Ongoing Design of a Case-Based E-Learning System Promoting Engineering Students' Personal Epistemology and Real-World Problem Solving Abilities: A Formative Evaluation[1]

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Abstract: The purpose of this project is to design and develop a case-based e-learning system that promotes the development of engineering students' epistemic beliefs (Perry, 1970) and thus enhance their problem-solving abilities to deal with real-world engineering problems. This e-learning system provides second-year engineering students with real-world problem solving experience through four major phases: exploring situations, constructing reality, creating solutions, and reflecting on the product and the process, which has been adapted from Choi & Lee's case-based e-learning model (2009). To design an effective and feasible e-learning system, it is necessary that the new innovation (e-learning system) itself, stakeholders (students, instructors, administrators, and researchers) for the utilization of the system, and existing college classroom environments should be continually adapted to the new changes through the iterative design and implementation processes. This paper reports the first cycle of design, development, implementation, and formative evaluation of the e-learning system in this ongoing research and development project.

Introduction

Uncertainty is one of the most important characteristics that we experience while dealing with real-world problems (Jonassen 2000). Real-world problems are often made up of complex situations surrounded by multiple perspectives among different stakeholders and have diverse solutions along with multiple criteria for evaluating the tentative solutions (Jonassen, 1997, 2000; Kitchener, 1983; Shin, Jonassen, & McGee, 2003; Schraw, Dunkle, & Bendixen, 1995; Woods, 1983). The uncertainty of the problems does not merely make the problems more sophisticated; rather, the uncertainty changes the nature of the problem. Thus, dealing with these uncertain, ill-defined problems requires fundamentally different skills and attitudes that may not be necessary for dealing with well-defined problems that have clear goals and known rules to apply (Jonassen, 1997; Schraw et al., 1995; Shin et al., 2003). It is important to provide college students with proper educational experience so that they can develop the necessary skills and attitudes to be able to deal with uncertain, ill-defined problems in a way that contributes to the improvement of our society.

1. Choi, I., Hong, Y.C., Kellam, N., Gattie, D. & Gay, M. (2010). Ongoing design of a case-based e-learning system promoting engineering students' personal epistemology and real-world problem solving abilities: A formative evaluation. In J. Sanchez & K. Zhang (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2010* (pp. 34-39). Chesapeake, VA: AACE.

The Role of Epistemic Stages in Solving Real-World Problems

One important factor that influences the performance of solving ill-defined, real-world problems is personal epistemic positions (Schraw et al., 1995, Perry, 1970/1999; King & Kitchener, 1994; Kuhn, 1991). Personal epistemology means one's belief about knowledge, knowing, and learning (Hofer & Pintrich, 2002) and reflects personal beliefs about what knowledge is, "how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs" (p. 4). This belief system determines one's method of approaching the learning process, evaluating information, constructing new knowledge, building arguments, creating solutions, and making decisions in complex, undefined problem space (Perry, 1970/1999; King & Kitchener, 1994; Kuhn, 1991). Recent empirical studies have indicated that students' personal epistemology plays a critical role in solving unclearly defined, complex problems. Kitchener (1983) initially verified that unclearly defined problems require epistemic monitoring skills while well-defined problems require only cognition and metacognition, as confirmed by later studies (Schraw et al., 1995; King & Kitchener, 1994). Perry (1970/1999) began to question why college students responded in totally different ways during their college experience and found that an individual's different stages/positions of epistemology play a crucial role in organizing the learning process and dealing with unclearly defined problems. Perry's original nine positions of epistemic development have been categorized as four major stages through refinement (Moore, 2002)--dualism (black-and-white types of thinking and its variations), multiplicity (acknowledging uncertainty and accepting multiple opinions), contextual relativism (acknowledging the importance of contexts for meaning-making), and commitment within relativism (adding ethical and moral responsibility and professional commitments to the contextual relativism).

Problems & Target Audience

Second-year college students are placed in a very important stage in Perry's (1968/1999) intellectual and ethical development scheme and King and Kitchener's (1994) reflective judgment model. According to Perry's epistemic development scheme (Perry, 1968/1999; Moore, 2002), most second-year students are in the process of moving from dualism (black-and-white type of thinking) to the multiplicity stage by acknowledging uncertainty and accepting multiple opinions. Likewise, in King and Kitchener's (1994) reflective judgment model with three major stages including pre-reflective, quasi-reflective, and reflective thinking, second-year college students usually are placed in the later stage of pre-reflective thinking (believing that knowledge is certain) and are about to move to the early stage of quasi-reflective thinking (acknowledging uncertainty in problems and knowledge). Thus, their way of approaching problems and learning from individual experience is significantly different between these epistemological stages. Therefore, this project aims to facilitate second-year students' epistemic growth to the multiplicity level or early contextual relativism level through an innovative case-based learning module for engineering design problems.

