teaching 21st century skills and engineering design. We will identify the support and guidance provided or should be provided for the children to acquire the skills. The findings may inform the design and coaching of similar programs so that they can better meet the challenge of teaching 21st century skills and engineering design.

2. Literature Review

2.1. 21st Century Skills and Engineering Design

In the National Research Council (2012) report, 21st century competencies are categorized into the following three domains: cognitive, interpersonal, and intrapersonal. Cognitive competencies refer to cognitive processes and strategies, knowledge, and creativity such as critical thinking, problem solving, decision making, system thinking, information literacy, oral and written communication, and innovation. Interpersonal competencies include teamwork and collaboration in addition to leadership. Intrapersonal competencies include intellectual openness, work ethics/conscientiousness, and positive core self-evaluation. A person with positive core self-evaluation thinks positively of oneself and has confidence in one's abilities.

Researchers synthesized the literature and identified some instructional design principles for teaching 21st century competencies in the cognitive competencies (National Research Council, 2012). The principles include the following: using multiple and varied representations of concepts and tasks, encouraging elaboration, questioning, and self-explanation, engaging learners in challenging tasks with supportive guidance and feedback, teaching with examples and cases, priming student motivation, and using formative assessment. Because there is limited research on how to teach intrapersonal and interpersonal competencies, researchers believe that these instructional design principles may work for these other two categories of competencies.

Engineering design is a new and separate component from scientific inquiry in the Next Generation Science Standards (Achieve, 2013). It describes an iterative design process. The following three core components of engineering design provide guidance to designers, but they are not steps in a "lock-step" process:

1. Defining and delimiting engineering problems involves stating the problem to

be solved as clearly as possible in terms of criteria for success, and constraints or limits.

2. Designing solutions to engineering problems begins with generating a number of different possible solutions, and then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

3. Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important (Achieve, 2013, p. 2).

2.2. First LEGO League (FLL) and Related Research

Like many other robotics competitions such as BEST and Vex, First LEGO League (FLL) (U.S. First, 2013a) is designed to introduce children to engineering, programming, and employment and life skills through building and programming robots. In FLL, participants work in teams to compete on a 4' x 8' playing field where their LEGO-based robot must autonomously complete as many of the specified challenges as possible within a set time of two and a half minutes (see Figure 1).

Each year FLL releases a new thematic challenge that includes three parts that includes the research project, the robot game, and Core Values. In 2012, the challenge was called Senior Solutions (U.S. First, 2013b). The research project requires the FLL teams to identify the problems brought about by aging and develop a solution to solve the problem. The robot game challenges the teams complete missions such as delivering or retrieving objects, and turning or pushing levers. The Core Values distinguish FLL from other similar programs in that it emphasizes the values of teamwork and teach children how to work with each other and compete with other teams.

Figure 1. FLL 2012 Challenge "Senior Solutions" table setup.

Research on robotics education programs is limited. Most of the studies use self-report data to show that students and teachers believe that robotics activities improve children's interest in physics and improve their knowledge and skills in programming, problem solving, teamwork, time and project management, hardware, electronics, and communications skills (Nourbakhsh et al., 2005; Petre & Price, 2004; Robinson, 2005; Sklar, Johnson, & Lund, 2000). These studies also found that robotics activities improve students' self-identification with science, engineering, and technology. Only a few studies went beyond collecting self-report data and the results are mixed. For example, Barker and Ansorge (2007) reported positive results of robotics activities in improving achievement in science, engineering, and technology from the pre-test to the post-test. Whereas another study (Wagner, 1998) found in comparison to the use of manipulative, the robotics intervention did not significantly improve science achievement or general problem solving, but did improve programming problem solving. Williams, Ma, Prejean, Ford, & Lai (2007) found that a robotics summer camp enhanced students' physics content knowledge, but failed to improve their skills in conducting scientific inquiry.

A few studies have identified issues and strategies involved in designing robotics education programs. In a robotics program implemented in an elementary school (Rogers & Portsmore, 2004), researchers found it important to provide extensive technical support to teachers. Williams et al. (2007) provide the following recommendations to embed resources in the robotics activities such as short lessons, tutorials, and example solutions in order to support scientific inquiry and acquisition of content knowledge.

3. Research Methods

The purpose of this study was to explore children's experience in this program in order to (a) identify opportunities for children to learn 21st century skills and engineering design in the FLL context, and (b) to determine the guidance and support needed for them to acquire these skills. Qualitative inquiry methods were chosen to guide data gathering and analysis because of the exploratory nature of the research (Creswell, 2004).

The following research questions guided the study:

1. What opportunities do children have to learn 21st century skills and engineering design?

2. What guidance and support have been or should be provided to help children acquire 21st century skills and engineering design?

3.1. Participants

The participants included six children. The children were members of a FLL team. They are all girls. Their ages were 8 to 10 at the time of the study. Four of the children were from three different elementary schools and the other two were homeschooled. Four children were Caucasians and two were Asian. This was their first-year experience with FLL.

3.2. Data Sources

The data sources included coaches' field notes and focus group interviews with the children.

Coaches field notes. The two coaches, who were also researchers for this study, kept 23 daily field notes of observations and reflections of the FLL experience. An entry of the field notes typically describes the sequence of activities and events for a certain day, the reactions and feelings of the children and coaches, and anything interesting in that day's FLL experience.

Focus group interviews with children. A focus group interview was conducted by one of the researchers/coaches. The coach asked the children what they liked and disliked FLL, what they have learned, and what parents and coaches should do to improve the program. The focus group interview lasted about 30 minutes.

3.3. Data Analysis

The authors imported interview transcripts and the field notes into NVivo 7, a software package that helps manage and analyze qualitative data. Miles and Huberman's (1994) data analysis procedures guided data analysis. First, in the data reduction step, we coded the transcripts and field notes into conceptual chunks and grouped them into categories. To categorize the support provided by the coaches to the children, cognitive apprenticeship (Collins, Brown, & Holum, 1991), an instructional model that consisted of strategies such as modeling, coaching, scaffolding, articulation and reflection, was used. Next, in the data display step, we ran queries to make sense of the relationship among the categories. The authors also created tables to compare the codes/themes with 21st century skills and engineering design components. Finally, we wrote up conclusions and verified them. To enhance the trustworthiness and rigor of this study, the authors adopted techniques such as triangulation, peer debriefing, discrepant evidence or negative case analysis, thick descriptions, and member checking (Lincoln & Guba, 1985).

4. Summary of Data

The robotics program is very challenging, which provided many "teachable moments" for children to learn 21st century skills and engineering design. The authors have identified the challenges that children experienced in the program and the possible skills that they may learn. For each challenge, we also identified the support that has been and should be provided. We categorized the challenges that children have experienced into three domains: cognitive, interpersonal, and intrapersonal.

4.1. Challenges in the Cognitive Domain

Table 1 shows a list of challenges that children encountered in the cognitive domain. It also describes the corresponding 21st century skills that the challenges might provide opportunity to teach and the support has been or should be provided to the children.

4.1.1. Challenge 1. Starting with a problem. One of the biggest challenges that the children encountered was their lack of strategies and methodologies on how to approach unstructured problems. At the beginning of the program, when looking at the missions, children did not know where to start. The coaches and members from another team who had two-year FLL experience analyzed the missions from the perspectives of the points that can be earned, distance of the mission from the base, and the difficulty level, and then developed strategies on how to group the missions. The girls had little input at the meeting. Because the team had little experience, the coaches guided the girls to choose missions that are close to the base and relatively easy to complete.

This situation may provide an opportunity for children to learn how to analyze a problem and how to consider multiple factors to make decisions on what missions to complete. They might also learn how to strategize when devising a plan for solving design problems. Although modeling from the other experienced team and coaches were helpful, more discussions with the children about strategies might help the children with articulation and reflection, which might make the learning more explicit.

Table 1. Challenges in the cognitive domain

	Key 21st century skills	Support Provided	Other Support Needed
Challenge 1. Starting with a problem	Analysis, systems thinking, decision making	Modeling, scaffolding	Articulation and reflection
Challenge 2. Building robots and attachments	Creativity, problem solving	Examples, scaffolding	Articulation and Reflection
	Executive function	Coaching	Modeling, scaffolding, coaching, articulation, and reflection
Challenge 3. Programming	Problem solving, information technology literacy	Examples, modeling, coaching	Articulation and reflection
Challenge 4. Knowledge	Problem solving	Modeling and coaching	Coaching, articulation and reflection
Challenge 5. Inconsistency	Systems thinking	Experiments	Articulation and Reflection
Challenge 6. Chain reactions	Systems thinking	Modeling	Articulation and Reflection

4.1.2. Challenge 2: Building robots and attachments. The children had difficulty building the robots and the attachment. Examples and scaffolding did help them move on. The coaches provided images on various attachments such as bumpers, plows, delivery boxes, and discussed their designs and uses. These examples seemed to have helped some children create their own designs. For example, from an example design, Melissa was able to create a robot arm, which served as the main attachment for most of the missions for the team. Scaffolding helped children understand the key concepts in design. For example, Melissa used a LEGO piece that has a 130-degree angle to hold squared LEGO "quilts," but she was not successful. A coach suggested that Melissa look for a piece that had a 90-degree angle to hold the "quilts" because the "quilts" were square. This suggestion helped Melissa to successfully build the attachment.

Another challenge related to building was the children's lack of planning. Once Melissa finished creating the attachment to deliver the "quilts," a coach asked her how she would attach it to the robot. She said that she had not thought about that yet. In another example, failure to think ahead made children's design completely useless. For example, Nancy and Lisa borrowed an existing robot arm design from a book to hold some LEGO objects. When they were building the arms, they focused on building without thinking about how the arms could be attached to the robot and how they could hold the objects. The arms turned out to be too long and unbalanced. They had to give up this design after spending a lot of time building it. These experiences may provide opportunities for children to see the importance of planning.

In summary, the challenge to build and create robots and attachments provided the children with opportunities to solve design problems, be creative, and practice planning. Examples and scaffolding helped the children gain knowledge and expertise with design. Adequate support had been provided to guide the children with planning. Modeling and coaching might show children how to plan, and articulation and reflection might help them reflect on the effectiveness of planning.

4.1.3. Challenge 3. Programming to complete the missions. The participants experienced many challenges when programming to complete the missions. One type of challenge related to controlling the robot. For example, for one mission Nancy and Lisa programmed the robot to move forward, make a 90-degree turn, and then go forward to deliver some objects. The children found that once the robot made a 90-degree turn, it was no longer going straight. From videos of previous competitions, the children learned that having the robot move forward or backward to push the nearby wall of the playing field would help the robot straighten up. This strategy helped them solve the problem. Another type of challenge related to troubleshooting programming problems. Nicole was confused as to which programming blocks correspond to which robot behaviors. One of the coaches showed Nicole how to add sounds in the program. The sounds could alert her to notice which parts of the code have been run. The coach also showed Nicole how to add comments to the code to help her and others understand what she has programmed.

In summary, the challenge related to programming offered opportunities for children to solve problems by using strategies acquired from examples, modeling, and coaching from the coaches. Articulation and reflection could help children make the strategies their own.

4.1.4. Challenge 4. Using mathematics and physical science knowledge. Children were challenged to use mathematics and physical science knowledge in completing the challenges. For example, the children tended to depend on trial and error instead of calculation to estimate the rotations needed for a robot to move a certain distance. The coaches taught the children how to calculate the number of rotations that the robot wheels should move by dividing the distance the robot needed to travel with the circumference of the wheel. In another instance, Megan and Nicole could not use the robot to push a LEGO object to the base although they set the robot speed to the maximum of 100. Megan thought that if she stopped the robot when it got closer to the object and then program the motor to turn at the maximum power, it would reach higher speed before pushing the object. A coach let her try and they noticed that the object was actually pushed for less distance. The coach explained to Megan that it takes some distance for a person or a vehicle to speed up. Megan then understood why her solution did not work.

The activities provided opportunities for children to learn and apply math and science knowledge in completing the missions. In the examples, modeling and coaching were helpful for children to learn the new skills. However, to convince children to use calculation instead of trial and error, more coaching, articulation, and reflection are needed.

4.1.5. Challenge 5: Dealing with inconsistency. One of the issues with the robot was its inconsistency in performance. For example, for many missions the children found that the robot performed inconsistently when the robot was on different playing fields or when it was used on different days. This may provide opportunities to discuss various factors that may impact the robot's performance such as the mat set up, power level of the robot, the battery level, and the lighting of the playing table. When children were programming for a mission, they typically stopped once the missions worked one time. The coaches encouraged them to try the solution many times and on different playing fields to test its consistency. The children were able to appreciate the importance of testing a program many times because they saw the inconsistency during tests, but they were not always aware of the factors that were at play.

These experiences provided opportunities for children to learn that there are multiple variables that affected a robot's performance and they needed to identify these variables to optimize the solutions. Experiments, articulation, and reflection could be helpful for them to identify and discuss the variables.

4.1.6. Challenge 6. Dealing with chain reaction. Another challenge for the children was to experience the chain reaction of changes. One small change might cause a series of problems. When Nicole and Megan were refining one of the missions, they made a couple of small changes and the robot could no longer complete the mission. The children did not understand what happened. A coach demonstrated to the children that when the robot moves an inch more than the previous program, it no longer pushed the object by using its center point, which turned the robot a little so that it can no longer move straight for the next step. The children saw the causal relationships of the steps and were able to fix the problem. When the robot was programmed to complete two missions in one outing, the chain reaction tended to be more of an issue because there were more steps involved in one run of the robot.

These situations afforded children the opportunities to identify the causal relationships between various steps in a system and learn to troubleshoot when the system did not work. However, although the coaches helped the children solve the problem, children may not have gained a deep understanding and appreciation of the chain reactions. More explicit analysis and discussions with the children may be needed

Table 2. Challenges in the interpersonal domain

	21st century skills	Support Provided	Other Support Needed
Challenge 1: Sharing products with others	Trust, cooperation, teamwork	Articulation and Reflection	Articulation and Reflection
Challenge 2: Reaching agreement	Negotiation	Articulation and Reflection	Articulation and Reflection
Challenge 3: Sharing work	Trust, cooperation, teamwork, communication	None provided for this incident	Articulation and reflection
Challenge 4: Personality conflict	Conflict resolution	Articulation and Reflection	Articulation and reflection

to help the children articulate and reflect on the chain reaction and the factors.

4.2. Challenges in Interpersonal Domain

Teamwork is the aspect that children talked a lot about when asked what they have learned from the afterschool program. See Table 2 for an overview of the challenges in the interpersonal domain.

4.2.1. Challenge 1: Sharing creations with others. Children had many challenges related to teamwork. One of the challenges is that children tended to have ownership over what they have created and hesitated to share with others. For example, Melissa created an attachment for one of the missions. Nancy and Lisa wrote a program for this mission, so the coach asked Melissa to give the attachment to Nancy and Lisa to try out the mission. Melissa was very unhappy because she built the attachment so she wanted to write a program to try the mission. After a discussion about teamwork and how the team needs to share the tasks and the attachments that are built, Melissa gave the attachment to Nancy and Lisa reluctantly. As the team used the same attachment for multiple missions, Melissa said that she was proud and happy that other team members used her attachment for multiple missions.

From experiences like this, children may learn to trust their teammates and share creations with them. In this situation, although the discussions with Melissa was helpful to her, more discussions with the whole team might help the team better articulate and reflect on what it means to be a team.

4.2.2. Challenge 2: Reaching agreement. Sometimes children had difficulty reaching agreement. For example, after voting for several times, the children still could not agree on a name for the team. Nancy came up with the name "a new generation." The coaches asked her why she chose this name, but she could not provide any reasons. She said that she just liked it and did not want to change it to anything else. One of the coaches gave them a talk about developing names that express the meaning and the spirit of the team. After some brainstorming, the girls eventually came up with a more meaningful team name.

This experience provided a good lesson about reaching agreement. Children may learn that when they disagree with each other, they need to provide their reasons, be open-minded, and compromise when necessary. More explicit debriefing would help children better articulate and reflect on these values.

4.2.3. Challenge 3: Sharing work. Another challenge that the children experienced was the lack of ability to work on a task together. Children worked in pairs to complete tasks such as building or programming. Nicole and Megan were able to share responsibilities when working together. One of them would focus on programming and the other would take control of the robot to do the testing. They would discuss how many rotations the robot should move and how it would turn when one of them wrote the program on the computer. They would also switch roles once in a while. The other children were easily distracted if they did not have direct control of the task at hand, whether it is programming or building. In some practice sessions, when some children were absent, the rest of the children were happy because they each had a robot to work with.

