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A Conceptual Framework for Technology-Enhanced Problem-Based Learning in Construction Engineering and Management Education

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Abstract

Construction Engineering and Management (CEM) education in the higher education system has been considered necessary nowadays. How to provide a better quality of education to students has come to be a more important issue. Today's students use technology, such as social networking, social media, texting, and digital games, in their daily life and expect the same for their education. However, most higher education environments are contrary to student expectations of a high-technology learning environment. For these students, the educator should raise questions about how to improve the quality of student learning, how to improve the effectiveness of teaching, and how to do both affordably and efficiently. Problem-based learning (PBL) is a valid pedagogical strategy and continues to arouse interest because the learning approach addresses several major concerns related to improving student learning. It also might be helpful to use current or emerging technologies to draw students' active engagement. This paper examines PBL from the pedagogical perspective; explores a perspective of CEM students on using technology for their learning; investigates the role of technology in PBL; and discusses strategies for implementing technology-enhanced PBL in construction education. The findings of this study will provide construction educators with the knowledge of instructional strategies when designing a technology-enhanced PBL module. Therefore, the educators can take the benefits of both PBL and learning technology for construction education.

Introduction

In a traditional classroom, the instructor controls the learning environment and students are considered passive learners into whom knowledge can be transferred. The instructor decides what students should know and what knowledge should be transmitted through a standard lecture. Nowadays, the construction industry requires critical thinking and problem-solving skills of recent graduates. However, like many of other professional domains, CEM programs have had limited success producing graduates who possess problem-solving and critical thinking skills. These skills become significant more and more due to the expanding body of knowledge. Consequently, the instructor is facing on the challenge to teach students how to think and solve problems like a professional. The instructor may need to examine and redefine their pedagogical approach, thereby reforming the way how students learn and how a course is delivered.

The instructor should understand the characteristics of current students who are acquainted with technologies in their daily life. In addition, a surge of online educational sites provide instant access to huge resources of information, which easily lead to the extension of students' learning experience. Obviously, modern technologies and internet accessibility have a large influence on alternative teaching paradigms [1, 2]. Most students, when they are motivated, prefer being self-directed and active learners to being passive vessels. In the same context, the instructor's role needs to be shifted from a knowledge transmitter to a facilitator. Under all these circumstances, the instructor may take benefits from using PBL in order to facilitate student learning in CEM education.

Construction is a highly complex and dynamic system which has a wide spectrum of interrelated elements with multiple feedback loops and non-linear relationships. This requires construction professionals to think critically and solve unexpected problems timely through effective communication. For this reason, it is essential for CEM students to explore such environments in their classrooms through solving problems embedded in authentic contexts. PBL may provide students with rich opportunities to experience real life problems, while promoting learning in a small group. Furthermore, PBL will be able to provide collaborative learning opportunities for students. Learning occurs, in the authentic context, through students' active engagement in the learning process and interactive communications with their peers. Technology can support student active engagement and interactive communications in PBL.

This paper reviews current literature on PBL in higher education and investigates how technology can play a role in integrating PBL into CEM courses. Furthermore, this paper suggests some instructional strategies for PBL in CEM curricula with the appropriate use of technology so as to motivate current CEM students and help them engaged in their learning.

Research Design and Methods

The main objective of this study is to construct a conceptual framework for the incorporation of technology-enhanced PBL into CEM curricula. To achieve this, four sub-objectives include (1) examining PBL from the pedagogical perspective; (2) exploring a perspective of CEM students on using technology for their learning; (3) investigating the role of technology in PBL; and (4) discussing strategies for implementing technology-enhanced PBL in construction education. For this study, the following questions must be addressed:

- What are the benefits and characteristics of using PBL?
- What efforts have been made to incorporating PBL into CEM curriculum?
- What technology can be used to enhance student learning?
- How can technology be used to support PBL?
- What strategies need to be considered when technology-enhanced PBL is implemented in construction education?

To address these questions, an extensive literature review was conducted. And, a survey was performed to understand students' perspective of using technology to enhance their learning in construction education.

Literature Study

Definition of Problem-Based Learning

Problem-based learning is not a new concept. In the early 1970s, it was first formally used by faculty in medical schools that were dissatisfied with the quality of students' professional preparation [3]. Since then, a variation of PBL has been developed in response to the necessity of professional education [4]. In the 1990s, the use of PBL expanded into other areas of education in professional schools including architecture, education, law, engineering, and management [5, 6, 7, 8]. This approach has been further developed in the alternative curriculum, blending PBL with elements of conventional teaching into a hybrid. Gallagher et al. [9] describe the characteristics of a PBL course as follows:

- Learning is student-centered.
- Learning occurs in small student groups.
- The instructor is a facilitator or a guide.
- Problems form the organizing focus and stimulus for learning.
- Problems are a vehicle for the development of problem-solving skills.
- New information is acquired through self-directed learning.