A Case-Based E-Learning System

Case-Based E-Learning Model for Enhancing Ill-Defined Problem Solving Abilities

Choi and Lee (2009) conducted a four-year iterative empirical study in the second-year teacher education course in order to develop a case-based e-learning environment model for enhancing students' ill-defined problem solving abilities. This study confirms that most of the second-year teacher education college students are at the late stage of dualism (or late stage of pre-reflective thinking), where they tended to simplify situations from a single perspective. Choi and Lee's case-based e-learning environment promoted the second-year college students from upper dualism to lower multiplicity after only a three-week implementation. This growth for college students would have required a longer period of time, from several months to a year (King & Kitchener, 1994). Thus, in order to help the second-year engineering students build successful real-world problem solving abilities, the instructional innovation should focus on scaffolding students' transition from the late stage of dualism to the early stage of multiplicity and beyond.

Choi and Lee's case-based e-learning environment model (2009), which has been developed based on the different models of ill-defined problem-solving processes, consists of the five major phases of learning activities. Table 1 explains the five phases of the learning model, the corresponding problem solving activities, and the key learning resources for each phase.

Table 1. Five Learning Phases for Ill-Structured Problem Solving

5 Phases of Case-Based E-Learning Environment Model	Problem Solving Activities	Key Learning Resources
Reviewing Problems	Interpreting situations	Case problems
Analyzing Problems	Considering multiple perspectives and developing justification for problem identification	Multiple perspectives
Creating Solutions	Considering multiple perspectives and developing justification for solution generation	Expert's multiple solutions
Making Decisions	Applying theories and developing justifications for problem identification and solution generation	Theories & Literature
Reflecting on Results	Reviewing others' comments on the results of the given case and reflecting on the lessons learned	Comments on Results

The Interface of the Case-based E-Learning Module for Engineering Design Problem Solving

Based on modification of Choi & Lee's model (2009), the design framework and the interface of the case-based e-learning module for engineering design problem solving was developed. This e-learning module consists of four major phases: Exploring Situation, Constructing Reality, Creating Solutions, and Reflecting on the Process and the Product. The purpose and learning activities in each phase are described in Table 2 and Figure 1.

Table 2. Four Learning Phases for Engineering Design Problem Solving

1. Exploring Situation	Students are introduced to a real-world case problem and then build their initial ideas about problems and solutions. The goal of this stage is for them to realize the limitations of their thinking and to consider engineering design as a process instead of a product.
(1-1) Exploring Situations	Students build their naïve understanding of situations and solutions.
(1-2) Exploring Experts' Approaches	Students are exposed to multiple experts' approaches and reflect on their initial approaches while considering experts' approaches.
2. Constructing Reality	Students are exposed to rich contexts of the situation and navigate necessary information to revise their understanding of the problem
(2-1) Articulating Questions	Students are asked to articulate what they want to know about the situation.
(2-2) Exploring Reality	Using the question-based interface, students look for information they would like to know to solve the problem.
(2-3) Exploring Interpretation	Students review/listen to how different experts interpret the given situational information and then reflect on their own thinking.
3. Creating Solutions	Students are exposed to multiple perspectives from different experts and then build their own solutions.
(3-1) Articulating the Solution	Students are asked to propose their solutions and also justify their own solutions.
(3-2) Exploring Experts' Solution	Students listen to/review different experts' solutions and their justifications for the proposed solutions.
(3-3) Refining the Solution	Students compare their solutions to the experts' solutions and refine their own solutions.
4. Reflecting on the Product and the Process	Students are asked to reflect on the process of problem solving and on the problem and solutions.

Figure1. Four Learning Phases

Formative Evaluation

Purpose

To design an effective and feasible e-learning system, it is necessary that the new innovation (e-learning system) itself, stakeholders (students, instructors, administrators, and researchers) for the utilization of the system, and existing college classroom environments should be continually adapted to the new changes through the iterative design and implementation processes. In order to get an initial idea of how engineering students respond to the new e-learning module as part of their coursework and how the e-learning module and implementation strategies need to be modified for better learning experience, a formative evaluation with a small scale was conducted. This formative evaluation focuses on the usability and the learning effectiveness of the e-learning system.

