Instructional Design Procedure of Bringing Professional Engineers' Workplace Authenticity to College Learning Settings: A Case Study of Developing a Course Prototype of Blended Learning

Kyungsun Park[1], Ilju Rha[2], Shin-Chun Ho[3]

[1~2] Dept. of Education, Seoul National University, Korea
[3] Dept. of Industrial and Manufacturing Systems Engineering,
University of Missouri-Columbia, USA

grace11@snu.ac.kr[1], iljurha@snu.ac.kr[2], shgv7@mizzou.edu[3]

Abstract

This study aims to propose instructional design processes and methods for developing a blended-learning course whose goal is to train engineering students to be competent engineers, who solve troubleshooting problems for energy audit work. A course prototype was developed in a blended form of learning, online and offline, in a large Midwestern university, USA. The task analysis method, PARI (Precursor-Action-Results-Interpretation) was applied to identify contexts of engineers' tasks and their cognitive processes in solving problems. In addition, domain, system, procedural, and strategic knowledge of engineers working through energy audit processes were analyzed based on Jonassen & Hung's research [1]. The types of knowledge were transformed into the forms of problem scenarios, visual aids, and questions. Situated Learning was implemented to design constructivist learning environments which enable students to experience professional engineers' problem-solving contexts. The blended learning course was designed to provide four problems which consist of online contents integrated with offline activities for one semester.

Introduction

It is said that there is a tremendous difference between knowing about engineering and becoming an engineer. General agreement of the difference is attributed to whether educational methods can bring professional engineers' workplace authenticity to the teaching-learning settings. The success of authentic learning depends on the delivery of practitioners' contexts into the classroom.

Situated learning theory claims that knowledge should be provided within authentic contexts of the real world [2, 3]. It emphasizes that learning should be understood within contexts of activities because human activities occur in the contexts [4]. Choi [5] states that the understanding of knowledge cannot be separated from the context where the knowledge is used. The criticism that the current public education is ineffective, abstract, and decontextualized means that what are taught and learned in schools are different from what are actually dealt with in everyday life. That is, well-structured, decontextualized problems that students solve in schools are quite different from ill-structured, contextualized problems that they run into in the real world [6]. The well-structured problems taught in schools are often provided without contextual information that is needed to solve everyday ill-structured problems. Therefore, even though students pass the test in schools, it is not rare to witness that they cannot apply what they learned to the real life situation [7]. Kwon [8] asserts that it is necessary to bring the out-of-school, ill-structured problems to classrooms in order to solve the current educational issue.

This study suggests the instructional design procedures and methods 1) to identify the characteristics of troubleshooting problems that engineers face in the real world, 2) to analyze authentic contexts where the professional engineers solve the problems, and 3) to develop the blended learning environment where students can experience the engineers' contexts in terms of their knowledge, skills, and attitude while solving the problems.

Cognitive Components of Troubleshooting Problems

Compared to what the novices usually do, the expert troubleshooters can more quickly and more efficiently identify problematic states of systems, construct a mental model of the problem, diagnose the symptoms based on their previous knowledge and experiences, and provide solutions [9]. The characteristics that the expert troubleshooters have represent that the troubleshooting competence is mostly a predominant cognitive task [10]. The cognitive components of troubleshooting problems have been studied in terms of the importance of knowledge states [11]. In the most recent studies, Jonassen and Hung [1] categorized essential knowledge for troubleshooting into domain, system (device or conceptual), performance (procedural), strategic, and experiential knowledge. Actually, Johnson [9] put an emphasis on the amount and organization of system knowledge as the primary differences between novices and experts in troubleshooting. System knowledge is the core component needed for casual reasoning in the process of problem solving [1]. Therefore, novice troubleshooters are encouraged to learn the system structure, the function of the components within the system, and the relationship with other components in the system.

Instructional Design Procedure for Workplace Authenticity Development

The course development was conducted with the objective of providing senior undergraduates and first year graduates in the college of engineering with practical experience and training of industrial energy audit. The learning environment provides troubleshooting problems for the students to perform a competent energy audit which requires them to obtain a combination of two skill sets: technical knowledge of energy systems and problem-solving ability.