These situations provided opportunities for children to learn how to cooperate and communicate with each other when sharing work. The coaches could have discussed strategies on how the children could share the workload when working together, how to brainstorm, and give feedback to each other.

4.2.4. Challenge 4: Personality conflict. Personality conflict is another challenge that the children had to face. Nancy has a strong personality. She liked to have control and it was difficult for her partners to work with her. At one time, she was paired with another girl who has the same personality as her. The two girls enjoyed each other because they were alike, but they also had many conflicts because of their similar personalities. One of the coaches talked to them about core values and how team members should be respectful of each other. However, when these two students worked together, they still tended to annoy each other.

This afterschool program challenged the children to learn to deal with personality conflicts. They needed to learn how to respect each other and how to compromise. Discussions with the individual children are helpful, but more activities are needed to help the children articulate and reflect on the learning of core values.

4.3. Challenges in the Intrapersonal Domains

The robotics practices and competitions posed intrapersonal challenges for children to display competencies such as flexibility, perseverance, and self-management. The following paragraphs describe these challenges and identified in Table 3.

Table 3. Challenges in the intrapersonal domain

	21^{st} century skills	Support Provided	Other Support Needed
Challenge 1: Trying new task	Intellectual interest and curiosity, flexibility	Modeling and coaching	Articulation and reflection
Challenge 2: Working under pressure	Perseverance	Articulation and Reflection	Articulation and Reflection
Challenge 3: Be persistent	Perseverance, grit	Modeling and coaching	Articulation and reflection
Challenge 4: Open to ideas	Flexibility, adaptability, continuous learning	Modeling, articulation and reflection	Articulation and reflection
Challenge 5: Take initiative	Self-management, initiative	Little support	Modeling, coaching, articulation, and reflection

4.3.1. Challenge 1: Trying new task. Unstructured problem solving, building, and programming were out of the children's comfort zone. Once they felt more comfortable in one area, they hesitated to try tasks in other areas. For example, after Melissa built some attachments, she gained confidence in building. But, when she was asked to try a programming task, she was reluctant to try. The coach sat down with her and helped her with the task. The positive experience reduced some of her fear of programming. However, Melissa and other children still tended to attribute outcomes of their work to their innate ability instead of effort.

The robotics afterschool program provided opportunities for children to tackle problems and complete tasks that are outside of their comfort zone. Modeling and coaching were helpful in encouraging children to try new tasks and build confidence in areas in which they had limited experience before. More articulation and reflection could help children understand that regardless if they are not good at some tasks due to limited experience, if they try the tasks with enough help they can learn to do it well.

4.3.2. Challenge 2: Working under pressure. FLL competition requires the children to complete as many missions as possible within two and a half minutes. Within this short period of time, the children need to position the robot correctly and run the first program, change the attachments and position the robot correctly when it is back to base, switch to the correct program, and run the robot again. This may repeat several times depending on the number of missions that they can complete within the competition time. They need to remember all the programs that they will run, all the starting positions for each mission, and all the attachments they will need for each mission. At the competition, two children go to the table to compete. They need to work with each other to complete the missions, so it is important for each to have a role and work together with one another. This is very challenging for some children. In the first competition that the children participated, one of the pairs almost missed all the missions. Because it was the first competition for the day, there were a lot of people watching them and there was a lot of noise. They were very stressed during this time. They got better later in other competitions after they practiced the procedures more with their partners. During the interview at the end of the season, the children talked about the importance of letting go of the stress and concentrating on the tasks. They also talked about how they should not be distracted or annoyed by the other children who were stressed or who were practicing their routines with the robot.

The FLL program gave children opportunities to experience how to work under pressure. By practicing the competition routines and getting exposed to the stressful competitions, the children became stronger when they had to work under pressure. More discussions with children on this issue might help them better articulate and reflect on the strategies of working under pressure.

4.3.3. Challenge 3: Be persistent. FLL is very challenging for the children. Children lack the experience for building, and the robot is not always consistent in its performance. It can be very frustrating for the children. Nancy describes her frustration with one of the missions, "you are like OMG, how in the world do you do this? And then you like I just changed….it kept running into the flag, and then it took a lot of the time, there is something wrong with the wheel." However, the excitement of problem solving also encouraged them to push through the difficulties with persistence. Lisa talks about the excitement of solving a problem. She said, "It is like…" Wait. I cannot figure this out. Wait. Here is the answer. Woo Hoo..." Guidance from the coaches seemed to have helped them to persist longer. For example, when Melissa was about to give up building the attachment for one of the missions, one of the coaches showed her two LEGO pieces that might be useful. She immediately had an idea of what to do and she persisted in completing the design of the attachment. In another instance, Nancy and Ann were very discouraged and negative toward each other when practicing for the regional competition. One of the coaches said that they might need to better position themselves so that they would not get into each other's way. She also pointed out to them that they were delayed because they were not familiar with the attachments for the first three missions. After they changed their positions and once the coach refreshed their memory on how to add the attachments, their performance improved greatly and their attitude got much better. A little guidance and success helped them persist to continue to work on their task.

The robotics after-school program was very challenging, which provided many opportunities for children to learn to be persistent. Modeling and coaching were effective in giving children guidance so that they did not give up easily. More explicit discussions with the team might help the children articulate and reflect on the importance of persistence and strategies to become more persistent.

4.3.4. Challenge 4: Open to ideas. Unlike the typical problems that children solve in the school, non-routine design problems do not have one best answer. In addition, the design process is iterative. A solution that is optimal in one iteration of the project may no longer seem optimal in the next. In the end of the season interviews, children described how they decided not to include one of the missions in the qualifying competition, but then changed their mind later and included it in the regional competition. They decided not to include it in the qualifying competition because it took too much time to run the program and the mission required the change of attachments. In addition, the point value was not high enough to make the mission worthwhile to complete. However, after the qualifying competition, the children reprogrammed this mission so that when it was completed, the robot moved forward to complete another mission close to it. Completing two missions in one run allowed the team to earn more points in a short period of time. Therefore, for the regional competition, the team changed strategy and included this mission and the other one that could be completed in the same run. During the focus group interview, the children used this example to talk about how they needed to be open-minded and willing to make changes to their strategies. Another example children talked about was that during the final practice before the regional competition, one child wanted to change the attachments. The coach told her that it might be too late because the competition was right around the corner. The child quickly showed the coach how she could add something to an attachment so that this attachment could be used for another mission. With this change, the number of attachments that children had to switch was reduced, which made it less stressful for the children during the robot competition. The coach reflected on this experience and discussed it with the children about the importance of being open-minded. One of the children said that "No idea is a bad idea." The children agreed that even when they might not think somebody's idea is good, they would still allow it to be tried first.

The FLL experience exposed children to situations in which design decisions made earlier may be changed later. These situations might teach them to be open to ideas and changes. One of the coaches modeled how to reflect and articulate in these situations. More discussions throughout the program may better facilitate the articulation and reflection of this issue.

4.3.5. Challenge 5. Self direction. Because of their lack of knowledge and skills in robotics and their limited experience in solving unstructured problems, the children tended to lose focus or interest when they were not given a specific task or when they were stuck in solving problems. In the beginning phase of the project, children needed a lot of guidance. Every time when the coaches were not readily available to help the children, they tended to quickly lose focus or become discouraged.

The experiences challenged children to take the initiative and become more self-directed. The coaches might need to model how to break down tasks so that they are more manageable. When children need guidance, instead of giving them a task, brainstorming with the children to identify tasks might help them learn how to be more self-directed. Articulation and reflection on self-management might be also helpful.

5. Research Results

Question 1. What opportunities do children have to learn 21st century skills and engineering design?

Table 1 shows that the robotics afterschool program provided opportunities for children to learn skills in cognitive processes and strategies, knowledge, and creativity, which are the three clusters of 21st century skills in the cognitive domain. Children may learn the following skills related to the cluster of cognitive processes and strategies: analysis, systems thinking, decision making, executive function, and problem solving. They may learn to use math and physics knowledge, which is related to the cluster of knowledge in the 21st century skills. They may learn to design robots and attachments, which is related to the cluster of creativity. The afterschool program also provided opportunities to learn engineering design. Challenge 1 in Table 1 is related to the first component of engineering design: defining and delimiting engineering problems. The rest of the challenges involve the other two components of engineering design: designing solutions and optimizing the design solution.

The robotics afterschool program provides opportunities for children to learn skills in teamwork and collaboration, which is a cluster of 21st century skills in the interpersonal domain (see Table 2). Specifically, children may learn the following skills: trust, cooperation, teamwork, negotiation, communication, and conflict resolution. These skills are important in all phases of engineering design.

The robotics afterschool program provides opportunities for children to learn skills in intellectual openness, work ethics/conscientiousness, and positive core self-evaluation, which are the three clusters of 21st century skills in the interpersonal domain (see Table 3). Children may learn the following skills: intellectual interest and curiosity, flexibility, perseverance, adaptability, self-management, and initiative. These skills are important in all phases of engineering design.

Question 2. What guidance and support have been or should be provided to help children acquire 21st century skills and engineering design?

For challenges in the cognitive domain (see Table 1), the authors found that coaches provided the following types of support to children: modeling, coaching, scaffolding, and experiments. For challenges in the interpersonal domain (see Table 2), articulation and reflection were the main guidance provided. For challenges in the intrapersonal domain (see Table 3), the coaches used the following facilitation strategies: modeling, coaching, articulation, and reflection. In many of the situations, the support was effective, but more articulations and reflections were needed.

6. Discussions and Implications

The findings of this study provide suggestions for coaches of robotics programs and educators interested in teaching 21st century skills. The first suggestion is that programs like FLL should be supported and children should be encouraged to participate even if these children may not go into science and engineering fields. This study shows that the FLL afterschool program provides many teachable moments for learning 21st century skills such as problem solving, decision-making, systems thinking, creativity, intellectual openness, persistence, and teamwork. FLL is designed to attract children to science and engineering, but the skills that children can potentially learn from FLL are important for all professions and daily life. Because children do not typically obtain these skills from school, programs like FLL are good options.

The second suggestion is that for children to acquire 21st century skills, robotics programs like FLL requires thoughtful design with the use of sound instructional strategies. Although FLL involves solving unstructured and non-routine problems, the teaching itself does not need to be unstructured. In order for children to learn the 21st century skills from these programs, a lot of support is needed. There have been debates among FLL coaches on the amount of support that should be provided to children (U.S. First, 2013c). Some coaches believe in providing minimal support so that children can discover the knowledge and strategies on their own. Some other coaches believe that children need a lot of examples and guidance to be successful. This study shows that children who have limited experience in robotics and non-routine problem solving would quickly lose interest and focus if support is not readily available. The finding is consistent with an analysis of education research in the past half-century that shows minimally guided instructions fail to help children achieve expected learning outcomes (Kirschner, Sweller, & Clark, 2006). An National Research Council (2012) report on the 21st century skills also emphasize the importance of supportive guidance and feedback, providing examples and cases, and using formative assessment as effective strategies for teaching 21st century skills.

Another suggestion is to choose appropriate instructional strategies to guide children. In this study, modeling, coaching, scaffolding, examples, and experiments seemed to have helped the children succeed in completing the missions, get exposed to or use various cognitive processes and strategies, and resolve various issues related to teamwork, intellectual openness, and persistence. This may provide suggestions for other coaches and educators interested in programs such as FLL. To help children succeed and gain confidence in FLL, the coaches may need to model, coach, or provide scaffolding such as hints and suggestions on how to use processes and strategies to solve problems, how to build and program, how to work with each other, and how to manage themselves and their emotions. They may also use examples and case studies of existing robot designs and programming to provide knowledge that the children may need to solve the problems.

However, for children to really retain and transfer the strategies and the 21st century skills that the afterschool program challenge them to learn, activities are needed for children to articulate and reflect on their learning. Articulation and reflection are critical components of cognitive apprenticeship (Collins, Brown, & Holum, 1991). In this afterschool program, the coaches seem to have used some cognitive apprenticeship strategies such as modeling, coaching, and scaffolding, but limited effort has been made to encourage articulation and reflection. Articulation refers to asking children to describe their knowledge, reasoning, and problem solving process. Reflection involves comparing one's problem solving with that of an expert (Collins, Brown, & Holum, 1991). Dewey (1933) and Schön (1983) argue that reflection occurs when one's routine approach fails, which encourages one to seek other solutions and restructure one's existing knowledge and problem solving process. Articulation and reflection are key steps for knowledge construction. In FLL programs, articulation and reflection of the design and problem solving process in a group environment may allow the children to make the tacit knowledge in problem solving become explicit so that they may use the knowledge in other context and share with their peers. Articulation and reflection on intrapersonal and interpersonal skills may encourage children to take more personal responsibilities for being persistent, be open to ideas, and for developing strategies to solve problems.

This study also provides implication for researchers. Although researchers generally consider articulation and reflection as beneficial instructional strategies, little formal research has been done to identify the effect of the strategies and best practices in specific educational contexts. Some studies of articulation and reflection have been conducted in the field of mathematics education (Brandenburg, 2002; Derrick 2005) but studies on articulation and reflection are difficult to find in learning environments that support unstructured or non-routine problem solving.

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Development of Visual Philosophy under Impact of Philosophy of Technology

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Abstract: *Throughout history the development of technology has been affecting people's lives. Any kind of technological innovation may give a qualitative leap in human society. The impact of technology has penetrated into the study of various disciplines. Philosophy is no exception. In 1877, Karp formally proposed the concept of "philosophy of technology." Technology has been studied from the practical aspect of a tool to the level of philosophy. Although the concept of visual philosophy has not yet been formally proposed, the thinking of philosophical vision has already existed. This paper is to analyze the impact of philosophy of technology on the development of visual philosophy, from the perspective of instrumental theory and humanistic theory, and to clarify current values and directions of visual philosophy.*

Keywords: development, philosophy of technology, technology, impact, visual philosophy

1. Introduction

Philosophy focuses on the origin and essence of objects and concepts, and is the basis and foundation of other superficial research. If someone's study wants to make progress, it must go back to philosophy itself. The study on vision, visual, visual literacy, and visual culture also need to return to the "visual philosophy." There are a lot of achievements on the study of philosophy of technology. The most significant achievement is that people have been able to talk about technical rationality, not just think of it as a tool. In different historical periods of visual philosophy, technology plays an important decisive role. Technology even promotes the development of visual philosophy. Either in the long history of visual philosophy or in today's image world, technology is intertwined with vision. This paper uses the historical and comparative methods to propose the history of visual philosophy, and to examine the influence and value of philosophy of technology on visual philosophy and propose the contemporary research direction and content of visual philosophy.

2. Philosophy, Philosophy of Technology, Visual Philosophy

Philosophy is an important tool for the human world to know and transform the world. The object of philosophical research is the relationship between human and nature. It gets to the bottom of the problem for an answer. Philosophy of technology and visual philosophy is about specific research in the field of philosophy. Philosophy of technology already has mature system of research. At present, technology has penetrated into every field and subject such as education, psychology, medical science, and also influenced visual philosophy. Although visual philosophy has not been lodged from the history of visual research, it has formed a clear research context. To establish visual philosophy research framework, theories and methods of philosophy and philosophy of technology are helpful for the research of visual philosophy.

2.1. Philosophy and its Universal Values

The word philosophy derives from Greek philosophia, formed by Philos and Sophia. Its meaning is "love and wisdom." Philosophy pursues the world's origin, nature, common, or absolute. Its research content is the scientific methodology of understanding and transforming the world. There has always been controversy for "what philosophy is." The study of philosophy lasts a long time. This research field evolving with the development of time has distinct characteristics. Philosophy has produced different branches of philosophy such as natural philosophy and philosophy of science, philosophy of technology, etc. The consensus view of philosophy research is that philosophy is a kind of method. Problems that cannot find the answer can be attributed to the study of philosophy. Philosophy also solves the problems of what objects and effects are like. Meanwhile it can give objects and effects definite descriptions in terms of definitions and concepts. Research on philosophy is based on rational thinking. It is not a simple description of phenomenon, but is based on the nature of thinking. Objects for philosophical research are the universal laws of nature, society, and human minds. Though the description of the philosophy is not the same, from the descriptions above all, one can find the value and significance of the research of philosophy. The reason why philosophy can have a far-reaching effect on other research fields and disciplines is that the philosophy has characteristics of holistic, fundamental, and common sense thinking. Therefore, philosophy has universal significance and value for further study of other fields and disciplines with the long-term development.