Especially in CEM education, project-based learning has been considered to be interchangeable with problem-based learning. However, there is a major difference between project-based learning and problem-based learning. Problem-based learning mainly focuses on the process of problem-solving and learning while project-based learning focuses on the outcome of a project.

Teaching and Learning Theories for Problem-Based Learning

Behaviorists postulate that learning can be caused by external stimuli in the environment and is indicated by an observable behavior [10]. Learning outcomes as a result of behavioral responses to stimuli can be shaped by succeeding reinforcement. In terms of PBL design, behaviorists claim three phases: analysis, research, and problem-solving. The emphasis when designing PBL must be on analyzing the behavioral objectives and assessing learner performance with criterion-referenced tests. In the PBL approach, learning should be reinforced through teaching strategies such as frequent cues, stimulus-response chaining, feedback, and repertoires.

Jonassen [11] posits that behaviorism and cognitivism are primarily objectivistic in that they both consider learning and knowing to be the process of representing an objective reality. Under this paradigm, learners strive to learn target objectives by the passive transfer of knowledge. On the contrary, constructivism claims that learners construct their own knowledge through interacting with the external world and interpreting the experience [12]. This learning process will be facilitated when learners are actively involved in a real-world context through collaborations and social interactions. From the constructivist's view, the instructor should provide students with a learning environment embedded in a real-life context where students can interact with peers to accomplish a task. By doing so, students can realize multiple perspectives to solve a problem and critically think of what they learned. In this case, the instruction should accurately describe the task, not define the structure of learning required to accomplish a task.

According to Hmelo and Evense [13], the major goals of PBL are problem-solving, self-directed learning, and team-based or collaborative learning skills. Especially for a professional education, the followings are generally assumed:

- Learning is a constructive process, not a receptive process [14]
- Self-monitoring skills called metacognition affect learning [15]
- Social and contextual factors influence learning [16]

Learning results from learners' actions and instructions play a vital role when they enable and foster constructive activities [17]. Thus, the instructor should focus on helping students be able to acquire the aforementioned skills in their learning.

In the PBL approach, real-world problems serve as the stimulus for learning. By analyzing and solving problems, students acquire requisite knowledge, critical thinking and problem-solving skills. Students encounter real-life and open-ended situations in a small group and the instructor guides and facilitates the learning process by asking questions and monitoring the problem-solving process.

Advocates and Critics of Problem-Based Learning

PBL is a somewhat different pedagogical approach from a traditional one. For this reason, there have been two contradictory perspectives. On one hand, much research has focused on virtues of PBL, advocating its benefits in higher education. For example, Knowlton [18] argues that the generic characteristics of PBL can promote an active and collaborative environment. Numerous studies [19, 20, 21] show that PBL promotes more in-depth understanding of content than traditional pedagogical approaches, increasing student's interest, motivation, and engagement in learning. On the other hand, some researchers argue that the PBL approach may limit students' opportunities being exposed to broader content [22]. While PBL focuses on higher-order thinking and better retention of knowledge over a longer period of time, it may lessen students' initial knowledge acquisition [19]. Thus, students may feel the initial transitions into PBL to be difficult due to students' lack of foundational knowledge about the subject at the initial stage [23] and the unfamiliarity with their own role in PBL [24].

In the PBL approach, students are expected to analyze a problem and identify resources for problem-solving. Students familiar with the traditional teaching paradigm may have difficulty in adjusting their active roles in learning at the initial stage. Despite these discomforts at the initial stage, students are generally satisfied with PBL due to its promotion of social skills, communication skills, and problem-solving skills [25]. According to Schultz-Ross and Kline [26], PBL is considered an effective method of learning and instruction which can be employed for higher education.

Problem-Based Learning in Construction Education

With the assumption that PBL can change the traditional teaching paradigm, there have been several efforts in CEM education in the attempt to incorporate the PBL approach into CEM courses [27, 28, 29, 30, 31]. Traditionally in CEM education, the project-based learning approach has been widely used for CEM courses.

Kajewski [32] proposed a PBL course called 'Professional Studies.' The course emphasized student-centered and self-directed learning. The course was divided into several units, each unit included one problem, and students were forced to solve the problem through research and collaboration. McIntyre [33] applied the PBL approach into a capstone course to provide students real-world design and construction practices. In addition to these, there have been some attempts to integrate the PBL approach into CEM education [34].

Previous PBL applications in construction education show the satisfactory results. The PBL approach will be able to bring positive impact on CEM courses. The following summarize some characteristics when PBL is incorporated into CEM courses [29, 33, 35]:

- Learning can be initiated with real-world problems which require specific CEM domain knowledge to think critically and solve the problems.
- Problems can drive students motivated and engaged in the student-centered and self-directed learning.
- Students as a group can be actively involved in problem-solving, thereby improving their social, communication, and collaboration skills.

