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# An Application of Problem Based Learning to an Earth Science Course in Higher Education

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**Abstract :** Problem Based Learning (PBL) is one of methods which has been developed to promote student-centered learning and to pursue self-directed learning for life-long learning. The purpose of this study is exploring the possibility of Problem Based Learning (PBL) in college Earth science course. The participants of this study were fourteen students attending an Earth science class at Sookmyung Women's University in Seoul. PBL was implemented in the form of group project with utilizing Web-based course tool. We provided questionnaires and conducted interviews to figure out students' perception about PBL. The findings were as follows: Through a given experiences, (1) students participated more actively than LBL (Lecture Based Learning), (2) more students were engaged with self-directed learning, and (3) students made higher cognitive efforts. LBL seemed to be more efficient way to acquire factual knowledge. In the meanwhile, PBL did not seem to affect the improvement of communication skills. Students could not make use of Web-based course tool effectively in communicating with other team members. In this study, we found that college student participants preferred problems related to everyday life, environmental issues and interesting but unusual incidents. On the other hand, they felt difficult in open-ended problems, especially when they were asked to provide their own evaluation. On the basis of PBL experiment in this paper, we present one method of successful implementation of PBL and suggest topics which should be studied in the future.

Keywords : Problem Based Learning (PBL), earth science course, higher education.

## Introduction

A few decades ago, instructions were regarded as transmission of knowledge and it was believed that learning could be acquired through direct instruction in the academic world. Teachers tried to deliver as much as information with well structured lecture in given class periods. As the amount of information students need to learn increases by geometric progression, it became difficult for teachers to cover all required information in the curriculum. And modern cognitive psychology tells us that learning is a process of not receiving but actively constructing new knowledge (Gijselaers, 1996). Ultimately, instruction must help students to construct new knowledge actively and develop self-directed learning skills.

There has been a general trend in higher education towards more student-centered approaches to stress self-directed learning, collaborative learning and learning involved with authentic problems. One of the examples of such innovative educational models is Problem Based Learning (PBL).

The purpose of this study is exploring the possibility of PBL as one of instructional methods in college Earth science course. Thus, this study focuses on (1) how students react to the problems in PBL and (2) students' perceptions about PBL and LBL.

## What is PBL?

### The principles of PBL

The idea of PBL was launched about thirty years ago as an alternative approach for professional education in the field of medicine (Barrows, 1994). In this problem-based approach, complex and real-world problems are used to motivate students to identify and learn the concepts and principles encountered during works for those problems. Stu-

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dents start with figuring out problems, instead of facts and theories. The role of instructor is primarily to guide, probe and support the students' initiatives rather than to lecture, direct, or provide solutions. While instructors still take a great part in a PBL course, learners pursue new skills and knowledge mostly on their own or in task groups using a variety of resources.

Glaser (1991) assumed three principles for learning and Gijselaers (1996) illustrated how these fundamental principles of cognition relate to instructional design in PBL. Firstly, learning is a constructive and not a receptive process. Knowledge is structured in networks of related concepts, named as semantic networks. As learning occurs, new information is coupled into existing networks. In PBL, the primary analysis of the problem through brain storming serves to activate prior knowledge, allowing students to couple new information to existing knowledge. Secondly, knowing about knowing, i.e. metacognition, affects learning. Successful problem solving is not only dependent on the possession of an extensive body of knowledge, but also on the use of problem-solving methods to accomplish learning goals. So, an instructor asks questions that monitor the progress of problem solving action: questions that students should be asked to identify the nature of problems and the kind of knowledge required to figure it out. Thirdly, social and contextual factors influence learning. To teach students how to use their knowledge to solve real-world problems, instruction should be placed in the context of complex and meaningful problem-solving situations. Social factors also influence individual learning.

Glaser (1991) argues that the learner's exposure to alternative points of view in small group is a real challenge to initial understanding. In small group work, students evoke their problem-solving methods and conceptual knowledge. They express their ideas and share responsibility in working with problem situations. Also, different views on a problem lead students to bring about new ideas.