2.2. Philosophy of Technology: Guidance of Philosophy to Technology and Technical Contribution to Philosophy

The development of technology has been the center of attention for a long time. Technology has been considered to be an important tool for humans to understand and transform the world. The recognition and understanding of technology is stuck on the level of tools and media. So the advance of technology usually refers to the improved tools or media. Technology as tools or media can help humans adapt to the nature. It is the "positive value" of humanity. However, as the intermediary of man and nature, the value of technology and technology alienation bring us to think the value of technology for people. Technology cannot be defined only from the viewpoint of the tool or medium. Technology alienation has brought about the negative effects on humans. Alienation refers to "the subject is in the process of development. Because of its movement the subject produces its opposites (object). This object has become an external alien force against the subject" (Guo, 2002, p. 1). The earliest use of alienation in the research category of philosophy is the German philosopher Hegel. He proposed that alienation refers to "man's creation turns against people and enslaves people, and became the alien force to control human" (Wu, 2011, p. 38). From the natural level, technology alienation caused the pollution of the environment, resource crisis, and population expansion; from the social level, technology alienation brings the threat of military technology such as nuclear war; from an ethical level, technology alienation led to chaos of ethical judgment such as the effect of cloning technology on human life. The reason for these phenomena is the nature of technology and the value of technology is like. Whether technical rationality means the technology itself has the ability of rational thinking, or the creation of technology has the ability of reasoning and thinking, the answers to these questions must be searched from philosophy. Philosophy is thinking about the nature of objects and concepts. Any essential research should be attributed to the study of philosophy. Philosophy of technology proposes precisely to solve these problems. In the research process of technology, the generation and development of philosophy of technology needs the enlightenment and guidance of philosophy from the ontological and methodological level.

Secondly, the study of philosophy of technology has made its contribution to the study of philosophy. Since the industrial revolution, the influence of technology has penetrated into various fields and disciplines. Technology has developed from a radical improvement in the level of people's material needs and meeting people's needs for survival. This has challenged people's rational thinking. Philosophy aims to study the relationship between man and nature, and technology plays an important role in the study of the relationship of man and nature. From the perspective of the significance of the relationship of man and nature, philosophy is divided into three branches (Chen, 2012): (1) the narrow natural philosophy, natural ontology; (2) philosophy of science, natural epistemology; and (3) philosophy of technology, natural transformation theory, which shows that research of philosophy of technology plays an important role in the study of philosophy. The emergence of philosophy of technology in 1877 is a direct manifestation of the important impact on the study of philosophy; it is also an important contribution to the study of philosophy. The study of technology shifts also exerts a profound impact on other areas of philosophy, including visual philosophy. This relationship makes philosophy of technology occupy a very important position in the whole philosophy of research areas. The penetration of technical philosophy in other areas is the important value performance in the study of the relationship between man and nature. Fundamentally speaking, the study of philosophy of technology has opened a window to analyze and solve problems from a technical level, and has improved the system of philosophy.

2.3. The Inevitable Emergence of Visual Philosophy

Philosophy is a universal sense of ontological and methodological research. The theory and practice of the visual theory also needs to seek the guidance of methodology from philosophy. In the analysis of vision, which serves as a sensory awareness and understanding of a kind of thinking, the interpretation of what the vision is seems not easy. Then, the questions to the principle of vision, visual law, and the relationship of vision and thinking will inevitably go to philosophy to locate the answer. Visual philosophy is philosophy about visual research. This study has existed in the practical activities of the people in the process of understanding and transforming the world. The philosophers, in the ways of thinking relationship between man and nature, are impossible to ignore the cognitive effect of the eyes or "window of the soul." Vision and thinking have always been inextricably linked. "More than 70% of the feeling of receiving of the human body is concentrated on the eyes"(Leicester, 2003, p. 18). To understand the problem of vision is to understand people's thinking. Turning over the history of the study of philosophy, the study of vision philosophical inquiry can be found everywhere. From great thinkers such as Plato and Aristotle, who are builders of visual centrism, to Cassirer, Benjamin, and Heidegger, whose rational understanding and reflection are famous to all. As can be seen, the study of vision does not stay on the superficial surface of visual centrism. In different historical periods, it demonstrates the rich connotation and research to help humans better understand and transform the nature. Visual philosophy has been in progress and it also responds well to related concepts such as "visual centrism." However, visual philosophy just has not yet established a clear and completely theoretical system. Philosophical research methods will guide all kinds of visual research; visual theory and practice research also serve as a contribution to the study of philosophy.

3. Origins of Visual Philosophy

From various sources, studies on the philosophical basis of visual culture and the philosophical study on the image culture is not uncommon. But, it is quite rare to clearly clarify the term "visual philosophy," which is not similar to the study of natural philosophy, philosophy of science, philosophy of technology. However, whether in the course of the division of the essence of vision, or a reflection of the current visual appearance and essence, the study on philosophy of "visual" essence has never stopped and will always be extended. Countless sages in history have been discussing this topic such as Plato, Aristotle, Michelle, and so on. From their discussions, two visual clues can be clarified in the philosophical development: the discussion about the "visual centrism" and the shift of philosophy from language to vision.

3.1. Prosperity and Collapse of Visual Centrism

Of all the problems, the core of visual philosophy is nature of vision. What is the vision? In the tradition of the western culture, the vision has always been considered to be the noblest of all the senses. Like the soul, vision is like a noble reason existing out of the flesh. The establishment and development of visual centrism can be traced back to ancient Greece, Plato, in the name of Timai Oswald said: "In my opinion, vision is the source of our most useful things ...... God invented vision, and ultimately it is given to us so that we can see the rational process in heaven, and can in turn apply this process to our own rational process." (Lacan, 2005, p. 4). Aristotle, the founder of the visual centrism said in metaphysical, "the pursuit of knowledge is human nature. We are pleased to feel is a description; Even if there is no practical purpose, people love feeling, and among all feelings, vision matters most"(Aristotelian, 1959, p. 1). The status of the visual centrism to ensure the purity of people's philosophical and rational thinking is critical. Visual centrism in modern times still has a lot of supporters. American phenomenologist Hans Jonas, said in a paper entitled noble vision, "only the vision can provide foundation for feeling, through vision the mind can produce long-lasting concept, or the eternal and the ever-present concept", "and thus where vision touches, the mind will be able to reach" (Jonas, 1954, p. 519).

However, with the arrival of the image of the world, structuralism, and post-modern thoughts constantly impact on the status of the visual centrism. The visual rational cognitive has been questioned. Omnipresent seeing and be seen are intertwined with confusing eyes. The link between the visible things and its represented invisible aspects is not so tight. What one has seen is not the nature of things. Behind the visual representation there is nothing. Mechanical reproduction in the machine industrial age has created numerous visual impressions, which is dreamy. When the vision sees purely visual representation, there has not been the difference between real and representation, the essence, and phenomenon. From Iraq Debord's "spectacle society" description to Anne Frye Berg interpretation of "the social image value-added" to Baudrillard's "Simulacra," the attention to visual object features that visual centrism has advocated for is overthrown, and visual philosophy research should focus on visual objects and the possibility mechanism of looking behavior. Thousands of years of visual centrism buildings collapsed in the process of human understanding and transformation of the world. This understanding is an important breakthrough in the visual study of philosophy. If the study on visual philosophy only focuses on visual objects, the audience will be more confusing and fall. At present the important content of studies on visual philosophy is concerning the relationship of seeing and being seen, the mechanisms of looking behavior from "look" to "see" to "read."

3.2. Shift of Philosophy of Language to Visual Philosophy

The process of visual centrism from the establishment to the collapse is an explicit clue of the historical development of visual philosophy. From the shift of understanding and characterization of human knowledge, there is an invisible clue for the development of visual philosophy. The attention on visual philosophy from two different shifts is from the peak to the trough and then rising again, moving forward difficultly. An important trend of the 20th century in Western philosophy is a "linguistic shift," in which this understanding is based on modern philosophers' concerning "ideology." Ancient philosophers are concerned more about the elements themselves, what is the look of its own form of things, or visually visible characteristics (i.e., visual centrism). Modern philosophers thinking of an accurate understanding of the concepts must be described from the "concept," which is expressed through language. The status of the noble visual sensory capacities is in decline. The precise degree of expression by language is directly linked with rationality, wisdom, and logic. To the mid-19th century, however, no prophet can predict the emergence of photography, telephones, movies, and their great impact on the language. The concept of "visual culture" during this period, which was the important theoretical results of visual philosophy, was mentioned here. University of Chicago scholars Michelle put forward "visual culture is the culture separated from the rational form of language, increasingly turning to the image centrism, especially to the movie-centric sensibility morphology. Visual Culture not only marks changes and formation of one kind of culture, but also means a conversion of the paradigm of the human mind" (Zhou, 2002, p. 72). Seeing by language is a big step forward in thinking. Language is the spokesperson of wisdom. In the picture era, the visual image can express ideas that language cannot explain. In front of the vivid images, language is pale. Images can also be "read out" beyond language to express the unity of a variety of connotations. The shift from "seeing" by language to using these images to "read," broke the center position of "language." The visual ration has pushed to the foreground. This shift marks visual philosophy is bound to rise.

Visual image is prevailing today. The status of vision has been highlighted, but thinking of the nature of vision also is puzzling. Today, we do not need to cheer the success of visual shift, but need to focus on the mutual conversion of language and vision. In the visual image world, can language rationality smoothly shift to visual rationality? Maybe this cannot. Reading the text does not mean the capability of reading the image. The lack of visual literacy is an urgent problem. In the same way, visual philosophy will no longer be easily turned to the philosophy of language. People, who used to read images, gradually became poorer in the ability of reading text and expressing by language. This seems to be helpless, but also it extends the research content for visual literacy. The training of visual literacy should be the awareness, understanding, and use of all forms of visual characterization.

4. The Influence of Philosophy of Technology on Visual Philosophy

The development of technology which has always focused on the function of technology can be roughly summarized as technical tools theory, technology media theory, technical rationality, and technological humanistic theory. Technology as an important symbol of human progress has been the main tool of the human conquest of nature. It is the grounds of technical tools theory. From ancient times people seek a more high-end, sophisticated and convenient technology to live better lives, thus the technology can be seen as a medium of communication between man and nature. In the face of negative effects brought about by the technology, people have deep thinking about the technology. It is worth studying that technical rationality stems from human or technology itself. Philosophy of technology that aims to find the nature of technology has a profound impact on the development of philosophy. Philosophy of technology also influences the development of research on vision and visual philosophy.

4.1. Study on the Impact of Technology to the Development of the Visual Philosophy from the Perspective of Instrumental Theory

Not difficult to see is that the two clues “Visual Centrism and “Visual shift” are in parallel with the development history of visual philosophy. The development of visual philosophy has gone through three historical periods: the era of visual centrism, the era of anti-visual centrism, and visual literacy training period. There are three different tools appearing in the three different periods from the mirror to the camera to the computer. In fact, learning from symbol philosophy proposed by German philosopher Ernst Cassirer, one can find the important revelation of philosophy of technology to visual philosophy implicit in the representation of technical morphological changes.

German philosopher Ernst Cassirer has deep thinking and research on “Symbol Philosophy.” He believes that in the course of human evolution, the symbol has also experienced a different evolution. The symbol showed as an icon experiences in the initial stage. Icon is the equivalents of nature, directly facing the nature, and reflects real natural attributes. In this case, the symbol functions like a mirror. The first symbolic development stage corresponds to the period of “mirror” morphology of the technology. A mirror faces the characterization of the object as a technical tool. A mirror reflects a true representation of objects. The visual object and characterization of objects is a peer-to-peer relationship. The elegance and authority of vision established the centrality of the vision.

In the second symbol development historical period, the relationship between the reality and vision had changed. The trait between the symbol and the reality was no longer a simple replication relationship, but a causal relationship. There was the complexity of the intermediation process. In this case, the function of a symbol was like a camera. Camera technology principle determines its performance, which no longer simply copies characterized objects. Not only does the lens of a camera have selectivity, but also has a shielding property. Photos only render the tip of the iceberg. The reason why the photo presented to the audience is such a tip of the iceberg, rather than any other part, is the complex causal relationships. Presented characterization does not truly reflect the visual object itself. Getting essential cognition of objects from phenomenon has more obstacles. Looking does not mean seeing, let alone understanding. Pictures of wanton stitching and the use of a variety of technical performance practice, makes the lens show visual objects that are handled and processed artifacts, not natural objects. With the human visual experience and misunderstanding, the magical image confuses eyes. Visual centrism begins to be questioned.

The symbol of its true meaning is in the third period of symbolic development. In this period, symbol and nature is directly separate. If a mirror is the performance of the symbols of nature rendered directly and camera performance is a symbol of natural indirect presentation, "symbol" in this period is not naturally a representation, directly or indirectly, but entirely separate from the raw state of nature and shows as a presentation of the spirit and thinking. The symbols function like computer. Computer as a technology tool, during this period, is the symbol representatives. The abstract of all the symbolic representation is "0" and "1," only two figures. Data programming techniques, a simple complex combination of the two figures can refer almost all generations of thinking and command, and has greatly enhanced the speed of people's understanding of transformation of nature. Today, in the image world, images not only affect the process of thinking, but they are the thinking itself. From a phenomenological point of view, something behind the image represented by computer technology tools is completely shelved. Technological image completely changes the original mechanism of visual communication, and these images are entirely under the control of political rights and media. It has become a consensus that visual literacy training is necessary and urgent during this period. Needed is to peel off the external power and politics and face reality and nature. These will be important content of studies on visual philosophy in this period.

4.2. Examining the Impact of Philosophy of Technology to the Development of the Visual Philosophy from the Perspective of Technology Humanistic Theory

The understanding of technology as tools is an important factor, which causes the historic absence of philosophy of technology. Although the technology serves as tools to help people understand and transform the world, the understanding of technology has not reached the height of philosophy. Until 1877, the German philosopher Ernst Carp formally proposed the concept of philosophy of technology in his book named Philosophy of Technology Platform. In the mid-18th century, the British Watt's improving the steam engine seemed as the starting point of the first industrial revolution. A series of technological revolutions brought about the shift from manual labor to the production by powered machines. This technology wave was then transmitted to the entire European continent from the United Kingdom, and spread to North America in the 19th century. Technology, which has brought revolutionary change to human society, makes people shift in attitude toward the technology: from disregard to face up to the reflection of technology humanistic theory. Technology humanistic theory believes the philosophical thinking about the relationship of human and technology, or the value of technology brought to people. In the early stage technology is created and took advantage of by humans, but as technology advances it has a great deal of positive value. However, when today's technology lead to ecological and natural crisis, people began to reflect on the negative value of the technology.

In the development process of visual philosophy, technology is experiencing from indifference to being confronted with squarely, and then reflecting on the process. In infancy, technology had once dubbed the "witchcraft" title. This slightly derogatory description reflected people's indifferent attitude towards the technology. In this case, the vision was a noble symbol of the thinking. The value of technology to human beings was only one side to reflect reality nature, just like "mirror." It did not predict that technologies would influence the status of vision. Entering the industrial age, people began to face the great strength of technology, especially when technology as a tool to subverted the form and means of visual representation. The technological image makes a mirror-like vision seem superficial, and the image technology makes vision begin to think. Technology has led to challenges to the visual experience. The visual think is often influenced by technology. People cannot discriminate the boundaries of the essence and phenomenon. At this time of the power of technology, it aims to improve the living conditions of the people and also change the "horizon." Today, technology has brought an even greater crisis to the human's visual experience. The robot can replace humans to complete the specific tasks that human beings cannot complete. Are robots people? Who dare to say that the robots are "Persons" or "Non-persons." Human beings as the master of the world have alternatives. It seems that the whole world can be digitized.

Technology was originally created by people as tools to understand and transform the nature. Today, technology sometimes cannot be in accordance with the established and artificial route that set to transform nature by people, and there has been phenomenon of a breach of human consciousness; the damage to human survival environment and technology alienation. However, the reasons of technology alienation are rooted in the improper values and behavior of human beings who creates and utilizes technology. Based on understanding, the aim of visual literacy education is to enhance literacy training on the aspects of the creation and production of technology. However, the visual representation of the image produced by any technical means, its creators, must be human. Human's rationality has created technical rationality. The correct understanding of the visual audience also depends on the correct understanding of generation mechanism and characterization. It is important enlightenment on visual philosophy that examining the relationship among "people - visual – technology" and exploring the value of visual technology to humans on the perspective of the humanistic theory of technology.