With the understanding of these PBL characteristics, the roles of technology in PBL also need to be explored. The characteristics of PBL may give the instructor some challenges. For instance, the instructor should find the best way of monitoring and facilitating students' learning process to provide valuable resources as well as useful feedback. Therefore, it is extremely significant to investigate how and what technology can support in PBL.

Students' Perspective: A Survey on Learning Technology

A survey was performed to understand students' perspective of using technology to enhance their learning in construction education. First, a pilot study was conducted with students during April 9, 2012 to April 13, 2012. Eighteen students participated in this pilot study. Through this initial study of the survey, students provided comments on the clarity and format of the survey instrument. The survey instrument was subsequently revised to improve the quantification of data to be gathered.

Sixty nine students in a CEM program were asked to participate in this survey. Thirty six students volunteered. The overall participation rate was 52%. Survey responses were collected from April 23, 2012 to April 30, 2012. Each student was asked to answer a series of questions. The initial questions of this study were divided into three main categories:

1) Technology for authentic learning
    - What kinds of tools or technologies do you think can be used for your learning in a real-like context?
2) Technology for providing resources
    - What kinds of tools or technologies do you prefer to use either for supplementing regular course materials or expanding your knowledge?
3) Technology for communication and collaboration.
    - What kinds of tools or technologies do you frequently use in your life for information sharing, communication, and collaboration with your peers?

This study found that 100% of the students prefer to use web technology for their learning. They want to access to course materials using smartphones, iPads, or laptop computers. In addition, 33% of the students expect game-based learning activities such as online games or video games. Through this survey, several web-based tools to support student-centered and collaborative learning were also identified as shown in Table 1.

Table 1. Learning Technology Tools Expected from CEM Students

	Technology	**Expectations**	**Examples**
Technology for Authentic Learning	Podcasting	Multimedia (e.g. photographs, audio and video clips, etc.)	YouTube iTunes
Technology for Providing Resources	Web Surfing	Course Website Internet Searching	Blackboard Google™
Technology for Communication and Collaboration	Social Networking	Discussion Boards, Wikis, Blogs Instant Messaging	Facebook Text Messages

Roles of Technology in Problem-Based Learning

McCreanor [36] proposes that technology can be applied to provide multiple avenues of learning, encourage students to be active participants in the learning process, and develop supplementary course activities. Technology can promote critical thinking, problem-solving, and collaborative learning. In fact, web-enabled learning environments have been successfully incorporated into various disciplines. Donnelly [37] advocates using technology to support PBL. Technology enables us to build interactive learning environments where students can play an active role in the learning process. Therefore, the use of technology allows students to be actively engaged in knowledge construction. Moreover, technology can support students in evaluating their own progress compared with others as well as receiving instant feedback.

This paper focuses on the roles of technology from three standpoints to support PBL in construction education: (1) providing a vehicle for authentic learning, (2) supporting social interactions, and (3) facilitating cognitive processes.

Providing a Vehicle for Authentic Learning

A crucial aspect of PBL is a way of presenting problems to be solved. Problems should be presented in a real-world context to motivate student learning and enhance active engagement. Jonassen [35] emphasizes that situating a problem in an authentic and meaningful context increases students' understanding and ownership for the solution of the problem. The authenticity of problems is significantly related to their presentation. Problems can be presented in three forms: a trigger, a descriptive statement, and a set of questions [38].

Technology can assist in creating a scenario and conveying an authentic problem situation. The instructor in a PBL course can bring multimedia, computer games and simulations, or web-conferencing with an industry expert for high authenticity. Video clips related to a course subject can be a trigger for discussion as well as a way of presenting problems. In addition, computer games and simulations can be powerful since students can be given their own role to play for problem-solving in virtual environments [39]. In a game scenario, students confront problems with little guidance but should act like a professional.

Supporting Social Interactions

In PBL, students are required to work as a group. Technology enables students to communicate and interact with peers anytime and anywhere, thereby improving communication and collaboration. Most course management systems such as Blackboard and Moodle include a multitude of tools which can support collaborative learning in PBL. Most of these tools can be used in synchronous or asynchronous settings to encourage students' active participation and cooperative activities. The following show examples of such tools:

- Asynchronous collaboration tools: journals, wikis, blogs, and discussion boards
- Synchronous communication tools: instant chat, web-conferencing, and multi-user virtual classrooms

For example, blogging allows students to share ideas and information with other students. Students can track all the posts and comments related to a particular issue or concern when solving a problem. The instructor can also monitor and control all the blog activities. One of the main benefits of using this tool is that students can develop metacognition and critical thinking skills by exploring and criticizing other students' opinions and thoughts [40].

