Using the PBL–Matrix Archive Frame for an Engineering Economy Class: The Case of the Management of Energy and Environmental Technology Class

Eunnyeong Heo[1], Sul-Ki Yi[2]

[1,2]Department of Energy Systems Engineering, Seoul National University, Seoul, Korea

heoe@snu.ac.kr[1], skyi@snu.ac.kr[2]

Abstract

Management of Energy and Environmental Technology is a liberal-education class in the Department of Energy Resources Engineering that teaches basic knowledge about engineering economy and some basic concepts in economic analysis, such as technology valuation, energy economics, environmental consideration, welfare economics, and government policy. Although the engineering economy class is one of the most popular liberal-education classes in an engineering college, new teaching models are needed for the class as it involves teaching social-science topics to engineering students practically and effectively.

A new concept that makes use of PBL strategies is suggested herein for a more effective engineering economy class in engineering colleges, including the development and application of a Matrix Archive system for the class. A blended e-Learning frame was also utilized for an easier-to-apply instructional system as far as both the teacher and the students are concerned. Various issues regarding the use of PBL with the Matrix Archive frame in the other liberal-education courses in engineering colleges were also addressed.

Introduction

'Management of Energy and Environmental Technology' is one of the required courses at the Department of Energy System Engineering of Seoul National University. The main objectives of the class are as follows: (1) to help the students understand the practical concept of engineering economy that they will most likely encounter in the real world outside the theoretical thinking framework of engineering; (2) to make the students undertake problem-based experiments to solve some student-friendly cases through group work assessment and discussion; and (3) to help the students understand the relationship between technology and economy, and fully grasp and comprehend the current environmental issues. To achieve these goals, lectures on engineering economy and basic concepts of economic analysis, such as technology valuation, energy economics, environmental consideration, welfare economics, and government policy, are given in the first half of the said class.

The economic approach (for the engineering majors) and short-term multidimensional case study are the main approaches used in the Management of Energy and Environmental Technology class. These approaches point to a strong need for a practical and effective teaching method that is different from the old, traditional methods. Having recognized such issue, class instructor has been doing his best to develop excellent problems that can be utilized in class for the last couple of years. Group activities, discussion, application of class contents to real cases, etc. have been utilized to make the class more practical and effective.

In this paper, based on the experiences in the Management of Energy and Environmental Technology class, a new concept based on PBL strategies is proposed, including the development and application of a prototype instructional system and a Matrix Archive system for the class.

Literature Review

To introduce the fundamental concepts in the teaching strategies proposed in this paper, problem-based learning (PBL) as well as blended e-PBL and Matrix Archive will be reviewed in this chapter, along with a brief literature review.

There are several definitions of and statements made regarding the features of PBL. According to Savery and Duffy

(1995), PBL was developed in the early 1970s as a teaching model for medical-school students. Since then, it has been widely implemented in business schools (Milter and Stinson, 1994); schools of education (Bridges and Hallinger, 1992; Duffy, 1994), architecture, law, engineering, and social work (Boud and Feletti, 1991); and high schools (Barrows and Myers, 1993). They also explained that the main feature of the PBL environment is that the learners are actively engaged in working on tasks and activities that are authentic in the environment in which they will be used. The PBL procedure is presented in table form in the paper of Savery and Duffy (1995). This procedure will be discussed in the next chapter.

PBL consists of five learning strategies, namely: (1) Learning begins with problems; (2) The problems to be presented to the students should be easy and should most likely be encountered by the students in the future; (3) Organize the knowledge that is supposed to be obtained by the students based on the problems rather than on the subjects; (4) Give the students responsibility over their own education and learning; and (5) Most of the learning must happen in a small-group scenario rather than in a lecture scenario (Bridges and Hallinger, 1992). PBL was also classified into problem-stimulated learning and student-centered learning. Which between these two should be adopted depends on the education curriculum and learning objectives.

The features of PBL are as follows: (1) All learning must be student-centered; (2) Learning must take place in small groups; (3) The instructor is only an advisor; (4) Organize the problems with motivation and learning cores; and (6) New information should be obtained through self-directed learning (Barrows, 1996).