4.3. Values of Philosophy of Technology to the Development of Visual Philosophy

The study of philosophy of technology not only focuses on the technology itself, but also on the reasonable judgment of the value of technology to humans. The reflection of visual philosophy is not limited to vision. Technological inventions often seem to make the eyes betray the mind. Visual philosophy needs to solve the problems of human beings with technology and technical rationality. The meaning and value of contemporary study of visual philosophy is embodied at this point.

The content of visual philosophy, in addition to the exploration of the relationship of the eyes, brain, and thinking, also needs to reflect the relationship of human, vision, and technology. This can develop visual literacy education for the audience and the inventor of visual representations. Contemporary theoretical value of visual philosophy is to reconstruct a theory building of visual philosophy through historic and comparison methods, and to make up for the deficiency of the overall architecture of the visual philosophy studies. As a start, we can sort out the history of visual philosophy studies, from vertical perspective, and clarify the characteristics, the main viewpoints and their practice process of each period of development of the visual philosophy. Though the system of visual philosophy has not yet been established, throughout the history of vision research, many research has dubbed the "visual philosophy" name, thus opening up a precedent for the study of visual philosophy such as Germany Nietzsche's perspective "writing instruments which contribute to the formation of ideas," Cassirer's theory symbol philosophy, Rudolf Arnheim's "visual thinking," and Walter Benjamin concentrating on the technology image and its rich achievements of the revolution triggered in the visual field (Meng, 2005, 4-10). We can stand on the shoulders of these sages to see farther and higher. Then, comparison methods can help us understand the relationship of visual philosophy and its related fields or subjects. In the foundation of rich research results of humanism and phenomenology, construct theoretical system of visual philosophy.

The practical value of studies on visual philosophy is to solve the real problem of how to interpret the image of the world. Current theoretical assumptions and studies of the vision focus on the understanding of the visual mechanism or the way of visual representation, and strategies of visual literacy training. These studies examine visual practice, but its goal is more realistic to better cope with the visual research. However in the final analysis, this is an assumption from the theoretical level. Such proposed research is a "stopgap measure" that does not solve the rooted cause of the problems in the practical study of visual philosophy. Digitization and virtualization are two key words in today's image era of visual representation. The practical research of visual philosophy should focus on the characteristic features of era and technical rational thinking to make full use of technology to create a better and more beautiful visual representation (i.e., visual educational resources) to carry out the actual social action and specific projects. Finally, people will realize the concept and strategies of visual literacy education through their participation in the process of practice. Since birth, the world's first touch is the "light of life" through vision. Visual perception accompanies a person's whole life. It is important that we have been concerned about the "look" ability and visual experience. Therefore, the understanding of the vision, since ancient times, is an eternal topic. Research on establishment and development of visual philosophy applies to daily activities. It needs to restructure ways of history and comparison. Due to the impact of technology and philosophy of technology, the development of the visual philosophy is endowed with new meanings and value. In terms of the "Then Time," "Current Time," and "Future Time," the power of technology will continue to affect people's practical activities of understanding and transforming the nature through vision.

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Development of a Scaffold Design Model in Inter-school Collaboration Environment: A Design-based Research

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Abstract: *This study examines the development of a theoretical framework for scaffold design in an inter-school collaboration environment. The research question primarily deals with how to design scaffolds for an Inter-school Collaborative Learning (ICL). Design-based research methodology was used in this study. Literature review, questionnaire survey, field survey, and interviews were used during the course of research. Forty-seven secondary schools in 25 provinces in China were selected and participated in the study. This paper reports the first circle of design-based research. Through design-based research, a scaffold design model was developed and revised. Eight key types of scaffolding for ICL were identified. Elaborated strategies and tools were summarized for implementation of these scaffolds.*

Keywords: collaborative learning, inter-school collaboration, scaffolding, instructional design

Abbreviations: ICL (Inter-school Collaborative Learning)

1. Introduction

As an important manner for cross-culture collaboration, Inter-school Collaborative Learning (ICL) has been proved to have significant benefits for students, teachers, and schools (Atkinson, Springate, Johnson, & Halsey, 2007). However, as one of the most complicated models of applying Information Communications Technology (ICT) in education, ICL is difficult to implement practically (Berenfield, 1996). Teachers, especially rural teachers need assistance on how to design and conduct ICL. This study aims to provide a theoretical framework for ICL design, so as to support rural schools to conduct ICL.

In the recent decade, academics are paying great attention on scaffolding again, especially scaffolding in a digital learning environment. Research on scaffolding in different learning environments have been focused on four key questions: (1) what types of scaffolds are needed, (2) what to scaffold, (3) when to scaffold and when to fade, and (4) how to implement scaffolding (Azevedo & Hadwin, 2005). Some researchers have put forward their own design frameworks or models of scaffolding in different learning environments

(Dodge, 2000; Hogan & Pressley, 1997; Kim & Bhang, 2008; McKenzie, 1999; Pressley & Harris, 1992). These scaffold frameworks or models try to partly answer the above four key questions of scaffold design. In this study, the authors aim to form a scaffolding model that tries to answer the four key questions.

Therefore, this study examines the development of a theoretical framework for scaffold design in an inter-school collaboration environment. The research question is how to design scaffolds for an ICL. The scaffold design model is developed following four sub-questions: (1) what types of scaffolds are needed, (2) what to scaffold, (3) when to scaffold and when to fade, and (4) how to scaffold .

2. Methods

2.1. Procedures & Methods

Design-based research methodology was used in this study. Questionnaire survey, field survey and interviews were used for data collection during the course of research. This paper introduces the first cycle of the design-based research.

Research procedures include three steps. Step 1 is the theoretical framework that consists of the draft version of Scaffolding Model of ICL developed via literature review and survey. A literature review and survey were used in this stage. Step 2 is utilization & evaluation that consists of the framework adopted to guide the practice: a large-scale ICL practice for rural schools in China. A detailed set of scaffolds, including related strategies and tools, were designed and developed for the practice. Meanwhile, both quantitative and qualitative methods were used to collect data including questionnaires, field surveys, and interviews. Step 3 is revising the framework by including suggestions proposed on how to select and design scaffolding for ICL, especially for rural schools.

Design-based research, also called 'design research' or 'educational design research,' is "a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab & Squire, 2004, p4-5). Design-based research is characterized as (Akker, Gravenmeijer, McKenney, & Nieveen, 2006):

- Interventionist: the research aims at designing an intervention in the real world.
- Iterative: the research incorporates a cyclic approach of design, evaluation and revision.
- Process-oriented: a black box model of input-output measurement is avoided; the focus is on understanding and improving interventions.
- Utility-oriented: the merit of a design is measured, in part, by its practicality for users in real contexts.
- Theory-oriented: the design is (at least partly) based upon theoretical propositions; and field testing of the design contributes to theory building.

Design-based research can contribute to increase the relevance of research for educational policy and practice. This study aims to develop a theoretical framework to guide the scaffold design of ICL. Design-based research aims at developing empirically grounded theories through combined study of both the process of learning and the means that support that process (diSessa & Cobb, 2004; Gravemeijer, 1994, 1998), therefore design-based research is selected as the methodology for this study.

2.2. Participants

An ICL program titled 'China Traditional physical Games& Culture' was conducted. This ICL program was designed to be inter-disciplinary and mainly covering Chinese, Information Technology Education and Physical Education. Multi-staged stratified sampling was used to select participating schools. Forty-seven secondary schools in 25 provinces in China were selected and participated in the study. Eighty-point-two percent of participating schools were rural schools with relatively low level of ICT skills, and 47.2% of participating schools were located in West of China. Participating students were mainly in Grade 7 and Grade 8, aging from 13 to 14 years old. One hundred and six teachers participated in this project to cooperate closely with the research team and to guide their students through the ICL program with the designed scaffolds.

2.3. Data Collection

2.3.1 Questionnaire

A questionnaire survey was used in the study to collect feedback from participating teachers. Teachers were asked to evaluate the effectiveness of these scaffolds and tools in supporting the ICL. A 5-point Likert scale was used to collect responses from the participants: strongly agree, agree, neutral, disagree, and strongly disagree. Six experts in this area were invited to measure the validity of the questionnaire. A total of 69 valid questionnaires were collected with a return rate of 65.1%.

2.3.2 Qualitative data

Interviews, field surveys, and content analysis of students' forum discussions were used to collect qualitative data. Eight participating schools were field surveyed. One-to-one interviews were made to 8 headmasters and 8 teachers in charge. Group interviews were conducted to 33 other teachers and over 100 students. Interview questions mainly include three parts: (1) how they conducted the ICL project, (2) how they evaluated the scaffolding tools provided, and (3) their difficulties and expectations.

3. Theoretical design Framework

3.1. Derivation of the Design Framework

The theoretical framework of the study, Scaffold Model for ICL, was first derived through considering the following four issues.

Issue 1: what are the key reasons/conditions for effective collaborative learning?

The effect of collaborative learning (CL) has been supported by different theoretical principles (Huang, 2003; Johnson & Johnson, 2002; Slavin, 1995; Zhao, 2006). Based on analysis of different theories, Salvin (1992, 1995) identified four major theoretical perspectives designed to explain the achievement effects of cooperative learning: motivational perspectives, social cohesion perspectives, cognitive perspectives, and cognitive elaboration perspectives. Based on analysis of different CL scripts, Dillenbourg and Jermann (2007) defined three types of schemata: the jigsaw schema, the conflict schema, and the reciprocal schema. Through an analysis of different theories related to CL, the authors found three key reasons or conditions for effective CL: positive interdependence, peer interaction, and cognitive conflict. These matched the three schemata defined by Dillenbourg and they emphasize key factors for successful collaboration.

Positive interdependence: In the views of motivation theory, field theory, contact theory, and social interdependence theory, the key reason/condition for success of collaborative learning is to promote motivation. These theories emphasize the positive interdependent and indispensible relationship between group members to promote motivation such as establishing goal interdependence, resource interdependence, and so on. The schema for positive interdependence is the jigsaw schema, which emphasizes the group members as being complementary and mutually dependent.

Cognitive conflict: According to Piaget and constructivism, the key reason or condition for the success of collaborative learning is cognitive conflict. The schema for cognitive conflict is the conflict schema.

Peer interaction: In the views of Vygotsky and social culture theory, cognitive elaboration, social learning, and humanistic learning theories believe the key reason or condition for the success of collaborative learning is the reciprocal interaction between peers. The schema for peer interaction is the reciprocal schema.

Issue 2: Which strategies can support these key conditions?

The existing practices and researches in CL field have produced a handful of strategies which can support the three key conditions (Aronson, Blaney, Sikes, Stephan, & Snapp, 1978; Berger et al, 2001; Dillenbourg, 1999; Hermann, Rummel, & Spada, 2001; Hoppe & Ploetzner, 1999; Jermann & Dillenbourg, 1999; Johnson & Johnson, 1994; Lampe, Rooze, & Tallent-Runnels, 1996; O'Donnell & Dansereau, 1992; Palincsar & Brown, 1984; Reiserer, Ertl, & Mandl, 2002).

Strategies to support Positive Interdependence. Group incentives, goal interdependence, incentive interdependence and other strategies are widely used to support ositive Interdependence. An essential strategy for positive Interdependence is 'task specialization,' which aims to build up an interdependent and mutual-value relationship among group members. Task specialization is widely used in many popular CL approaches such as Jigsaw, GI, Finding Out, etc.

Strategies to support Cognitive Conflict. To arouse cognitive conflict, one strategy is to conduct a collaborative argument, and another is to intentionally put two sides of opposed views into one group. These strategies are widely used in collaborative debate, argument map, and other CL approaches.

Strategies to support Peer Interaction. There have been a lot of strategies to support Peer interaction such as collaborative script, peer feedback, peer evaluation, reciprocal teaching, and so on.

Issue 3: Which types of scaffolds are needed for CL, according to existing scaffolding framework?

Some researchers put forward their own design frameworks of scaffolding in different learning environments. Dodge's scaffold model for WebQuest (2000) and Kim and Bhang's scaffold framework for CSCA (2008) frameworks are the most typical. However, existing scaffolding frameworks mainly focus on two questions of scaffolding design: (1) what types of scaffolds are needed, and (2) what to scaffold. Dodge's scaffold model and Kim and Bhang's scaffold framework tried to answer the question 'how to implement scaffolding.' But, both of them implemented each scaffolding type by a list of tool examples that might still be difficult for rural teachers to operate.

Although no research on scaffolding for ICL was found, these scaffolding researches in traditional classroom, inquiry learning, and CSCL put forward different dimensions on scaffolding design. Therefore, the authors identified that the Scaffolding Model for ICL would try to answer the four key questions of scaffolding design. Moreover, on the fourth question 'how to implement scaffolding,' the authors proposed to adopt strategies to bridge each scaffolding type and supporting tools.

Issue 4: Which scaffolds for ICL are especially needed by rural schools in China?

The last question is to consider China's national condition. What are the main difficulties in practice when rural schools carry out ICL in China? What scaffolds do they need especially? A questionnaire survey was conducted in 50 rural middle schools across China, together with a field study in 3 rural schools of different regions. Five major difficulties were identified for rural schools to carry out ICL. With reference to the results, scaffolding needs were proposed to solve these difficulties.

The first major difficulty is low level of schools' information technology infrastructure. Information technology is required to support scaffolding. This is true in the process of ICL by which students need to know how to collect and process data and how to present their works. The second major difficulty is teachers and students' lack of experiences and abilities on collaborative learning. Hence, scaffolding support with collaboration skills is required. The third major difficulty is the heavy workload in schools, and thus, objective scaffolding is needed to provide clear objectives for schools. Content scaffolding and evaluation scaffolding are also needed to keep students on task. The forth major difficulty is the great differences between schools. On one hand, this is an actual difficulty that ICL faces. On the other hand, it is an important condition and characteristic that ICL needs to achieve its potential effects. Therefore, specific grouping scaffolding can make use of this and solve the difficulty. The fifth major difficulty is deficient emphasis of school leaders on information technology. Considering this factor, an effective incentive mechanism should be designed to stimulate school leaders' interest and enthusiasm in ICL.

3.2. Scaffolding Framework for ICL

Through considering comprehensively the above four issues, eight types of scaffolding for ICL are identified as shown in Table 1.

Table 1. Draft version of Scaffolding framework for ICL.

Scaffolding Type	Scaffolding Content
Goal Orientation Scaffold	Clarifies subject, purpose, and expectation of task
Content Direction Scaffold	Provides clear direction and explains structure and content arrangement in details
Group Building Scaffold	Helps in forming groups, making collaborative plans, assigning tasks, and the like.
Peer Interaction Scaffold	Fosters collaborative and communication skills
Data Collection Scaffold	Guides students to collect, organize, and record relevant resources
Data Process Scaffold	Assists students to process and analyze collected data using text, tables, figures, and so on.
Outcome Scaffold	Helps students to produce and present their project outcomes
Evaluation & Incentive Scaffold	Clarifies evaluation standards and incentive mechanism, and helps assess the process and production of group collaboration

4. Results

4.1. Implementation

In the cross-regional inter-school collaboration, 47 schools participated and the expected collaboration outcome was a website of 'China Traditional Physical Games & Culture.' To support the practice, 8 types of scaffolding were designed and implemented, with 24 strategies and 49 tools. Take 'Goal Orienting Scaffold' as an example, two strategies was used to scaffold students being goal-oriented: interpreting common goals and seeking unity of conceptual understanding. Three activities were designed to realize the strategy of interpreting common goals, with support of three tools. Two activities were designed to realize the latter strategy, with support of another three tools. Table 2 shows the relationship between the strategies and types of activities and tools.

Figure 1 shows a concrete example of the e-portfolio implemented for Evaluation Scaffold in this study.