Facilitating Cognitive Processes

Once a problem has been identified in technology-enhanced PBL, technology can facilitate the process of PBL, making all types of resources and references easily accessible and searchable. The instructor may upload or provide valuable resources with links for a particular problem. Otherwise, students need to search resources necessary for problem-solving. Using search engines like Google can be useful for obtaining relevant information. Through information and communication technology, it is possible to respond promptly to individual questions and alleviate frequently asked questions. Furthermore, the instructor can provide informative feedback to guide students in their learning. With the support of technology, students are able to gather proper information to solve a problem, identify and evaluate alternative solutions, and select the best solution to the problem situation. Therefore, students can be encouraged in self-directed and collaborative learning.

Computer games and simulations can be used to facilitate highly sophisticated problem-solving processes by playing a role. In games and simulations, the results of their strategy for problem-solving can be seen immediately. In particular, games and simulations provide useful means to understand their thinking process. Using games and simulations in PBL, students can practice on problem-solving and decision-making in a real-like context without any risks or damages caused by failure.

Assessment in Problem-Based Learning

Assessment in PBL may become a challenge since PBL concentrates on the learning process. In the traditional approach, the instructor assesses students' performance through an objective measurement such as quizzes and tests. However, students' performance in the PBL approach need to be assessed based on their critical thinking, problem-solving approaches, and collaborative interactions. Thus, it is essential for the instructor to adopt assessment techniques which focus on judging the status of student's learning process and knowledge construction.

Anderson and Puckett [41] emphasize using rubrics to objectively measure students' learning process and assess students' performance in PBL. Sadler and Good [42] describe peer- and self-ratings as effective assessment methods to measure students' self-directed learning, critical thinking, group cooperation, and communication. McIntyre [33] developed some criteria which can be used for assessment and evaluation in a PBL course. To measure students' performance in PBL, he employed process-oriented assessment methods such as peer- and self-ratings. Considering PBL's emphasis on self-directed learning, collaborative learning, and knowledge discovery, the use of peer-ratings, self-ratings, and reflection is highly recommended.

Technology can assist in assessing many aspects of PBL. It is possible to assess PBL via the Web in order to measure students' confidence and collaboration in their learning. The result of peer- and self-assessment can be summarized automatically for both the instructor and students. A series of self-assessments makes it possible to observe student's learning process over a period of time. In this way, technology can also be employed for peer-assessments to measure each individual's contribution to their own group at each specific point in time.

In terms of the outcome-based assessment, student's performance should be measured and evaluated at each stage. Most course management systems such as Blackboard and Moodle can be used to provide a range of different types of questions to measure students' level of knowledge. Computer games and simulations can also be used to evaluate students' critical thinking and problem-solving skills.

Discussion

PBL modules can be interchangeable with instructor-oriented course lectures. Technology can be used as a tool to support student-directed and collaborative learning. In technology-enhanced PBL, the instructor's main role should be a guide and facilitator to share information with students, support creativity, promote interaction among students to solve problems, and respond to students' cognitive needs and development. In addition, the instructor should observe, correct, and encourage students' learning process. Learning environments in technology-enhanced PBL should be student-centered, where students are encouraged to construct knowledge from their own learning experience. The following describe some strategies when the instructor implements technology-enhanced PBL in construction education.

- Stop organizing contents, generating examples, and asking questions
- Stop telling students everything they need to know. Instead, let them find out what they need to know
- Focus on designing a problem to be solved since it is a vehicle by which learning occurs
- Demonstrate how industry professionals approach a problem-solving task
- Encourage students to work together on problem-solving
- Be involved in the PBL process to facilitate students' learning
- Maximize students' learning through instant feedback and continuous assessment on their performance

Again, technology can be used to support PBL. However, technology-enhanced PBL is not meant to teach how to use technology or software packages.

Conclusions

As mentioned above, the main objective of this study is to build a conceptual framework for incorporating technology-enhanced PBL in CEM education. For this reason, the scope of this paper is somewhat limited to the discussion about the characteristics of PBL in higher education to effectively adopt PBL in CEM courses in the near future. There are numerous ways of using technology to support PBL. Nonetheless, there has not been much evidence of how technology can support students' learning in PBL. Based on the study, it is asserted that the generic features of PBL such as student-directed, research-based, and collaborative learning can create suitable learning environments in construction education when technology is blended in a supportive manner. This paper concludes that PBL is an effective teaching paradigm for construction education. In the PBL approach, students will be able to develop problem-solving, critical thinking, metacognitive, and social skills to better prepare themselves for professional careers. Finally, technology-enhanced PBL enables the instructor to provide a rich and active learning environment in which students can use necessary technology for their learning.

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