Step 1. Select and identify an authentic task that practitioners or experts solve

This study selected a complex troubleshooting task that a professional energy audit engineer solves in order to isolate and diagnose faulty states of energy systems and to produce appropriate solutions. Step 1 requires engineering faculty and instructional designers to observe or experience the specific problem solving situation so that they may be able to understand the whole contexts that energy audit engineers face and experience in the real world. Therefore, the researchers observed and experienced all the whole activity processes and tools, namely, what an expert, professor of energy audit, an experienced graduate, and a group of capstone students participated in for an authentic energy audit work of D company located in Missouri, Columbia, USA. The audit processes include pre-audit analysis, walk-through audit analysis, and recommendation & follow-up.

Step 2. Model experts' cognitive and behavioral processes of solving the authentic task

The PARI (Precursor (or Prerequisite) - Actions (or Decision) – Results - Interpretation) cognitive analysis was used as the core method to bring professional engineers' workplace authenticity to the learning environment. Jonassen et al. [12] stated that the purpose of the method is to analyze domain knowledge, system knowledge, procedural knowledge, and strategic knowledge that are precursors to solving troubleshooting problems in situated, real-world environment settings (p. 121). To articulate professional experts' reasoning in solving problems, the method requires two professionals to make a pair; one as problem poser, the other as problem solver while they deal with an authentic problem. After the problem poser presents a problem, the problem solver performs actions and provides results of these actions, and then, the problem poser interprets the results. However, actually, in this study, the PARI was modified because the study reality made the researchers work with two graduated students, not with professional experts. The one experienced many audit projects with a variety of clients. The other was from the instructional design team members who worked as subject matter expert for the developmental research project. Also, their major was the same as each other. In addition to presenting the pair of student experts with a troubleshooting problem, more articulated methods were additionally performed. That is, they were asked to develop visual aids for prospective students to use for their training. After the one student expert finished creating concept maps, checklists, and flowcharts regarding the troubleshooting problem-solving process, the other provided feedback and modified them. Several times, they met together to make and change decisions on what they created. Based on concept maps they developed and interview data they provided, the authors analyzed what essential knowledge and skills should be taught and designed for the learning environment. Using flowcharts and checklists the students made, the researchers figured out what procedures students should follow to improve their skills. In summary, the outcomes from the task analysis were used to design and develop authentic problem scenarios, visual aids, and questions which consist of the most important components of knowledge and skills embedded in the learning environment.

Step 3. Analyze the context of solving the task

Activity theory is used to identify activities in which both professional engineers and students are engaged, the nature of the tools used in the activities, social and contextual relationships among the collaborators in the activities, goals and intentions of the activities and outcomes of the activities [12]. This step allows to identify the discrepancies of context between professionals and prospective students, which should be decreased with a instructional design prescription.

The major outcome from step 2 and 3 is to write performance objectives in order to decrease the gaps between them. In addition, what components consist of authentic tasks as well as what resources are available for teaching and learning should be taken into consideration based on the performance objectives. Both of them can be used as fundamental components to design and develop learning modules in step 6.

For learner analysis, one student familiar with energy audit processes was formally interviewed. In addition, capstone students were informally interviewed during a plant tour for walk-through audit analysis.

Step 5. Develop instructional strategies to provide authentic contexts by utilizing technologies

In this step, technology is the appropriate tool to decrease the differences between the authentic real-world and virtual learning settings. That is, step 5 requires to make effective and efficient use of technology to narrow the gap of authenticity between workplace and classroom.

The blended learning strategies were applied to promote learning and to support teaching according to four case problem sets in two modes of learning delivery: face-to-face and online.

The face-to-face sessions before each problem-solving will be taught by instructors who provide students with core knowledge such as concepts, rules, and principles regarding each energy system. The classroom sessions will guide, support and facilitate the following online activities. In addition, discussion (or argumentation), feedback, and presentation sessions will be provided online and offline.