The authors mainly examined whether and how effectively these 8 types of scaffolds support the ICL practice. Qualitative and quantitative data were collected to evaluate the eight types of scaffolds. A questionnaire survey was used to collect evaluation from teachers. A 5-point Likert scale was used in five levels:

Table 2. Implementation of Goal Orienting Scaffold

Strategies Used	Activities	Supporting Tools
Interpreting common goals	To read project introduction To guide stage goals To present tasks and goals of big steps	Project introduction Stage goal introduction Big-step task and goal description
Seeking unity of conceptual understanding	To explain key concepts To mind-storm	Key concepts explanation, Key concept illustration Mind-storming introduction

Figure 1. E-portfolio for evaluation Scaffold.

strongly agree, agree, neutral, disagree, and strongly disagree. The authors also site-visited 8 schools, interviewed over 40 teachers and students, and observed and analyzed the postings and reflections that teachers and students created through the process.

4.2. Findings

Results indicated that the 8 types of scaffolds were all considered effective to support ICL, means of which varied from 4.14~4.66 (as shown in Table 3). The 25 scaffolding strategies were also considered effective, with means ranging from 4.08~4.84 and a standard error from 0.37~0.81.

Survey results indicate that the 25 strategies and 8 types of scaffolds were regarded as very useful and supportive for ICL. Qualitative data through interviews and field surveys also show that teachers highly appraised the effectiveness of the 8 types of scaffolds on supporting them to conduct the ICL successfully. Using 'Goal Orienting Scaffold' as an example, questionnaire results showed (as in Table 4) that 94.20% and 94.93% of teachers and students regarded its two strategies effective. Means of the two strategies were 4.507 and 4.514.

In interviews, teachers also expressed the supportiveness of the two strategies. For instance, once teacher stated that, "In the beginning, we were confused about what is 'Sports game' and 'Sports culture'. Everyone had his own understanding. But this strategy (Seeking unity of conceptual understanding) helped us to unify our understanding and cleared obstacles for the following collaborative tasks."

However, from these survey data, observations, and interviews, the authors discovered that:

- Scaffolding of 'Group Building' and 'Peer Interaction' were inadequate. Both teachers and students approved the value and design of the two scaffold types: group building and peer interaction. However, means of the two scaffold types were the lowest with 4.14 and 4.23. During interviews, teachers expressed that

Table 3. Survey results.

Scaffolding Type	No. of Tools	Means	SD
Goal Orientation Scaffold	3	4.51	0.59
Content Direction Scaffold	2	4.66	0.63
Group Building Scaffold	10	4.23	0.89
Peer Interaction Scaffold	4	4.14	0.84
Data collection Scaffold	7	4.50	0.77
Data Process Scaffold	3	4.27	0.70
Outcome Scaffold	11	4.62	0.60
Evaluation & Incentive Scaffold	5	4.46	0.73

Table 4. Questionnaire results for Goal Orienting Scaffold.

Types of scaffolding	Strategies used	Mean	SD
Goal Orienting Scaffold	Interpreting common goals	4.507	0.590
	Seeking unity of conceptual understanding	4.514	0.595

they were "not clear at the detailed roles, responsibilities, and tasks among different schools in our inter-school group."

- It was difficult to distinguish between 'Data Collection' scaffold and 'Data Process' scaffold. During the course of design and implementation, the authors found that the two types of scaffolds were highly inter-dependent and sometimes shared an identical supporting tool. They found that it was also difficult for teachers and students to distinguish the two in the course of application and evaluation.

- Organizational support was significantly needed in an inter-school collaboration environment. The authors found that the performance of schools in an ICL environment had high positive correlation with the attitudes of school leaders.

4.3. Implications

Based on the implementation, the authors concluded that the design of scaffolding was positive and effective in an ICL environment. However, these findings encouraged further refinement to the proposed scaffold design framework.

- Scaffolding on group building and peer interaction should be stronger, especially for inter-school groups. In the beginning of inter-school groups, strategies such as establishing a common identity and making group rules are necessary for inter-school group building. More strategies and activities are also needed to scaffold inter-school peer interaction.

- Data collection scaffold and data process scaffold can be integrated into one type of 'Data scaffold.'

- One type of scaffold, organizational guarantee scaffold, should be added to the scaffold design framework, which is also a specific type of scaffold in an inter-school collaboration environment. Organizational guarantee scaffold will provide both policy support and organizational support for ICL.

5. Discussion

5.1. Revise of Scaffold Design Model

Through the circle of design-based research, the scaffold design framework was revised (as shown in table 5). The 8 key types of scaffold were changed and typical strategies to implement the 8 scaffold types were confirmed.

The revised version of Scaffold Design Model for ICL tries to answer the four key questions of scaffold design in an Inter-school Collaborative Learning (ICL) environment.

Question1: What types of scaffolds are needed for ICL?

Through the first round of design-based research, eight key types of scaffolds for ICL were re-identified, which are: target scaffold, content scaffold, group scaffold, interaction scaffold, data scaffold, outcome scaffold, evaluation scaffold, and organizational scaffold. Among them, organizational scaffold is a specific type of scaffold needed especially for inter-school collaborative learning environment.

Question 2: What to scaffold?

Scaffolding target and content of each type of scaffold was listed. For example, the 'Data Scaffold' scaffolds required students to collect, organize, and record relevant resources to process and analyze collected data using text, tables, figures, and so on. The 'Organizational Scaffold' aimed to provide both policy support and organizational support for ICL.

Table 5. Revised version of Scaffold design framework for ICL

Scaffold Type	What to scaffold	When to scaffold	How to scaffold
Goal scaffold	Goal orientation	Beginning of each stage	• Interpreting common goals • Seeking unity of conceptual understanding
Content scaffold	Content direction	The whole process	• Structured presenting activity content • Offering clear schedule • Guiding by different roles
Group scaffold	Group building	Initial stage of each group	• Forming a group • Ice-breaking • Establishing common identity • Making common rules • Making clear responsibilities
Interaction scaffold	Peer interaction	The whole interaction process	• Explanation • Argument • Raising questions • Problem solving • Sharing and communication
Data scaffold	Data collection & data process	Problem-solving process	• Preparing for methods • Making plans • Process recording • Data analysis • Multimedia processing
Outcome Scaffold	Design, production, & distribution of group works	The forming process of group works	• Designing of works • Producing and distributing
Evaluation Scaffold	Evaluation & motivation	at the beginning & end	• Making clear evaluation standards • Reflection • Establishing reward systems • e-portfolio
Organizational Scaffold	Policy and organizational guarantee	The whole process, but especially at the early beginning	• Forming unions of school principals • Optimizing the organizational structure • Seeking policy suppor

Question 3: When to scaffold/when to fade?

The revised version of Scaffold Design Model for ICL analyzed when each type of scaffold was needed and when to fade. For example, the 'Organizational Scaffold' is needed all throughout the process of ICL, and especially necessary at the beginning of ICL. Important was to provide clear and sufficient policy support at the early beginning of ICL, so as to guarantee the incentive and engagement of teachers and students.

Question 4: How to implement scaffolding?

In this model, the authors suggested that each type of scaffold be implemented through some strategies, and these strategies be further supported with some tools. Typical strategies and samples of tools were summarized for each type of scaffold. For example, the 'Content Scaffold' could be implemented through 3 typical strategies: (1) presenting structured activity content, (2) offering clear schedule, and (3) guiding by different roles. To support its implementation, some supporting tools could be developed and provided such as a mind-map, a timetable, and a role-based collaboration script.

5.2. Guidelines of Choosing and Designing Scaffolds for ICL

With reference to the practice and results in the study, some guidelines were concluded on the selection and design of scaffolds for ICL, especially for rural schools.

a) This study indicated that eight key types of scaffolding were needed to support ICL from different dimensions.

b) As one of the most complicated collaborative learning, Inter-school Collaborative Learning is difficult not for only students, but also for teachers and school leaders. Therefore, in an Inter-school Collaborative Learning environment, scaffolds should be designed and provided for students, teachers, and school leaders.

c) Not only eight types of scaffolds should be designed for ICL, but also detailed strategies and tools should be developed to support rural schools. In this study, the authors found that scaffold design would be much easier and feasible through the three layer implementation of 'scaffold type – strategies – supporting tools.'

d) Design and development of three types of scaffolds should be emphasized: content scaffold, outcome scaffold, and goal scaffold.

e) In order to achieve an in-depth inter-school collaboration, it is important to strengthen the scaffolding intensity for inter-school groups. Because school-to-school collaboration is the most difficult to achieve, the design of 'Group Scaffold' and 'Interaction Scaffold' should lay stress on scaffolding of inter-school groups.

f) Scaffolding intensity of each type should vary in accordance with different targets and stages.

6. Conclusion

This study aims to develop a scaffold design model to support inter-school collaboration. Through design-based research, a scaffold design model was developed and revised. Eight key types of scaffolding for ICL were identified. Elaborated strategies and tools were summarized for implementation of these scaffolds. This study and the scaffold design model are expected to provide a theoretical framework and guidelines on how to select and design scaffold in an inter-school collaboration environment.

This study's main contribution is the theoretical framework for ICL design which may not only guide the instructional design of ICL, but also be helpful for scaffold design in other learning environments. However, the limitation is that design-based research is time-consuming, and only one circle of design-based research is examined in this study. In the future, more circles of design-based research and further experimental studies would be conducted to further refine the framework.

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Examining Student Participation in Three Learning Activities Supported by Social Annotation Tools

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Abstract: *Social annotation (SA) allows learners to highlight and comment on Web pages and share annotations with each other online. Despite its potential in promoting collaborative learning, examining how to integrate it into educational settings has not been fully studied. The purpose of the study is to examine student participation in three different SA-based online activities: (1) peer review, (2) annotated discussion, and (3) collaborative reading. Students participated in all three SA-based activities and took a survey at the end reporting the effectiveness of these activities. The analysis of students' annotations and their survey responses suggested that although participants perceived the use of SA tools in all the three activities to be relatively effective, their levels of participation in the three activities varied greatly. The authors discuss the pros and cons of using SA in each of the activities based on the findings. Suggestions for future use and development of SA tools are also provided.*

Keywords: social annotation, collaboration, peer review, annotated discussion, collaborative reading

1. Introduction

Social annotation (SA) tools are one type of online application that enables multiple learners to annotate and comment collaboratively on content material synchronously or asynchronously on the Web. In contrast to traditional text-based annotations that are hard to share among learners, social annotation tools allow learners to work continuously and collaboratively on one file, and the annotations and comments are automatically stored in an online database for everyone to review (Novak, Razzouk, & Johnson, 2012). Essentially, social annotation tools promote collaboration by eliminating the back-and-forth information exchange process and enabling real-time learner-centered collaborative annotation (Nokelainen et al., 2005; Su, Yang, Hwang, & Zhang, 2010).

In recent years, the number of studies conducted examining the adoption of social annotation tools in educational settings in an attempt to discover what effect they have on the achievement of students has been increasing (Novak et al., 2012). Despite the enthusiasm in using SA tools for teaching and learning, relevant research in this area is still limited. In our study, the authors attempt to explore possible ways of using SA tools to support collaborative learning in online learning settings by examining three types of SA-supported instructional activities in a graduate-level online course, and reporting students' perceived learning experiences and the challenges of using SA tools educationally.

2. Research on SA-Supported Collaborative Learning

SA tools are an emerging technology that has not yet been widely used or investigated in education, and related research is still scarce (Novak et al., 2012). Nevertheless, due to the social and collaborative nature of SA tools, there has been research conducted to examine the incorporation of SA tools to support collaborative learning (Glover, Xu, & Hardaker, 2007; Hwang, Wang, & Sharples, 2007; Johnson, Archibald, & Tenenbaum, 2010; Nokelainen et al., 2005; Samuel, Kim, & Johnson, 2011). In this section is a review of the research concerning SA tools being used in educational settings and their effects on learning.

2.1. Educational Use of SA Tools

Despite potential that the use of SA tools has to promote collaborate learning, research in this specific area has been minimal. In fact, the majority of extant studies pertaining to collaborative learning were conducted in online environments such as discussion forums, wikis, and blogs (Yadegaridehkordi, Iahad, & Ahmad, 2013). Contrastingly, SA tools were rarely examined. In reviewing the empirical studies on the use of SA tools, the authors found that reading comprehension and peer review appear to be the two major activities in which SA tools were used and evaluated.

2.1.1. Reading comprehension. Depending on how the instructor sets up the collaborative learning activity, the integration of social annotation tools could take different forms. One popular use is to engage learners in reading comprehension activities (Johnson et al., 2010; Kawasaki, Sasaki, Yamaguchi, & Yamaguchi, 2008; Razon, Turner, Johnson, Arsal, & Tenenbaum, 2012; Sakar & Ercetin, 2005; Samuel et al., 2011). In such activities, learners are instructed to read learning materials available on the Web or provided by the instructor. Using a social annotation platform, learners can interact with learning materials and each other by adding markups and annotations as the material is being read.

The degree of collaboration varies significantly in those reading comprehension activities. In some studies, minimal collaboration was involved as the purpose of these activities was primarily to enhance individual learners' reading comprehension skills (Kawasaki et al., 2008; Sakar & Ercetin, 2005; Samuel et al., 2011). Learners used more traditional and fundamental features in SA tools such as comments and markups to facilitate their individual reading processes. Those features allowed learners to anchor within the context, making annotations associated with particular words, paragraphs of a text, or a section of an entire document (Wolfe, 2002).

Some studies place more emphasis on the collaborative aspect of learning (Hwang et al., 2007; Johnson et al., 2010; Mendenhall, 2010; Nokelainen et al., 2005). The use of SA tools in such environments encourages both synchronous and asynchronous collaboration among learners and instructors. When multiple learners are working on the same reading material using SA tools synchronously, they can comment on the text and engage in real-time discussion. Collaboration can also be achieved asynchronously as learners work on the same file at their own pace. Learners will receive real-time notifications as annotations are created. The instructor can design activities that allow collaborations to take place both synchronously in classroom settings and asynchronously outside the classroom, depending on the learning goals and the degree of flexibility the instructor would like to provide (Novak et al., 2012).

2.1.2. Peer review. Peer review is a type of collaborative activity commonly used in the classroom where instructors ask the students to write their reflections, share with one another, and critique each other's work in small groups (Mendenhall, 2010; Samuel et al., 2011; van der Pol, van den Berg, Admiraal, & Simons, 2008). SA tools afford peer review activities by providing a convenient platform in which interactions among peers can be seamlessly accomplished.

Similar to collaborative reading activities, peer review with SA tools can occur synchronously and asynchronously to support student learning. In one study (Mendenhall, 2010), students were grouped into pairs providing feedback to one another. The feedback could be either general (one that is not linked to a specific portion of the text) or specific. Mendenhall (2010) asserted that the use of SA tools allowed students to focus on specific portions of the text during the critiquing process. However, research that examines SA-supported peer review activities remains limited.

2.2. Educational Effects

There is evidence to suggest that participation in SA-supported collaborative learning activities can impact student learning affectively and cognitively. In the affective learning domain, it has been found that using SA tools may enhance student engagement, participation, and motivation. Across the studies, the majority of students perceived the use of SA tools favorably (Kawasaki et al., 2008; Mendenhall, 2010; Nokelainen et al., 2005; Novak et al., 2012). Researchers also found that students were highly motivated when they participated in SA-supported activities (Hwang et al., 2007; Kawasaki et al., 2008; Nokelainen et al., 2005; Razon et al., 2012; Samuel et al., 2011).

In the cognitive learning domain, studies were conducted to investigate if SA-supported activities promote student learning. Some experimental and quasi-experimental studies have suggested that reading comprehension skills can be potentially enhanced by SA-supported reading activities (Johnson et al., 2010; Kawasaki et al., 2008; Mendenhall, 2010; Razon et al., 2012). In using SA tools, students reported that they were more likely to stay on task and more focused on the reading material. Researchers found that when working in small groups or participating in peer review activities, students were able to investigate their own mental models through interacting with their peers, allowing them to engage in a deep and reflective thought process (Merrill & Gilbert, 2008). Some stated that SA tools facilitated the group/pair work process by reducing the redundancy of critique items and promoting the construction of concentrated and in-depth content (Mendenhall, 2010). Others reported that annotations promoted more reflective responses to a text (Wolfe, 2008). However, researchers have not found any statistically significant results when measuring such variables as critical thinking and meta-cognitive skills (Johnson et al., 2010; Mendenhall, 2010; Razon et al., 2012).