IMSA (Illinois Mathematics and Science Academy), which adopted PBL in the elementary level, defined PBL as an educational approach that organizes all student learning by centering it on carefully formulated unstructured problems. The students gather and apply the knowledge that they obtained from various principles to come up with a solution to the problem that they chose from among the choices that were presented to them. They state the problem, formulate a hypothesis, gather data, conduct experiments, and finally come up with a solution. The students are guided by the instructors in the series course in determining the optimal solution to the problem considering the facts surrounding it. The instructors are trained to act as cognitive coaches. They guide the students into improving their critical thinking skills, problem-solving abilities, and cooperative attitudes. PBL helps the students accept complexity, find relations, enjoy learning, and improve their creative and responsible problem-solving abilities in the real world (Sage, 1996).

Lee et al. (2008) conducted a research on the blended e-PBL and Matrix Archive approach. They cited the works of Spiro et al. (1992) and Kang (1996) in explaining the cognitive flexibility theory. Spiro et al. (1992) applied the cognitive flexibility theory in a class that deals with unstructured subjects. They insisted that the unstructured side of knowledge causes trouble in the acquisition of high-level knowledge, and that the acquisition of high-level knowledge can be improved through the application of the cognitive flexibility theory. The high-level knowledge concept involves the following: understanding the complex factors affecting important concepts, using the obtained concepts as logical inferences, and applying conceptual knowledge flexibly to a new situation (Spiro et al., 1992).

Kang (1996) explained that cognitive flexibility is the ability to connect various categories of knowledge and to meet the situational demands, which are changing rapidly in various ways. Based on these concepts, Lee et al. (2008) insisted that cognitive flexibility and high-level knowledge will be able to play a very important role in some classes, especially in those classes in which the application of new principles obtained by learning and freely crossing many categories of knowledge is important. They also cited the work of Harvey, Godshalk, and Miheim (2001) to explain why the teaching plan based on the cognitive flexibility theory is useful for interdisciplinary courses, as follows: (1) In such courses, various case studies are required to confirm the diverse possible situations; (2) Such courses focus on cross-cases involving how the concepts and principles are applied; (3) Such courses involve concepts that are applied and connected to one another over and above the cases.

Lee et al. (2008) suggested that the multidimensional-landscape crisscrossing concept based on the cognitive flexibility theory can be developed into the matrix archive form. Matrix archive is nonlinear, like the cognitive flexibility hypertext, and it can suggest a process of thinking and the step of obtaining a point of view by presenting many cases. Table 1 presents the common features and points of difference of the cognitive flexible hypertext and Matrix Archive.

Table 1: Common features and points of difference of cognitive flexible hypertext and Matrix Archive

Common Features	Points of Difference
Both of them bring forward concepts and principles related with examples in a multidimensional and nonsequential way.	Compared with the cognitive flexible hypertext, Matrix Archive brings forward several cases at a time. Matrix Archive helps the blended e-PBL strategy to progress effectively by presenting cases by activity and stage.
	Matrix Archive can present contents by case, but it also presents contents by activity so that the students would be well aware of the process that contains the stages and procedure of obtaining such contents.

Case Study: Management of Energy and Environmental Technology Class (2008)

We utilize lecture materials in the fall semester of 2007 for the analysis. In the search for ways of improving these cases, Matrix Archive was conceived. Matrix Archive was developed for the following purposes: (1) to improve student learning in practice; (2) to help the students learn based on problems, while with the existing strategy, the students could learn the examples based only on their sequence; (3) to organize an archive that the students can use whatever problem they may encounter; (4) to store and manage the results of every discussion and communication through a problem-solving sequence; and (5) to furnish learning contents timely even if the instructor should proceed with the lecture so as to limit the number of offline classes.

Matrix Archive, which was developed for the aforementioned purposes, is expected to help both the instructor and the students. The basic concept of Matrix Archive that was applied in this study is schematized in Fig. 1. An advanced learning resource based on the multidimensional-landscape crisscrossing concept, which is based on the cognitive flexibility theory, is suggested.