Context and Procedure

A two-week implementation of this e-learning module was administered during weeks 14 and 15 in a 16-week sophomore course entitled *Introduction to Environmental Engineering and Sustainability*, which was offered at a large southeastern land-grant university. In this course, the instructor introduced different topics such as energy, water, natural resources, transportation, food production, materials use and processing, and waste handling. A total of 12 students took this course and all of them participated in this formative evaluation. After a brief orientation of the system, an epistemological belief survey and a pretest for problem solving were administered in class. The students then independently visited the case-based e-learning system to learn about an issue related to food sustainability during a one-week period as part of their homework assignment. After their one-week e-learning activity, the students completed a perceived learning experience survey and a posttest for problem solving in class.

Result: Usability and Perceived Learning Experiences

The students' overall learning experiences with this e-learning module were negative. Through further analysis, we have identified two major issues in the e-learning module and our implementation strategies.

Students were overwhelmed with the given learning resources and activities. They complained that there was too much information in the given case activities. During one case study, students were asked to review nine video clips (5 to 15 minutes per clip) explaining the case problem situation, about 70 interview video clips (about 5 minutes per clip), and additional written resources to gain engineering content knowledge. They were also asked to summarize what they reviewed and how they changed their views of the problem and the potential solutions by answering about 30 open-ended questions during their case-based learning. These activities were certainly too much for them to complete during a one-week period as part of their homework assignments (10% of their final grade; by simply participating in this learning activity, students received the full points). In addition, considering the fact that this e-learning module was implemented during the final season of the semester (weeks 14 and 15 in a 16-week semester), students' stress level might have been heightened. We suspect that learning with overwhelming resources within a short period of time might be one of the major reasons that contributed to the students' negative experience with the e-learning module.

Students experienced technical difficulties while completing the second phase activities in the e-learning module. Many students did not complete the learning activities provided in the second phase (Constructing Reality) of the e-learning module. Later, we realized that there was an unexpected error in the system. This error confused students while navigating the interface of the second phase. The second phase of the e-learning module is particularly important because it is designed to promote students' diverse thinking and to open their minds to multiple perspectives on the given problem situation, which is the major learning outcome this project aims to achieve.

Result: Learning Outcomes

The *t*-test results on problem solving tests indicated that there was no significant difference between the pretest (M = 1.61, SD = .29) and the posttest scores (M = 1.33, SD = .29), t (9) = 2.04, p = .076. Considering the fact that students experienced technical difficulties in completing the second phase of the case-learning activities and the overwhelming learning load in their case-based learning, it is somewhat expected that no positive learning outcomes occurred in this implementation. The descriptive statistics of the pretest and the posttest indicated that posttest scores were even lower than the pretest scores. Lower pretest scores are likely due to students' lack of attention on the posttest caused by their overwhelming learning experience in the final week of the semester.

Likewise, there was no significant difference between the pretest (M = 82.0, SD = 6.4, N = 7) and the posttest (M = 80.1, SD = 7.9, N = 7) in the students' epistemic belief, as the results of a two-way within-subject ANOVA demonstrated (Λ = .90 , F[1, 6] = .69, p = .44, η^2 = .10). The second phase of the learning activities were particularly designed to promote the development of students' epistemic belief from dualism level to multiplicity level. However, the second phase was not fully experienced by the students due to the technical error. Thus, any change in their epistemic belief was not expected in this particular implementation.

Further Recommendations

Based on this formative evaluation, we conclude the following five major recommendations for the revision of the e-learning system and its implementation strategies.

- The learning resources should be streamlined. The video clips should be shorter without losing the main storyline in particular.
- More time should be given to the students for the case-learning activities. Instead of one week, three or four weeks may be more realistic in order to maximize the current learning resources for the intended learning.
- In-class discussions for the case learning should be combined with the independent e-learning activities. Many students suggested that having in-class discussion would help their learning with the e-learning module.
- The last few weeks of the semester should be avoided for these heavy learning activities unless this activity is assigned as part of a final project. Instead, earlier in the semester would be more appropriate.
- The second phase of the interface should be reconsidered and the technical error should be fixed.

The purpose of this ongoing research and development project is to design, develop, and implement a feasible case-based e-learning module that can be integrated into current college classroom environments in order to promote students' epistemic development and real-world problem solving abilities. Through the iterative cycle of design-development-implementation process, the e-learning system, implementation strategies, and the classroom environment will be calibrated to maximize the learning experience. In this calibration process, it is important to begin with minimal changes in the current classroom environment with the innovation. As we find the gap, we will add more changes in the current learning environment with the innovation. Thus, this paper demonstrates a snapshot of our first implementation with minimal changes of the current classroom and curriculum. This will be the baseline for our next revision of the e-learning system and incremented changes in its implementation strategies.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 0837340. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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