A brief review of current research indicates that SA tools have the potential to support collaborative learning. As Novak et al. (2012) noted more research needs to be done in this field given the fact that the use of this technology in general is still in its embryonic stage. As demonstrated in the literature review, to date, SA tools in most of the research studies are used for reading comprehension purposes (Novak et al., 2012). Few studies have explored the use of SA tools for purposes other than enhancing student reading comprehension. The authors failed to find any studies in which the adoption of SA tools was accomplished in a fully online environment. Questions such as how instructors should use SA tools to help students learn more effectively, and how to design such activities in a purely online learning environment remain unaddressed.

In this study, the authors examined three distinct SA-supported activities in an online course. We showcased the activities that we designed and implemented for unique educational purposes, and addressed the following research questions by analyzing data collected from the survey, along with students' online annotations and markups. We used the following research questions to guide the research:

1)How did students participate in the three collaborative SA-supported activities?

2)How did students perceive the effectiveness of the SA-supported activities?

3)What were students' perceived challenges and limitations of integrating SA tools into teaching and learning?

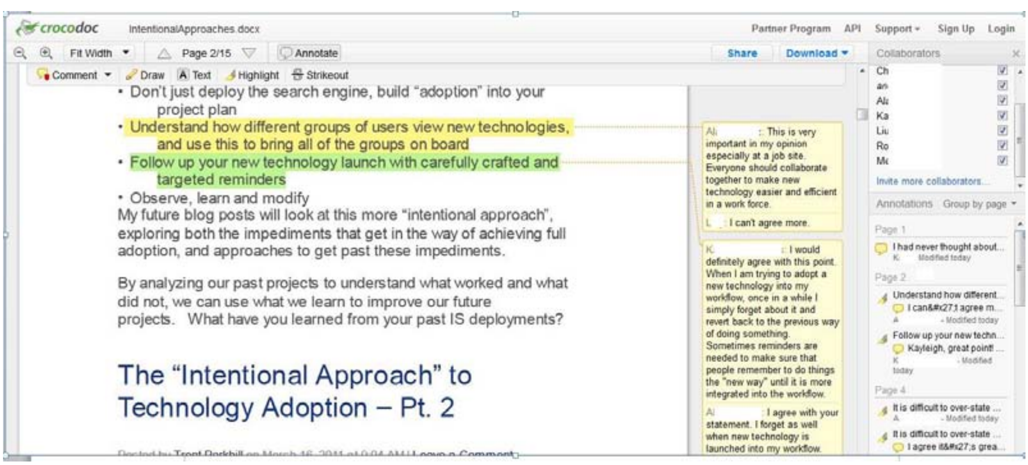

Figure 1. Screenshot of the crocodoc interface

3. Two Social Annotation Environments: Crocodoc and Wikispaces

3.1. Crocodoc

As a collaborative Web annotation tool, Crocodoc supports basic annotation features such as highlights, sticky notes, strikeouts, and collaborative functions that allow users to add and reply to comments on a shared document in real time. New annotations are displayed simultaneously to other users who are viewing the file concurrently (see Figure 1). Offline users can also receive real-time notifications when annotations are created.

3.2. Wikispaces

The online course was held on Wikispaces. The built-in annotation tool worked as one of the collaborative editing functions afforded by Wikispaces. Once registered and logged in students could edit the same page collaboratively with other online users. In the editing mode, the annotation tool in Wikispaces allows users to highlight one part of the text and add sticky notes on the side. Users need to save their changes in the editing mode so that other users will be able to see it afterwards. The annotated page shows the comments, the time when the comment is created, and the comment creator's name (see Figure 2).

4. Method

4.1. Research Design

The adopted methodological approach is a case study. Case studies embrace a multi-dimensional approach to analysis, especially through the use of multiple sources of evidence (Yin, 2009). A combination of qualitative and quantitative methods is often found in case studies and serves the best purposes, as the different strengths and weaknesses of both qualitative and quantitative methods are essentially complementary.

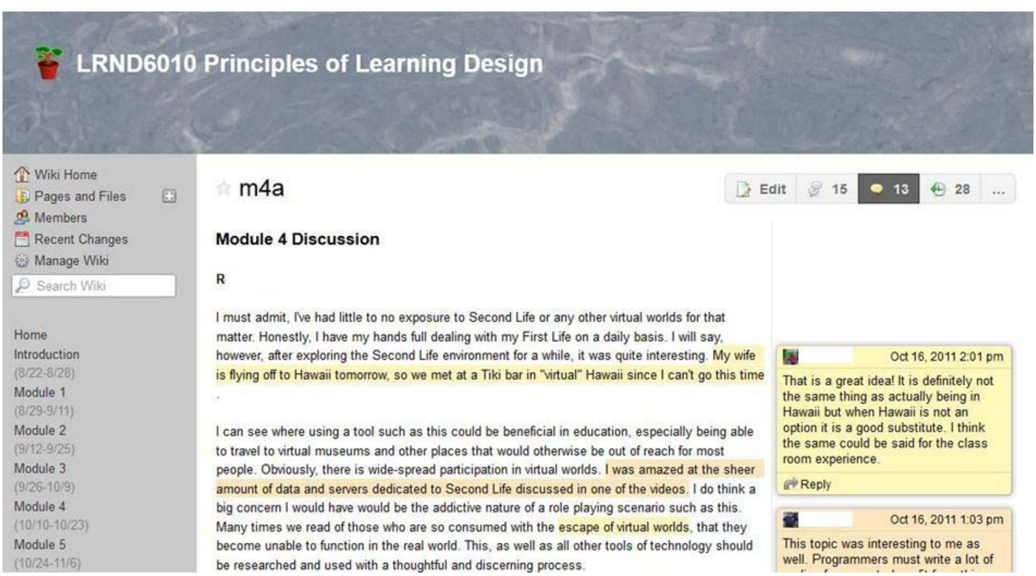

Figure 2. Demo of the annotation tool within Wikispaces interface

In this study, three collaborative SA-supported instructional activities were selected and examined in-depth to answer the research questions. Both qualitative and quantitative data were collected, including formative data generated from the three collaborative activities and student responses to a survey at the end of the course. The survey consists of three sections: (1) questions on students' overall enjoyment of using SA tools in this course, (2) questions on students' perceived effectiveness of using SA tools in the three collaborative activities, and (3) students' demographic information.

4.2. Participants and Settings

Participants were seven graduate students taking an online class on Instructional Design. The average age of this group is 38, among which three were between 20 to 30 years old, two between 31 to 50, and two above 50. Most participants reported to possess a high level of technological literacy. All of them have had experience taking online courses prior to this course (see Table 1).

The goal of this online course was to explore and synthesize relevant literature in the learning field, explain how technology impacts and influences learning, evaluate the effectiveness of learning technologies, and experiment with technology-supported teaching and learning strategies. On the Wikispaces course site, students were provided with tutorials that introduced the SA tools used in this course. Because online discussion and collaboration were important parts of the course, students were expected to visit the course site at least three times a week for effective learning.

4.3. SA-Supported Instructional Activities

Because this course is purely online, activities supported by collaborative online tools provided important means for students to interact with and learn from each other. Students participated in three unique SA-supported instructional activities throughout the semester. All of them were graded as a part of the assessments of the course; that is, student participation in these activities was required, not optional.

Table 1. Participants profile

Name	Self-rated technological literacy level	Age	Number of online courses taken
Candy	Beginner	49	2
Emmy	Intermediate	24	1
Kathy	Advanced	26	3
Alex	Advanced	34	2
Melissa	Advanced	58	7
Jennifer	Advanced	23	4
Roy	Expert	52	1

4.3.1. Instructional activity 1: peer review. This peer review activity was embedded in a module on reflective learning to engage students in a reflective learning process. Students posted their lesson plans online in Crocodoc for others to review and were instructed to provide feedback to two of their peers' lesson plans. The instructor suggested two ways of providing comments: (1) using the social annotation tools in Crocodoc to provide specific comments, and (2) writing more general and summative comments at the bottom of the lesson plan page using a different color. Students were not required to use the annotation function, but it was encouraged. The instructor also provided detailed guidelines on how to conduct peer review to ensure the quality of the comments.

4.3.2. Instructional activity 2: annotated discussion. In the module - virtual learning environments, students were required to use the annotation/commenting function embedded in Wikispaces to discuss with their classmates on a wiki page on their experience with Second Life and the educational potential and challenges of virtual worlds. The rationale behind this activity is to highlight annotation functions that allow students to respond directly to specific sentences or paragraphs of their classmates' posts, which is not possible in most online discussion forums. Students were asked to post at least two replies to others' posts using the annotation function and were free to decide the length of their replies.

4.3.3. Instructional activity 3: collaborative reading. The third activity was a collaborative reading activity in Crocodoc. An article on technology adoption was shared in Crocodoc. Students were instructed to share their ideas and critiques while reading the article online by making at least one comment and responding to at least one of their classmates' comments. The purpose of this activity was to have students construct a collective and thorough understanding of the article by reading and annotating the article collaboratively.

4.4. Data Analysis

The data analyzed in this study included students' annotations and comments and the summative survey responses. The data sources were triangulated to better answer the research questions.

As the three activities were conducted at different times with varying purposes, the authors chose to analyze the data generated from each activity separately. The number of annotations/comments, as well as the number of words in each annotation/comment, was counted. Also the quality of the comments was examined to understand student participation. Student-perceived effectiveness of the SA tools was measured by calculating the mean and standard deviations of student ratings on their perception of each activity in the survey. Finally, responses to the open-ended questions in the survey were coded to identify the perceived challenges and limitations of using SA tools in education.

5. Results

5.1. Student Participation

5.1.1. Instructional activity 1. In the first collaborative activity, few participants used SA tools to complete the peer review tasks, as their use was optional rather than mandatory. Most reviewers just posted summative comments, and only two used the annotation features to provide specific feedback by highlighting and focusing on particular sections of the lesson plans. Table 2 demonstrates student participation in this activity.

In contrast to the majority of learners, Kathy and Alex demonstrated great interest

Table 2. Student participation in peer review

ID	Name	Provided summative review	Provided in-text annotation
1	Kathy	Yes	Yes
2	Alex	Yes	Yes
3	Emmy	Yes	No
4	Roy	Yes	No
5	Candy	Yes	No
6	Melissa	Yes	No
7	Jennifer	Yes	No

in using the SA tools to provide specific content-pertinent feedback. For example, Kathy provided 20 responding comments in total to two peers' lesson plans, including two summative comments and 18 specific comments using the SA tool. The feedback focused on the specifics in the lesson plans and involved detailed suggestions, probing questions, and useful resources. In one of Kathy's annotations, for example, she highlighted and commented on the implementation procedures of her peer's lesson plan, stating that "I found these steps to be a little bit confusing. I think that is because there was not enough detail." She further suggested her peer utilize what was learned from the class to revise his lesson plan:

> *Now that we have read over Merrill's first principles, I think that your lesson plan would adapt well to these principles. You may want to consider restructuring these steps so that they follow Merrill's first principles exactly: Introduce the Problem, Activation, Demonstration, Application, Integration. You had addressed the first two steps and the last step to some extent in the other steps; however, I think that it would help to clearly identify each step along the way and provide a bit more detail as to the content of each step.*

5.1.2. Instructional activity 2. In the discussion activity, all seven students wrote responses in the wiki site to the instructor's prompting questions, and five students engaged in collaborative discussion using the SA tool in Wikispaces and provided 15 total comments on the first four posts. On average, each student provided approximately two comments (mean=2.14, SD=1.57). The average length of the posts was approximately 112 words. Looking at the 15 comments contributed by seven participants, we found that Alex, Roy, and Melissa were responsible for 11 comments. Other students, such as Kathy and Jennifer, chose only to provide one or two long and elaborative comments. One student, Candy, chose to respond only to instructor's questions. Student participation in this activity is demonstrated in detail in Table 3.

5.1.3. Instructional activity 3. In this activity, all seven participants engaged in the collaborative reading on Crocodoc and

Table 3. Student participation in collaborative discussion

ID	Name	Number of words of each student's post in response to instructor's questions	Number of replies to their classmates' posts per student	Average number of words of the replies
1	Kathy	458	2	91
2	Alex	524	3	46
3	Emmy	394	1	29
4	Roy	210	4	26
5	Candy	434	0	0
6	Melissa	765	4	35.25
7	Jennifer	508	1	73

Table 4. Student participation in collaborative reading

ID	Name	number of posts	average number of words (mean=45.07)
1	Kathy	6	42.33
2	Alex	4	33
3	Emmy	4	20.75
4	Roy	2	34.5
5	Candy	2	76
6	Melissa	5	53.4
7	Jennifer	2	55.5

generated 26 annotations on the reading material using the SA tool. The average number of annotations per student was roughly four (mean=3.71, SD=1.70). The average number of words in each post was 45.07 per student. Students who contributed more in the previous activity, such as Kathy, Alex, and Melissa, remained active in this activity. Although the overall participation using SA tools was higher, the issue of unequal level of participation remained unchanged. Student participation in this activity is presented in Table 4.

5.2. Perceived Effectiveness of SA-Supported Activities

Table 5 displays the means and standard deviations of students' ratings of their perceived effectiveness of the SA-supported activities in each collaborative activity.

Table 5. Student perceived effectiveness of using SA tools

ID	Name	The annotation tools supported effective peer review	The annotation tools supported effective discussion	The annotation tools supported effective collaborative reading	Average Ratings	Standard Deviation
1	Kathy	4	3	4	3.67	.58
2	Alex	2	2	3	2.33	.58
3	Emmy	2	3	3	2.67	.58
4	Roy	4	4	2	3.33	1.15
5	Candy	3	3	3	3.00	0
6	Melissa	3	3	3	3.00	0
7	Jennifer	3	3	2	2.67	.58
Mean and SD of each statement		3.00 (.82)	3.00(.58)	2.86(.69)		

Overall, participants perceived the use of SA tools in the three activities to be relatively effective. Six out of seven participants rated their perceptions favorably. Only Alex reported a neutral perceived effectiveness. Four students reported that the tools were very easy to use and intuitive to master. As Jennifer wrote, the use of annotation tools was effective "because it allows for concise feedback in an easy to follow format. It makes it easy to see the content and the comments simultaneously in an organized manner."

Interestingly, students' ratings of their perceptions were not always consistent with their participation in the collaborative activities. Some students, such as Kathy and Melissa, who participated actively in all three activities, also rated the three activities highly. In contrast, Alex was among the most active participants of the class, but he rated the effectiveness of two activities as "0." This is counter-intuitive, as the authors might naturally assume that students who participate more actively should rate the system more positively. A closer look at Alex's written comments showed that Alex, in general, preferred a synchronous mode of communication as compared to asynchronous collaborative annotation by saying, "Basic discussions would be fine to discuss on the annotation tool in Wikispaces," but "I feel we can get more in a live setting vs. what is said on Wikispaces."

An analysis of students' responses to open-ended questions also revealed their attitudes toward each of the activities. When asked about the peer review activity, participants reported that the use of SA tools was effective in associating the comments with the corresponding texts. Kathy wrote that "It is very helpful to know exactly where in the article the reviewer is addressing his or her comment." Alex also reported that "I thought it was very helpful to point out specific parts of the article." In addition, Roy reported that "It makes it easy to see the content and the comments simultaneously in an organized manner." In the discussion activity, students considered the way that the SA tool was effective in presenting and organizing comments. Four students stated that they benefited most from being able to pinpoint specific content and highlight the part of the document on which they were commenting. As Jennifer stated, these features made it easy for them to collaboratively comment on each other's work. In the collaborative reading activity, students were able to identify more affordances of SA tools in addition to those in the previous two activities. Melissa felt that "It was really great to have a conversation with peers over an article. I was very interested to read what they were thinking as they went through the article." Some other students reported that the collaborative reading helped them attend to some issues that they would have otherwise missed, "There were some things in the article that I glimpsed over before, and having their comments there, I paid more attention to it." Additionally, Jennifer believed that the use of SA tools allowed for ongoing discussion on the reading material.

5.3. Challenges and Limitations

The SA tools used in this study hold promise for fostering collaborative learning. Most students perceived this integration favorably and benefited from using those tools. However, challenges and limitations coexist with the benefits. From students' responses to the open-ended questions, the authors identified the following challenges that instructors need to be mindful of when attempting to incorporate SA tools.

5.3.1. Technical glitches. Although participants in this study were relatively technologically capable, some of them still encountered intermittent technical difficulties resulting from some immature functionalities. In particular, when multiple students were simultaneously working on the same file, students reported that some iterations were not updated in time. This hampered the ongoing communication and interaction during the collaborative learning process.