## Why has PBL been used?

The characteristics of PBL are as follows. Firstly, PBL emphasizes cooperative activity. This reflects the constructivism that individual knowledge is constructed through social interaction. In addition, effective communication skills can be acquired through discussion. Secondly, a teacher's role is a facilitator or a guide of learners rather than information provider. That means a teacher does not instruct directly but guides learners to achieve the learning objectives. Thirdly, PBL utilizes student-centered learning. Learners must find, evaluate and use appropriate learning resources to solve the problems through self-study and group works. In other words, self-directed learning ability can be acquired. Fourthly, PBL does stress not only the outcomes but also the whole process of problem-solving.

Bridge (1992) summarizes some of the claims made by advocates of PBL in comparison with more conventional didactic methods: Firstly, PBL students develop 'substantially more positive' attitudes toward the learning environment. Secondly, PBL students tend to study for meaning rather than to duplicate instructor-proffered material. Thirdly, in PBL, students complete instructional programs in less time and with fewer dropouts than students in traditional environments. Fourthly, small differences in students' basic knowledge of disciplines in favoring of traditional programs, but PBL students show steeper growth during study period. Fifthly, there was small differences in clinical competence in favor of students in PBL programs.

### PBL Procedure

PBL procedure are shown in Fig. 1. The first step in PBL is creating problems. One of the keys to success in implementing PBL is the type of problems used. The characteristics of good PBL problems are as follows (Duch, 2001). Firstly, an effective problem should relate the matter to the real world to stimulate students' motivation. Sec-

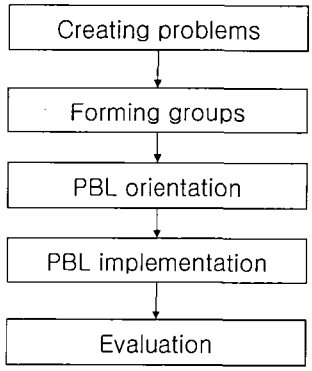


**Fig. 1.** PBL procedure.

**Table 1.** Students' specialty

| Specialty | The number of students |
|---|---|
| Biology | 6 |
| Physics | 3 |
| Chemistry | 3 |
| Law | 1 |
| Food and nutrition | 1 |

**Table 2.** Attending objectives

| Attending objectives | The number of students |
|---|---|
| To acquire qualification for teaching | 6 |
| Be interested in environment issue | 4 |
| Be interested in earth science | 4 |

ondly, problems sometimes should require students to make decisions based on facts, information, logics and rationalization. Thirdly, the problems should be complex enough that collaborative efforts from all members of the student group will be necessary in order to effectively solve them. Fourthly, problems should be open-ended, based on previously possessed knowledge, and/or be controversial so that all students in the groups are actively engaged in discussion. Fifthly, the problems should challenge students to develop higher-order thinking skills, moving them from Bloom's lower cognitive levels of knowledge and comprehension to the higher levels, where they analyze, synthesize, and evaluate.

The second step is forming groups. Creation of heterogeneous groups can expose students to new ideas and distribute assets and responsibility evenly. Friendly working environment can be built and work positively within the student group also. Hong (1989) argues that cooperation within the group and competition between groups played key roles in improving the quality of interaction among group members.

The third step is PBL orientation. Instructors must explain why he/she applies PBL as well as explain the method of implementing PBL. Students must be introduced to implementing PBL with a simple problem.

The fourth step is implementing PBL. The instructor presents problems and students start to solve the problems. The time given for solving problems will vary according to the difficulty and complexity of the problems, ability and commitment of students and so on.

The last step is evaluation. The evaluation in PBL is very important. The assessment should include individual and group assessments about the group activity as well as the final report.

## The Characteristics and Objectives of the Course

The college course involved in this study is Earth science at Sookmyung Women's University. It is introduced for general education curriculum, but students majoring in physics, chemistry or biology have to complete this course to prepare for the teaching profession. Table 1 and 2 show the list of the students' majors and attending objectives. None of them had experienced PBL before taking this course.