Figure 1: basic concept of Matrix Archive

Problem	Week 1	Week 2	Week 3	...	Week 11	Week 12
	Establishing Alternatives	Net Present Value	Benefit-Cost Analysis	...	Assessing Environmental Value	Risk and Uncertainty
Selecting Optimal Renewable Energy Source for SNU	List and set optimum scale of available energy source	Transform cash flow into NPV for each alternatives	Conduct BC analysis for selection	...	Emission trade price	Consider price uncertainty of renewable energy
Selecting Optimal Fuel of Shuttle Bus for SNU	List available alternatives	Compare NPV of each alternatives due to the induction time	Conduct BC analysis for selection	...	Compare environmental effect between diesel bus and CNG bus	Assess equipment deterioration and the reason for the uncertainty about the number of passenger

Old weekly linear education procedure

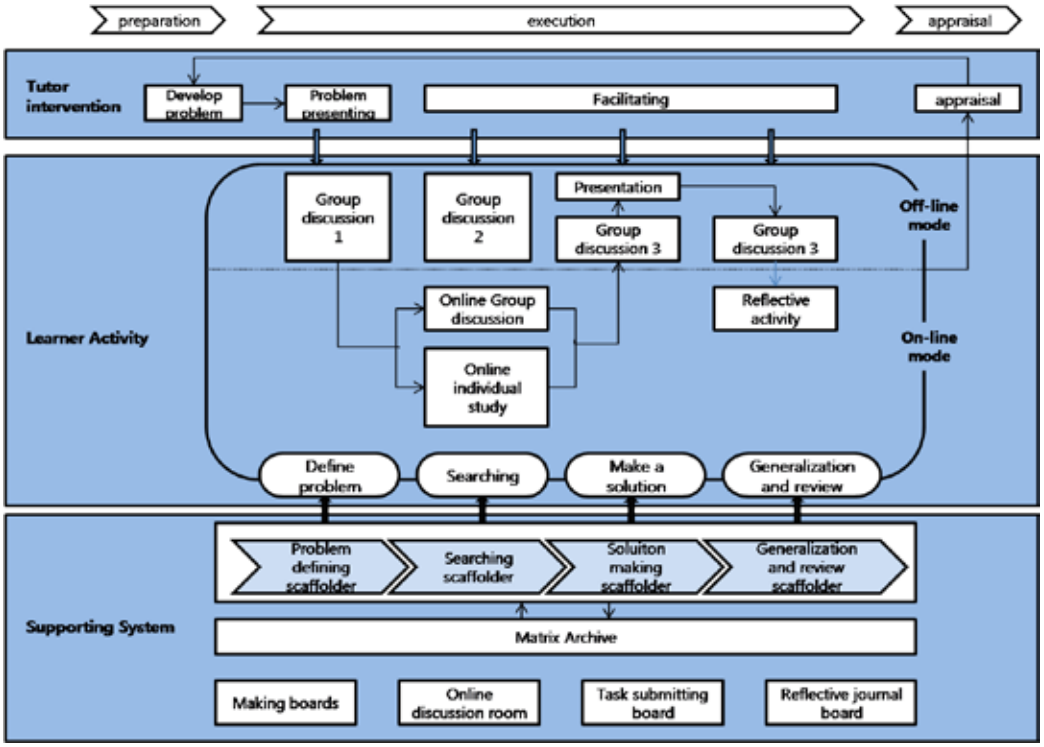
Problem	Activity 1	Activity 2	...	Activity 6	Activity 7	Activity 8
	Selecting reasonable interest rate	Questionnaire	...	Assessing Environmental Cost	Technology Valuation	Regarding Future Uncertainty
Selecting Optimal Renewable Energy Source for SNU	Interest rate for public facilities as educational facilities	Public affinity due to the renewable energy importing	...	Estimate contamination reduction and emission trade price	Commercial potential of the renewable energy technology	Uncertainty about the price of Renewable Energies
Selecting Optimal Fuel of Shuttle Bus for SNU	Rate of return having been applied for buying shuttle bus	Investigate satisfaction level of students due to the shuttle bus importing	...	Environmental comparative advantage with diesel bus	Stability in CNG	Uncertainty about the number of passenger

Structure of Matrix Archive

In addition to the previous statement, the matrix archive of the Management of Energy and Environmental Technology class embodied online as a prototype could be expanded into a multidimensional matrix. For example, it consists

of two dimensions, time (week) and subject, but one can add another dimension: difficulty. That is, one can add the difficulty dimension using the data obtained from the advanced Management of Energy and Environmental Technology class. This matrix archive, having a specific feature that is provided online, could be combined with PBL, which has been employed in class, and together, they could be an effective strategy (blended e-PBL). Fig. 2 describes the blended e-PBL support system based on Matrix Archive.