5.3.2. Difficulty in affording sustained conversation. In the discussion and peer review activities, participants raised the issue of the SA tools current capability in sustaining conversation. Because students were only able to post their annotations on the margins of a page, the comments became cumbersome and difficult to read when the conversation lengthened. It also added a layer of difficulty for people to truly build upon the ideas and contributions of others. As Alex stated, because the place where comments and annotations were displayed was restricted, the comments tended to be brief, and it was difficult to be engaged in "a true back and forth discussion."

5.3.3. Difficulty in affording solid content creation. Participants also noted that some comments generated through SA tools were relatively superficial. Although this is not necessarily a problem with SA tools, participants found that some comments were lacking depth, and were therefore, brief and superficial. As Melissa commented, "The comments you make and receive are brief and fairly superficial. The reviews I gave and received were not in-depth." It could be that SA tools tend to afford meaningful construction that is contextualized within specific content rather than conclusive and in-depth comments.

6. Discussion

Included in this discussion are the levels of student participation in the three SA-supported activities. These include examining peer review, discussion, and collaborative reading, the pros and cons of using SA in each of the activities, and suggestions for future practice and SA tool development.

First, the SA tools were used by only two of the seven students in the peer review activity. Although students acknowledged the benefits of using SA tools, participation was minimal, as students were not required to use the tools. As shown in the findings, most students only provided a summative comment in this activity instead of providing an in-text comment using the SA tools. One reason may be that students were unfamiliar with the SA tools as it was their first experience using them in this class. The fact that a few students used the SA tools extensively suggested that although some students may choose not to use them, others may feel this was a particularly useful tool for their own learning. As a result, it could be important for instructors to provide options to students so they can select whatever tool works for them during the learning process. This study suggests that more instructional support may be necessary to enhance the effectiveness of using SA tools for peer review activities. If the instructor provides necessary tips and examples of what types of annotations are expected, continuously encourages interaction and probes for in-depth thinking, students may be more likely to engage in a deeper analysis of their peers' work (Johnson et al., 2010; Mendenhall, 2010; Razon et al., 2012).

The SA tools were used with relative effectiveness in fostering discussion. The authors found that students particularly favored SA tools because they support focused and to-the-point discussions. With SA tools, students can highlight a specific part of the text and make comments on the side margin that allows for to-the-point discussions (van der Pol et al, 2008). Through this method, students were more likely to focus on specific learning materials and associate knowledge construction with specific learning content (Wolfe, 2002). Additionally, students could concentrate and comment on one particular page at a time, which reduces the cognitive load involved and can be beneficial to learning (Sweller, 1988). However, sustained and elaborate discussion was restricted due to the limitations of SA tools. When a number of students have multiple conversations in the SA platform, some functionality of SA tools such as the way student comments are displayed may restrict the depth and length of the conversation. Therefore, an improved system is needed to enable threaded discussions anchored to specific sections of the page without visually overwhelming the page or margins would be ideal (Johnson, Archibald, & Tenenbaum, 2010).

Students' participation in collaborative reading was more active as compared to the previous two activities. Findings showed that the use of the SA tool in the collaborative reading activity enabled students to learn from each other's ideas and also directed their attention to important sections of the reading. Using SA tools, students can review and analyze reading materials in a more detailed fashion, highlight important information within the text, and have discussions with their peers on the reading materials (Nokelainen et al., 2005). The authors also found that the use of SA tools allowed for an ongoing discussion on the reading material. As students were continuously working on only one primary text, they were able to build upon the existing texts and comments. This finding suggests that the collaborative reading activity seemed to be most favored by students as compared to the other two activities. Given the current features afforded by SA tools, collaborative reading activity seems to be best afforded because SA allows learners to effectively analyze and review the reading materials.

The findings in this study suggest that the use of SA tools holds promise for fostering collaborative learning. However, promoting critical thinking and meta-cognitive learning reflected by in-depth discussion and sustained conversation remains an issue. In this study, students responded positively to the use of the SA tools, but they also noted various limitations in supporting learning. Interestingly, experimental studies that statistically measured critical thinking and cognitive learning have rarely rendered any significant gains (Johnson et al., 2010; Mendenhall, 2010; Razon et al., 2012). Optimistically, the authors believe that the extent to which collaboration is achieved invariably depends on how the instructor designs and implements the collaborative activity. As Novak et al. (2012) stated in their research, students should be provided with substantial instructional support during any collaborative learning activity to maximize the learning benefits of the SA tools.

Another issue raised in this study is an unequal contribution and participation among all the collaborators, which is fairly common in collaborative writing activities afforded by social technologies (Arnold, Ducate, & Kost, 2009). Motivation is certainly one major contributing factor to learners' participation (Xie & Ke, 2011). Apart from this, research on collaborative learning suggests some other factors attributable to the differences in learners' degree of participation such as learners' learning styles and their personalities (Durán, 2011; Yadegaridehkordi et al., 2013). It is largely unclear why the levels of participation are so different among students in this particular study, and there is a need for future research investigating how to optimize student participation in SA-supported collaborative learning activities.

7. Conclusion

In this study, student learning experiences using SA tools in three collaborative learning activities were examined. These three practices were effective in keeping students on task and stimulating them to learn. With slightly different purposes, all these activities supported with SA tools facilitated collaborative learning by allowing peer-commenting and annotating efforts. Educators who are interested in using SA tools in teaching and learning may gain insights on how to design SA-supported learning activities from this study. This study suggests the need to understand how to support prolonged discussion and promote critical thinking and meta-cognitive learning using SA tools. Questions such as in what ways, under which conditions, and within which context these SA tools could be optimally utilized to promote deeper learning should be addressed in future research. Besides conducting robust experimental research, researchers may use a design-based research approach to observe instructional activities over a longer period of time, and examine the corresponding effects of the student learning process. Additionally, more studies need to be done to provide insight on how to motivate the laggards and ensure an appropriate amount of participation across learners of all levels.

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Deep Learning through Reusable Learning Objects in an MBA Program

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Abstract: *Being able to leverage an organization's processes and core competencies to sustain its competitive advantage is important (Ray, Barney, & Muhanna, 2004). One learning objective of an on-line MBA is to teach students how to apply the VRIO (value, rarity, imitate, and operationalize) model, developed by Barney and Hesterly (2006), in order to identify an optimum strategy. However students in the program have had difficulty in understanding this model, partially because of the traditional pedagogy used in online teaching. This case study demonstrates how reusable learning objects (RLO) can facilitate knowledge in an online learning environment. The RLO developed and applied in this study was able to enhance student learning through interaction and subsequent deep learning.*

Keywords: deep learning, on-line learning, reusable learning objects, distance learning, MBA education.

1. Introduction

"Deep learning applies substantive insights from the learning disciplines to exploit the affordances of the technology, in order to develop contexts that empower learners to achieve educational goals" (Boyle & Ravenscroft, 2012, p. 1225). According to Boyle and Ravenscroft (2012):

> the design [of interactive technologies] requires not just a construction of the overall learning context, but detailed concern with the tasks, the activities of learners, and the means of knowledge representation used. We need to weave these into a learning context in such a way as to enable learners to succeed where they might otherwise fail. (p. 1230)

A layering of tasks can help the learning gain a deeper understanding of the concepts (Kurubacak, 2007). Knowledge management systems organize resources so that information can be built upon (Arshad & Bhalalusesa, 2012). This was found to be the case in the MBA Marketing Management course, where it was determined that readings (textbook and online mini-lectures) were not sufficient to teach students how to determine the buying behaviors of potential customers; a new concept taught in this course (Rufer & Adams, 2012). The next layer of learning implemented was to include narrated PowerPoint lectures and Webinars to align with learners that were auditory as well as visual. In addition, online discussions were incorporated to move from contextual learning to reflective learning, through collaboration:

> In a traditional classroom, the faculty member facilitates synchronous learning and collaboration. This becomes more difficult in a Web-based learning platform. Furthermore, differences in student learning styles are exasperated by the linear design of many web-based systems. As a result, the differences in learning outcomes may be related to the student's ability to adapt to the mode of the information presented, not just their ability to learn. (Rufer & Adams, 2012, p. 327)

However, the lesson learned about improving learning outcomes through deep learning, has application for traditional students, as well as those taking online courses (Zitter, de Bruijn, Simons, & Ten Cate, 2012). Knowledge management systems are important for developing processes that do more than just transfer information.

2. Deep Learning and the Learner

The pedagogy under evaluation in this paper is part of an MBA program developed for adult learners through a Web instructional management system. This program was chosen because the learners are self-directed, come from diverse backgrounds, and in many ways benefit from a flexible pedagogy because of time and space constraints. However, the lesson learned about improving learning outcomes through deep learning has application for traditional students, as well as those taking online courses.

3. A Case Study

One of learning goals of this MBA program is to teach students how to make strategic decisions that will enable the organization to sustain its competitive advantage. As part of the process, students apply common strategic management tools such as a SWOT (Strengths, Weaknesses, Opportunities, and Threats) and competitive analysis. In addition, being able to leverage an organization's processes and core competencies to sustain its competitive advantage is important (Ray, Barney, & Muhanna, 2004). Barney (1991) first looked at the firm's resources and their value, rarity, ability to be imitated, and the ability of the firm to operationalize these resources to sustain a competitive advantage known as VRIO model. Students are taught this model in their first course of the program. Later in the MBA Marketing Management course, students are asked to use this model to identify a viable strategic direction for their marketing plans.

Table 1. Percent demonstrating understandingof VRIO model without the use of an interactive RLO

	% demonstrating
Class Name	VRIO
SAEC	77%
MMS	72.4%
SEL	77%
average	75%

The model assesses the ability of the students to critically evaluate the sustainability of a firm's resources. This contains a series of "yes and no" narrative instruction and questions, and students judge a rational of the competitive strength of the firm in a report format (see Figure 1 later in the paper). However, it was shown that only 72% of the students were able to apply this model to effectively identify the sustainable resources of the organization as indicated in Table 1.

Furthermore, as students moved from the advance Marketing Management (MMS) course to their capstone project (SAEC and SEL course sequence), only 77% were able to apply this critical management model in spite of several layers of learning as indicated in Table 1. The capstone course for the MBA is divided into two parts. The first part assesses the macro and micro environmental factors that affect the organization's performance (called SAEC in Table 1). The second part is the development of a full strategic plan including the optimum strategy for leveraging the competitive advantages of the organization (called SEL in Table 1). Because students in SAEC and SEL had previously completed the Marketing Management course, it was expected that 80 to 90% of the students would have been able to demonstrate competency in this area. In all three courses, there are readings and mini-lectures on the model, as well as online discussions of the role of the model in assessing the resources to determine an organization's strategy. Capstone students also present their applications of the model as part of blended learning and reflection in a face-to-face residency with the professor and their classmates, where the professor highlights the proper way to apply the model (Barney & Hesterly, 2006). However students fell short of meeting the expected learning outcome goal. It was believed that these activities would create a learning environment able to reach diverse learning styles.

The layered activities should have been able to reach diverse learners through visual (the readings), auditory, and kinesthetic activities at the residency. Collaboration and reflection through the online discussion was added to enhance the earlier layers to provide deep learning at the student level. These Web-based learning activities appeared to be "dynamic in order to accommodate learners' different backgrounds, competencies, and interests" (Lee & Su 2006, p. 6-7). Yet only 77% of the students grasped the concept by the end of their degree programs. One reason may be attributed to the fact that this content knowledge was not used anywhere else in the program and may have been easily forgotten (Dernt & Motschnig-Pitrik, 2005). Another reason may be reflective of the learner's style of learning and how engaging the on-line learning was for the student as Yaghmaie & Bahreininejad (2011) states:

> The whole idea of adaptive learning is that there exists no learning style that fits all types of learners' needs. Two approaches have been introduced in this area and the challenge of adaptive systems is to balance between these two different forms of adaptation: (1) adaptivity, which relates to the extent the system output is flexible based on some knowledge about the learner and (2) adaptability, which is system reliability in response to user modifiability. (p. 3280)

Much has been written about learning styles and student learning outcomes. Adams & Rufer (2010) mention that "Learning styles [have been] described by the cognitive, affective, and psychological behaviors of how students learn; approaches to learning looked at three ways to engage in learning: a surface approach (rote memorization), a deep approach (exploring and questioning), or a strategic approach (with tactics to earn the desired final grade); and intellectual development (with the highest level defined as that which follows the scientific method)" (p. 2). Based on this previous work by Rufer and Adams (2010), the authors understand that changes in pedagogy using technology that provides both deep learning and at the same time interactivity can engage students regardless of learning styles. In Boyle & Ravenscroft's (2012) work, "Boyle delineated three possible layers of explanation for learning: the physiological, cognitive and interactional layers. He argues that the interactional layer is the appropriate one for the learning designer and that 'context' is the key concept at this layer" (p. 1226). Context here can be viewed as an activity system that "weaves together" the learning.

The authors expected that using a reusable learning object to create a knowledge management system would result in improved student learning outcomes. It became the objective to incorporate a learning activity that would "weave together" the learning throughout the student's degree program. To accomplish this objective the authors developed a reusable learning object (RLO) for VIRO that could be incorporated into the first course of the program, the marketing management course, and the capstone courses. This RLO was also designed to be interactive by engaging students who learned through visual and kinesthetic learning activities. As indicated by Lee and Su (2006):

> Internet users have much more diverse backgrounds than students. Therefore, web-based learning has to be dynamic in order to accommodate learners' different backgrounds, competencies, and interests. To meet this requirement, learning object service must have the following dynamic properties: active, flexible, adaptive and customizable. (p. 6-7)

4. Reusable Learning Objects

Idrosa, Mohameda, Esaa, Samsudina, and Dauda (2010) recognized that "a single learning object may be used in multiple contexts for multiple purposes" (p. 703). According to Valderrama, Ocana & Sheremetov (2005), "Learning objects are self-contained learning components that are stored and accessed independently. RLO is any digital resource that can be reused to support Web-based learning" (p. 274). Mavrommatis (2008) believes that reusable learning objects are small learning components that can be combined and reused in different contexts and that these objects are "best" designed to facilitate knowledge rather than communicate knowledge. Readings and mini-lectures in an online learning environment communicate knowledge. In the case presented here, an interactive model was used to support online student learning in the MBA program. This model facilitated the student's ability to critically assess a firm's resources and identify those resources that could be leveraged to create a sustainable competitive advantage (Barney, 1991).

5. Methodology: Research Design

The sample to be used was two different sections of the same course. A cluster sampling method was used because it was assumed that both sections were made up of students with similar experiences. All students in both sections were asked to evaluate the resources of an organization in a case study using the VRIO model described previously. Both sections were given a variety of learning objects including reading, PowerPoint presentations, and online discussion. However, the second group was also presented with a reusable learning object.