Situated learning theory is the major instructional design theory for this developmental study. Anchored instruction is a manifestation model of situated learning theory for teaching in the classroom. Cognitive apprenticeship is also a core enculturation strategy for novice students to get engaged into experts' profession in a situation-based learning. Also, goal-based scenario is applied to make anchored instruction and cognitive apprenticeship situated in the online environment. More detailed descriptions are as follows.

Anchored instruction

Instead of giving direct instructions to students in order to present energy problems, the course makes students work on problem scenarios which are of complex and real-world energy efficiency issues. Even though the scenarios are not delivered in the video format, they help students identify problems, diagnose symptoms, and produce solutions while solving the problems in the blended learning environment. Students take responsibilities for what data should be collected and analyzed for energy assessment activities. The scenarios were developed authentically enough to make students think that they may be working as intern auditors at the spot of energy auditing.

Cognitive apprenticeship

While students are engaged in working on problem scenarios, they may interact with experts (or instructors) who share their expertise and provide professional feedback. In addition, students may discuss and cooperate with peer students who have different levels of knowledge and skills, but have the same goals to achieve. These kinds of learning activities and social interactions may make students situated in authentic practices of energy audit.

Goal-based scenario

To perform a competent energy audit, students need to obtain both technical knowledge of energy systems and problem-solving skills. The course provides students with the opportunity to be active participants who need to achieve sub-goals as well as a comprehensive goal in each problem set. The comprehensive goal is to write an energy audit report while they develop their problem solving skills. The sub-goals are to solve energy efficiency problems of each energy system. The scenarios were developed representing the authentic and real-world environments where students should obtain essential knowledge and develop problem solving skills. For the improvement of the students' skills and knowledge transfer, each problem set provides students with the opportunities to practice their knowledge and skills in the problem-centered learning environment.

Step 6. Develop authentic tasks and activities

The instructional design products from the previous steps were used to design learning modules, or case problems whose levels are different from each other according to learners' characteristics. The one semester-long engineering course has four case problems and each problem has four different energy system issues. Each case problem includes problem scenarios which have a story for students to work on. According to the blended learning framework, tasks and activities were designed online and offline. Multiple-choice questions, short-answer questions, and a transfer test were embedded along with the problem scenario in the online learning environment. More detailed descriptions of instructional outcomes regarding learning tasks and activities are as follows.

Modeling

Flowcharts and checklists provide students with opportunities to experience the procedures that experts take in the energy audit process. They may help students shorten the performance time, and offer them exact and quick steps to follow. Through the use of "learning resource" menu and hyperlinks of the online environment, students can have access to the flowcharts and checklists effectively.

Concept maps provide the overall and core understanding of audit process in each energy system. Even though each energy problem scenario doesn't cover all necessary concepts for learning, concept maps may help students to recognize what the essential components of each audit process are.

Coaching

Through the use of "course guide" menu, students can be guided how the course is organized and how they learn. The menu's contents also provide a table of how and where each learning menu guides them in the problem-centered learning environment.

After students submit their reports and reflective journals in the online discussion board, argumentation and feedback from peer students and instructors will coach students' learning. Especially, instructors' corrective feedback may make students' cognitive and social abilities improved.

Scaffolding

There are at least 5 chances to make students have discussion (or argumentation) sessions with peer students and instructors. Using the online discussion board, students can have instructors' cognitive and affective help while arguing about what they analyze and solve with evidences.

Along with each problem scenario, there are several questions provided to make students check whether they have a clear understanding of conceptual, procedural, and strategic knowledge. While working on the questions, students may improve and elaborate their understanding. In addition, the use of rubrics may motivate students to focus on participating in learning actively and correctly, so that they might have more chances to check what they need to know.

Conclusion

The purpose of the study is to provide instructional design procedures and methods to bring expert engineers' knowledge, skills, and attitude of the real world to learning settings. Six step-by-step processes were introduced for engineering faculty as well as instructional designers who do not have enough experiences to work in the field of engineering education. Situated learning theory is an over-arching theory applied to the development of blended learning course prototype, where anchored instruction, cognitive apprenticeship, and goal-based scenario were supplemented. Further studies are expected in the following areas: to complete and elaborate developing all four learning modules of case problems and to examine the effects of blended learning course by conducting an empirical study.

References

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