Case-Based E-Learning for Solving Real-World Engineering Design Problems:
Nurturing Epistemic Growth for Second Year College Students
(The first cycle of design, development, and implementation)

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Background

Uncertainty in Real-World Problems
Uncertainty is one of the most important characteristics that we experience while dealing with real-world problems (Jonassen 2000). Solving 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). Thus, 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.

Epistemic Positions in Problem Solving
Recent empirical studies have indicated that students' personal epistemology plays a critical role in solving unclearly defined, complex problems (Schraw, Dunkle, & Bendixen, 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 is knowledge, and "how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs" (p. 4). This belief system determines one's way 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).

Sophomore Students' Epistemic Positions
According to Perry's epistemic development scheme (Perry, 1968/1999; Moore, 2002), most second-year college 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 (Choi & Lee, 2009). 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). Their way of approaching problems and learning from individual experience is significantly different between these epistemological stages.

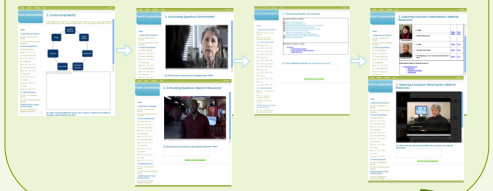
Objectives

To design and develop an innovative case-based e-learning environment that:
1) Promotes second-year engineering students' epistemic growth to the multiplicity level or early contextual relativism level, and thus
2) Enhance engineering students' real-world problem solving abilities.

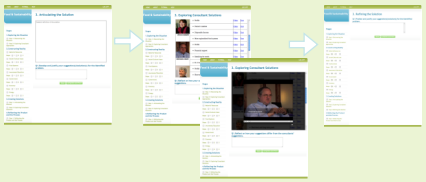
Instructional Design Framework: Four Learning Phases

Phase I: Exploring the 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.

Phase II: Constructing Reality
Students are exposed to rich contexts of the problem situation represented by multiple stakeholders and experts, and they navigate necessary information to deepen their understanding of the problem.



Phase III: Creating Solutions
Students are exposed to multiple perspectives from different experts and then will build their own solutions.



Phase IV: Reflecting on the product & the process
Students are asked to reflect on the process of problem solving and on the problem and solutions.

Choi & Lee (2009) have developed a case-based e- learning environment for real-world problem solving based on Jonassen's (1997, 1999) constructivist learning environment model and the general process of ill-structured problem solving (Sinnott, 1989; Voss et al., 1991). Their four-year iterative empirical study confirms their model promoted the development of teacher education students' personal epistemology and ill-defined problem-solving abilities. Based on the modification of Choi & Lee's model (2009), the four phases of case-based learning environment was developed.

Design Principles

Principle 1: Personally relevant case problems

Principle 2: Three types of knowledge integration (Situational, strategic, and content Knowledge)

Principle 3: Gradual scaffolding while keeping the complexity

Principle 4: Belief failure and just-in-time learning (Information-on-demand)

Principle 5: Peer-interaction scaffolding for reflective thinking

Table 1: Four Learning Phases

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 problem situation represented by multiple stakeholders and experts, and they navigate necessary information to deepen 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 re-view/listen to how different experts interpret given situational information and then reflect on their own thinking.
3. Creating Solutions	Students are exposed to multiple perspectives from different experts and then will build their own solutions.
(3-1) Articulating the Solution	Students are asked to propose their solutions and also to justify their own solutions.
(3-2) Exploring Experts' Solution	Students listen to/re-view 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.

Preliminary Implementation

- In order to get a sense of (1) how engineering students respond to the new e-learning module as part of their coursework and (2) how the e-learning module and implementation strategies need to be modified for better learning experience
- A two-week implementation during weeks 14 and 15 in a 16-week sophomore course entitled *Introduction to Environmental Engineering and Sustainability* during the spring semester in 2010.
- Sample size: 12 students.

Pretest (1) Epistemological belief survey
(2) Pretest scenario problem solving

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Two-week online implementation

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Posttest (1) Epistemological belief survey
(2) Posttest scenario problem solving
(3) Perceived learning experience survey

Preliminary Results

Usability and Perceived Learning Experiences
- The students' overall learning experiences with this e-learning module were negative.
- Students were overwhelmed with the given learning resources and activities.
- Students experienced technical difficulties while completing the second phase activities in the e-learning module.

Epistemic Development
- 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) as the results of a two-way within-subject ANOVA demonstrated (L = .90 , F[1, 6] = .69, p = .44, h2 = .10).

Problem Solving
- 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.

Next Implementation

Based on the first implementation, the revised module will be implemented in a 16-week sophomore course entitled *Introduction to Environmental Engineering and Sustainability* during the spring semester in 2011.
- Students will be given eight weeks for the case learning activities instead of two weeks. And this will be implemented at the beginning of the semester to avoid the heavy workloads during the final season of the semester.
- In-class discussions/guidance for the case learning (five minutes for every class) will be combined with the independent e-learning activities.
- The interface for the second phase learning activities has been improved.
- Sample size: 35 students.