RLO Tool Design

To improve student learning in this MBA marketing management course, a team was formed to address the problem. Collaboration was an important step in developing a solution for this learning object. One member from the team was an expert in the field of marketing and strategic management and the other an expert in instructional design. As such the authors began the process of developing the RLO by forming a "community of practice." According to Berkani & Chikh (2010), "one person can share the best way to design a special kind of learning situation based on his own experience, which may enable the other members to be inspired from it in order to design other learning situations" (p. 4437). The marketing and strategic management expert identified the concept that student were not properly applying. In this case, it was the application of Barney and Hesterly's VIRO model of how to assess an organization's resources for sustainability (Barney & Hesterly, 2006). Students wanted to identify which resources were rare, which were valuable, and which were not easily imitated, rather than assessing each resource for providing the firm with a sustainable competitive advantage. The authors felt that it was important to develop the RLO to help students envision this complicated topic: the relationship between resources and sustainable competitive advantage. The individual proficient in instructional design felt the RLO needed to be designed as a "highly interactive learning objects [to] allow for continuous, bi-directional interaction with all essential parameters" (Hanisch & Straβer, 2003, p. 647). According to Hanisch and Straβer (2003), to create a "highly interactive learning objects, requires expertise in subject, programming, pedagogics, didactics, and design" (p. 649). The objective was to "design them (the RLO) within the framework of a well-planned curriculum, one that incorporates standards compliant classification schemes allowing for consistent labeling of RLOs and efficient retrieval of the RLOs from databases "(Leon, 2002, p. 2). Katz, Worsham, Coleman, Murawski, & Robbins (2004) states that:

> The concept of the reusable learning object frequently has been linked to LEGOs. All the instructional parts are considered interchangeable, fit neatly together, and make impressive and creative structures. This analogy does not implicitly consider the application of sound instructional design and learning theories to the creation of reusable learning objects. While chunks of information can go together in such a way, good instruction does not. Instructional objects are not dynamically interchangeable, rarely fit together well as is, and when attempted, the results are rarely impressive inherent instruction. However, it does require an individual who is adequately equipped with the proper knowledge of learning sciences and ISD to ensure the effective reuse, repurpose, and reference (R3) of instructional objects. (p. 7)

When creating the RLO, the instructional designer considered how to turn "good" instruction that might be found in a traditional classroom into an online learning object. The first step in the design of this RLO was to map out a decision tree that students should follow to assess the sustainable competitive advantage of an organization's resources (see Figure 1). The course instructor identified ten common organizational resources that could provide an organization with a sustainable competitive advantage. If the resource was not valuable, the decision tree led the student to a node that stated the resource was a disadvantage, if it was valuable but not rare, it was identified as providing the firm competitive parity. If it was both valuable and rare, but could be imitated, it was identified as providing a temporary advantage. If the resource was valuable, rare, not easily imitated, and the organization could leverage the resource through its operations, then

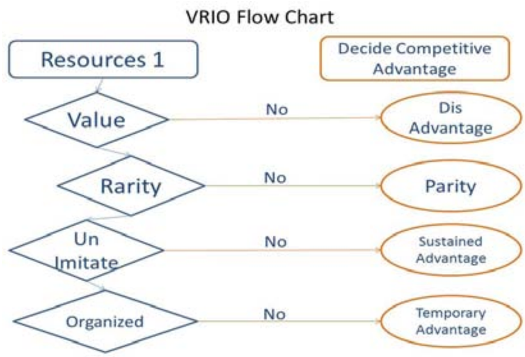

Figure 1. RLO decision tree

the resource was identified as a sustainable competitive advantage.

The instructional designer identified several technology resources that could support this type of decision making process. Valderrama, Ocana, & Sheremetov (2005) mention, "Intelligent Reusable Learning Components Object Oriented (IRLCOO) are described, a special type of Reusable Learning Objects (RLO) producing learning content rich in multimedia, interactivity and feedback" (p. 274). One type of technology resource that can provide for interactivity and feedback is that of an interactive PowerPoint presentation. According to Littlejohn, Falconer, and McGill (2008):

> a set of PowerPoint slides [can] provide the information content at the heart of learning activities representing all five forms [in which learning resources may be use]:
>
> 1.Narrative – if downloaded by the learner from a website or database;2. Communicative – if used as the basis for a discussion;
>
> 3.Interactive – if searched or scanned for bibliographic entries;
>
> 4.Adaptive – if edited with PowerPoint software; and
>
> 5.Productive – if the ideas from the slides are used as the basis for reconceptualization using concept mapping software. (p. 760)

A prototype RLO developed using PowerPoint in this case study was embedded in the Web-based course management system, where learners could download it and use any time. Guided by Littlejohn's principle, the RLO design processes designed here contained all five forms. During the design phase, the narrative activity instruction direction was governed by an overall navigation flow. Each of the resources probed an evaluation of the concept and solicitude a decision, to reach either a conclusion or evaluate a further decision steps for the concept. In addition, as part of the narrative for the students, the authors asked students to print out the last page of the PowerPoint to fill in as they moved through the decision making process. It was also suggested that students replace any resources that were not identified by the designers with those that were not a core competency of the organization (strength from the SWOT analysis).

5.1. Communicative

The RLO was designed with a unified communication message. Most of the interfaces were designed with global instruction and all the navigation buttons were named consistently such as "Home," "Go to the Next Question," or "Go back to Previous Question," etc. According to Boyle and Ravenscroft (2012), "design requires not just a construction of the overall learning context, but detailed concern with the tasks, the activities of learners, and the means of knowledge representation used" (p. 1230). The instructional designer paid close attention to this as she created the interactive PowerPoint presentation.

5.2. Interactive

The RLO was developed with an interactive mechanism and students could jump to any resource section, use as many times as needed, test different scenarios, or adapt the tool to their relevant organization whenever they wanted (see the "adaptive" form in this design process). The instructional designer created these interface in order to create interactive experiential knowledge for the learner as "Experiential Knowledge is the knowledge that is often modified and easily expressed, captured, stored and reused" (Berkani & Chikh, 2010, p. 4440). The authors expect that an increase in student learning comes from providing learning approaches that are congruent with a variety of cognitive learning styles and an increase interaction and reflection. We suppose that design patterns do not only increase the efficiency and flexibility of the design effort for novices, but also increase their understanding of the design process and the domain in which they design. Furthermore, we considered the cognitive effect of offering knowledge in the shape of design patters, and its implications for learning efficiency (Kolfschoten, Lukosch,Verbraeck, Valentin, & de Vreede, 2010). According to Kolfschoten, et al., (2010) "a learning task is less complex when part of it is already understood" (p. 654). In this case study the learner demonstrated greater ability in evaluating the value, rarity, inimitability, and the ability of the organization to leverage each resource in a systematic, interactive, and repetitive decision making process.

5.3. Adaptive

In this RLO the authors used a design pattern to allow learners to evaluate each resource separately. The RLO is designed as non-linear process to facilitate adaptively as a learner chooses any resource to evaluate. As indicated earlier, students prior to beginning this process created a SWOT and competitive analysis for their organization under evaluation. This provided students with a list of core competencies of their organizations under evaluation. It was our expectation that by doing this, the learner would then develop a sense about the importance of each resource for the organization's sustainable competitive advantage. Thus, this RLO was not only interactive it was also adaptive based on the SWOT and VIRO competitive assessment.

5.4. Productive

As a result, students can obtain very informative visual expressions to help him/her to make final decisions as relate to the marketing strategies (see Figure 2). If students reach this level of learning they will have transcended from a surface approach to learning to that of intellectual development and deep learning.

6. Findings

As noted earlier, the concept of developing strategy around the resources of the firm is a learning objective in the marketing

Resources Does the Organization have	Value	Rarity	Unable to Imitate	Organized Properly	Competitive Advantage
1. A Strong Financial foundation	YES	YES	YES	YES	Sustained Advantage

Figure 2. Example of a final decision strategy

Table 2. Percentage demonstrating mastery of concept before and after RLO

Class	Control (no RLO tool)		% after using tool	
SAEC	17/22	77%	40/43	93.0%
MMS	21/29	72.4	62/70	88.6%
SEL	7/9	77%	23/24	95.8%
average		75%		92.50%

Table 3. Chi-squared testing for relationship

course		Value	df	Asymp. Sig. (2-sided)
SAEC				
	Pearson Chi-Square	3.345[b]	1	.067
	Pearson Chi-Square	65		
MMS				
	Pearson Chi-Square	3.951[c]	1	.047
	N of Valid Cases	99		
SEL				
	Pearson Chi-Square	2.582[d]	1	.108
	N of Valid Cases	33		
Total				
	Pearson Chi-Square	9.306[a]	1	.002
	N of Valid Cases	197		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.22.
b. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.71.
c. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 4.69.
d. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .82.

management course, the capstone project, and the first course in the MBA program. The RLO developed here was first applied in the marketing management course and also applied in the capstone two-course sequence. Just as in the case study in the marketing management course, students in the capstone sequence showed mastery of this learning objective once they used the RLO (see Table 2).

The percent of students correctly evaluating their organization's resources to develop a strategy increase from 75% to 93% overall during the Fall 2012 term. The control (or those that did not use the RLO) were below the targeted 80 to 90% demonstrating competencies in this area. However, with the RLO, all three courses met or exceeded targeted learning outcomes. The chi-squared test supported the expectation that there was a relationship between student learning outcomes and whether or not they used the interactive RLO (see Table 3).

7. Conclusions and Discussion

Established in the management literature is the strong relationship between resources, strategy, and performance. The VRIO model is one way to assess the firm's resources or core competencies in order to identify an optimum strategy, "Business performance is a function of the effective deployment of resources associated with the strategy, not simply the content of the strategy" (Parnell & Carraher, 2001, p. 15). This RLO helps students identify the resources that can be leveraged to provide a competitive advantage. The next step in the learning process is for students to identify the strategy that will lead to a sustainable advantage. As evident by this case study, the RLO provided students with a way to think about their resources, and thus, the strategic direction of the organization in creating the desired learning outcomes.

The design of the RLO attributed to the successful engagement of the students. The RLO used probing as an evaluation method of each resource and solicitude a decision to reach either a conclusion or evaluate further decision steps for identification of the value, rarity, inimitability, and the ability of the organization to exploit the resource. This repetitive nature helped facilitate knowledge rather than just communicated it. The process provided deeper learning for the student by adding one more layer to the reflective learning process. The RLO also produced learning content rich in multimedia, interactivity, and feedback. For learners with diverse learning styles, the narrative nature of the RLO was congruent with their style; however, the interactivity helped to reach students who favor kinesthetic learning. The discussion at the residency and online helped provide increased reflection, and thus, a deeper learning experience. In addition to improving student learning outcomes, the RLO designed here proved to be reusable in several studies, with similar improvements in student learning outcomes.

8. Future Research and Limitations

This same tool was then introduced to students in the first course in the program at their opening residency experience in spring of 2013, to see if these students had similar learning outcomes to those applying the tool later in their degree program. Kurubacak (2007) mentions "To save labor, time, energy and money in programs, online workers (communication designers, online educators, technology staff, online learners, stakeholders, etc.) should share their knowledge and experiences with each other to easily modify and powerfully reuse resources" (p. 2669). Just as during the design phase, a community of practice was created to ensure that the RLO could be used by first term students. Idrosa, Mohameda, Esaa, Samsudina, & Dauda (2010) state:

> These computer-mediated learning objects were developed around the principles of reusability, meaning that lessons can be generated and customized for specific topics. Therefore a single learning object may be used in multiple contexts for multiple purposes and these were developed as an outcome of the 'curriculum analysis.' (p. 703)

One limitation of this study is the small sample size for the second of the capstone courses. This affected the chi-squared statistical analysis with two cells less than expected (see Table 2). Another limitation is that the authors based conclusions on the use of a single RLO technology.

While "it is clear that developers are enthusiastically creating reusable learning objects (RLOs) in ever-increasing numbers, and are sharing them by placing them into learning object repositories (LORs)" (Bond, Ingram, & Ryan, 2008, p. 603), a PowerPoint may not be the only useful tool for this RLO. One technology tool considered by the instructional designer is the use of Generative Learning Object (GLO Maker), "GLO Maker is of interest for two reasons: it employs an explicitly generative approach to the design and realization of virtual contexts for learning and the design is placed within an explicitly layered approach" (Boyle & Ravenscroft, 2012, p. 1231). It was decided that the RLO should be designed in two phases with the first being PowerPoint technology as a prototype, because students were already familiar with this technology. The second phase would be to replicate the RLO using GL-Maker.

It is suggested that the Generative Learning Object (GLO Maker) authoring tool can be used to design some learning objects specifically tailored for a subject learning (Greaves, Roller, & Bradley, 2010), and can easily adapted for creating rich, interactive learning resources for different subject areas or content needs (Khademi , Haghshenas , & Kabir, 2011). The GLO-Maker populates publication in HTML CD-ROM package and SCORM package for import to any LMS, that requires no specialized programming skills to create media rich RLOs. Figure 3 shows the GLO-Maker authoring tool in Design.

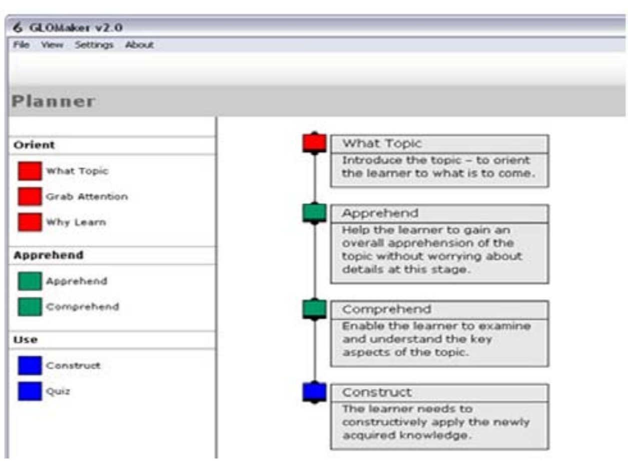

Figure 3. GLO maker tool planning interface

GLO-Maker was recommended to be the primary authoring tool for developing RLO, because many specific learning objects can be generated from well-designed core pedagogical formats or patterns. The GLO Maker tool is free to download [http://www.glomaker.org], and can be used for educational purposes. It is an open-source and easy to be adapted. GLO-Maker is popularly used by CETL, the Centre for Excellence for the Design, Development and Use of learning objects, partnered with London Metropolitan University, the University of Cambridge and the University of Nottingham [http://www.rlo-cetl.ac.uk/]. GLO-Maker's most unique feature is reusable pedagogical design, and neither content nor concrete learning objects. One of the benefits is to develop many specific learning objects based on similar pedagogical pattern (see Figure 4).

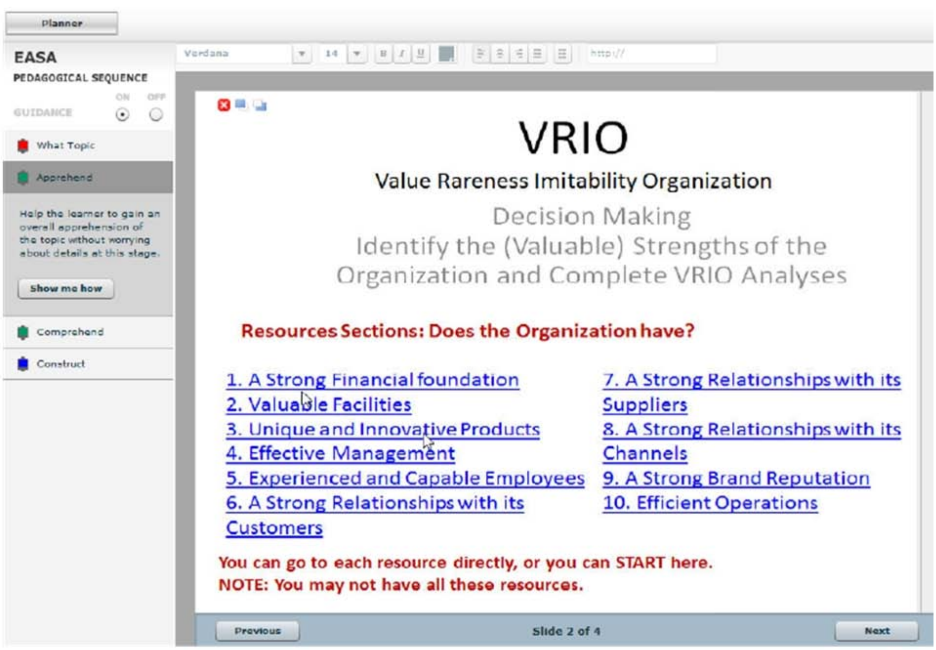

Figure 4. GLO maker tool design interface

9. Implications

A RLO appears to be a successful tool for an online learning environment. It is an effective way to create collaborative learning communities, bringing together teams with disciplinary and design expertise. The reuse of an RLO provides for both an efficient and effective way of engaging students. As each application of the RLO improves student learning outcomes, the RLO itself can be modified based on successive results. For example, in this case study the RLO was adapted by each student to include the core competencies found in their organizations being evaluated. In addition, the technology design itself will be modified to evaluate different technologies. The first technology applied was that of a PowerPoint presentation. This was selected because of the familiarity of students with PowerPoint. Students were able to quickly work within this technology with little effort. Other technologies that will be evaluated in the future are GLO maker and Flash. Both can provide an interactive learning experience for the student. The RLO needs to be both interactive and layered, so that the students are able to reflect on the outcomes. The RLO studied here provided students with the repetitive application of the theory for a "deep learning" experience. It is the authors expectations that GLO maker will have similar results as the PowerPoint presentation.

The use of an interactive RLO is important in online learning environments, especially for complex theoretical constructs. In the example here, neither textbook readings, discussion questions, nor mini-lectures were able to reach twenty-five percent of the students. However, ninety-five percent of the students were able to better understand how to assess an organization's sustainable resource through the RLO. This case study demonstrates an effective way to apply technology to improve student learning outcomes.

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