Figure 2: blended e-PBL support system based on Matrix Archive (Lee et al., 2008)



Management of Energy and Environmental Technology composed of two main parts which are instructor's lecture and problem solving activity based on PBL. The instructor gives a lecture with lecture note and the text book by the mid-term. In the lecture period, the lecture is focused on the concept which is needed to solve the problem such as engineering economy and basic concepts of economic analysis, such as technology valuation, energy economics, environmental consideration, welfare economics, and government policy. As described later, PBL process which begins in earnest after the mid-term is also conducted during the lecture period. In the problem solving period, students are encouraged to put the Matrix Archive and online lecture community to practical use.

The new lecture process was conducted in the Management of Energy and Environmental Technology class in the fall semester of 2008, based on the blended e-PBL strategy, using the Matrix Archive prototype. Two problems were proposed to the students: (1) Selecting an Optimal Renewable-Energy Source for SNU; and (2) Selecting an Optimal Fuel for a Shuttle Bus for SNU. Throughout the semester, the students endeavored to solve the problem that they themselves chose at the beginning of the lecture. A parallel lecture was conducted, though, with the contents presented in Table 2. Two groups were formed for each problem, and these two groups were made to compete with each other.

The following was the procedure that was observed in the Management of Energy and Environmental Technology class in 2008, based on the PBL process formulated by Savery and Duffy (1995).

Starting a New Class

The instructor and three tutors planned the lecture before the semester began. The problems that were to be presented in the lecture were defined. "Selecting an Optimal Renewable-Energy Source for SNU" and "Selecting an Optimal Fuel for a Shuttle Bus for SNU" were agreed to be the problems to be presented to the students. Plans for the efficient

use of the preset Matrix Archive prototype were discussed, and the Matrix Archive prototype was uploaded to the online lecture community so that the students would be able to access it easily. The specific roles of the instructor and each tutor were also defined.

Starting a New Problem

The tutors introduced the problem to the students at the beginning of the semester. The students decided which problem they wanted to deal with, and the exact group specifications were settled in the online lecture community. The students internalized the problem that they chose and came up with a presentation on their strategies. The first presentation consisted of the students' own conjectures on the hypothesis that they formulated in the course of solving the problem, and of the related data that they needed. After the presentation, the instructor and tutors conducted a review of what the students presented.

The tutors also explained the role of the instructor, tutors, and students and discussed the details of the lecture plan and the teaching strategy. This worked because many of the engineering majors in the class were not familiar with the strategy.

Problem Follow-up

During the class, the students occasionally had time for group discussion. The tutors participated in such discussion and revised the students' hypotheses. Before and after the discussion, the instructor and tutors talked about how they could properly give assistance to the students. The instructor and tutors provided the students with helpful data and took part in correcting their research plans. They also encouraged the students to engage in a lively discussion in the online lecture community and to vigorously make use of the online matrix archive.

Performance Presentation

The students came up with three presentations throughout the semester. In such presentations, the two groups that were assigned to work on the same problem discussed their opponent's work. After the presentation, the students discussed their respective future research plans with the tutors.

Final Report

The students submitted a final report on their group work at the end of the semester.

Conclusion

Matrix Archive is a system that supports both the instructor and the students. The instructor can manage problems through the archive. As there are various sub-problems linked to the main problem within the matrix archive, the instructor can make good use of it. Moreover, with Matrix Archive, the instructor can become more efficient because he or she does not have to spend too much time explaining the problem to the students. As for the students, Matrix Archive provides more data, which they can use to define and solve the problem. The students can examine problem cases other than the one that they chose to work on. As such, they have more chances to look back on their tasks from a multisided viewpoint. Thus, Matrix Archive relieves the instructor's burden and maximizes student learning.

The strategy that was suggested in this paper, however, is not a finished strategy. As such, many adversities have to be overcome before success could be attained in its implementation. Therefore, an additional procedure for examining the actual effectiveness of the strategy and the possibility of generalizing it is needed. The features and roles of Matrix Archive will be elaborated through this process. It can also provide some opportunities for the blended e-PBL strategy to be applied more frequently in reality. Then the system proposed herein can be proposed for use by instructors, managers, and administrators.

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