The objectives of the course were acquiring wide comprehension about Earth science and extensive knowledge with various field. In addition, critical thinking, information literacy, self-directed learning and communication skills had been pursued as learning goals through PBL. For this study, PBL were implemented with four different projects by use of Web-based course tool. Student groups spent

**Table 3.** Bloom's level of the first project

| | The first project's problems | Bloom's level |
|---|---|---|
| Question 1. | Can extraterrestrial exist? Why do many astronomers think that way? | Knowledge Comprehension Synthesis |
| Question 2. | Is there any evidence that planets exist except solar system? | Comprehension Analysis |
| Question 3. | Is it possible that extraterrestrial can come to the earth or we can go to the extraterrestrial planet? | Application Synthesis Evaluation |
| Question 4. | What is SETI and is there any way we participate in SETI? | Knowledge Comprehension |

**Table 4.** Bloom's level of the second project

| | The second project's problems | Bloom's level |
|---|---|---|
| Question 1. | What's the purpose of dams? | Knowledge |
| Question 2. | Explain whether the construction of dams will result in positive or negative effect? Explain the answer you choose. | Comprehension Analysis Synthesis Evaluation |
| Question 3. | What is the most useful one among dams, you think, which has been constructed in Korea? explain the reason. | Application Evaluation |
| Question 4. | What is the worst one among dams, you think, which has been constructed in Korea? explain the reason. | Application Evaluation |
| Question 5. | What should be considered to select a site for constructing dams in economical, geological, political and any other fields? | Analysis Synthesis Application |
| Question 6. | Is there any alternative ways in substitute for the role of dams? | Knowledge Synthesis |

**Table 5.** Bloom's level of the third project

| | The third project's problems | Bloom's level |
|---|---|---|
| Question 1. | What's the weather marketing? | Knowledge Comprehension |
| Question 2. | What are highly value added business fields using weather forecast? Choose five fields. Write the relation between the chosen business fields and weather forecast of short and long period. | Synthesis Application Evaluation |
| Question 3. | Which business field is the least relation to weather forecast? Write three fields and the reason. | Application Evaluation |
| Question 4. | If you work on cosmetics, discuss the ways raising the sale using weather forecast of short and long period. | Application |
| Question 5. | If you work on furniture company, discuss the ways raising the sale using weather forecast of short and long period. | Application |
| Qustion 6. | Why did insurance companies introduce the weather related goods? | Knowledge |
| Question 7. | Which companies are in need of weather financial goods? Choose three and write the reason. | Synthesis Application |

**Table 6.** Bloom's level of the fourth project

| | The fourth project's problems | Bloom's level |
|---|---|---|
| Question 1. | Explain the principle of nuclear power generation briefly. | Knowledge Comprehension |
| Question 2. | What's the benefit of nuclear power generation comparing with water power generation and steam power generation? | Knowledge Comprehension Synthesis |
| Question 3. | Why do you think resistance to construction of nuclear power generation has increased all over the world? | Analysis Synthesis Evaluation |
| Question 4. | Do you think nuclear power generation affects the global warming? explain the reason | Analysis Synthesis Evaluation |
| Question 5. | When a site for disposal of nuclear waste is to be determined in making use of GIS, write the important factors, the way combining the factors and procedure. | Synthesis Application |

4 to 5 days to complete each project. Classroom lectures were provided also during working with PBL.

## Method

In Table 3~6, problems and Bloom's cognitive levels of each project are included. The first project is in relation to astronomy, and the second and fourth project are in relation to environment. The third project is related to marketing using weather forecast. Each project is involved with open-ended problems encourage students to achieve the evaluation level in Bloom's texanomy.

As recommended in researches of PBL, students were allowed to make groups for promoting cooperation within the group. The total number of groups was five and the number of students within a group was two or three.

Peer tutors often guide group activities, that is, help their group members carry out PBL to the right direction in the class and out of the class. In this study, Web-based course tool was introduced instead of peer tutors. The reasons for using this tool are as follows. First, Web is the source of various materials and informations. The ability to retrieve information, so called, information literacy can be improved during working with PBL projects. In addition, comparison of various informations can improve critical thinking skills. Second, students can post materials they think important or controversial and write their ideas in Web discussion room any time. Interactive communication with the other group members and the teacher may be possible, too. Third, the whole progress of PBL can be observed. Whenever instructors think group activity to be distracted from the learning objectives or think students not to catch a main idea to solve the problem, appropriate comment can be made. In addition, whenever instructors think the atmosphere of group activity slowing down or not active, motivation and encouragement can be offered. In conclusion, the role of a instructor as a facilitator and a coworker can be performed efficiently.

'Classtown' was used as a Web-based course tool. It provided each group with a discussion room in cyberspace, asynchronous tool. Students carried out collaborative projects within their group discussion room. Fig. 2 shows an example of Class-

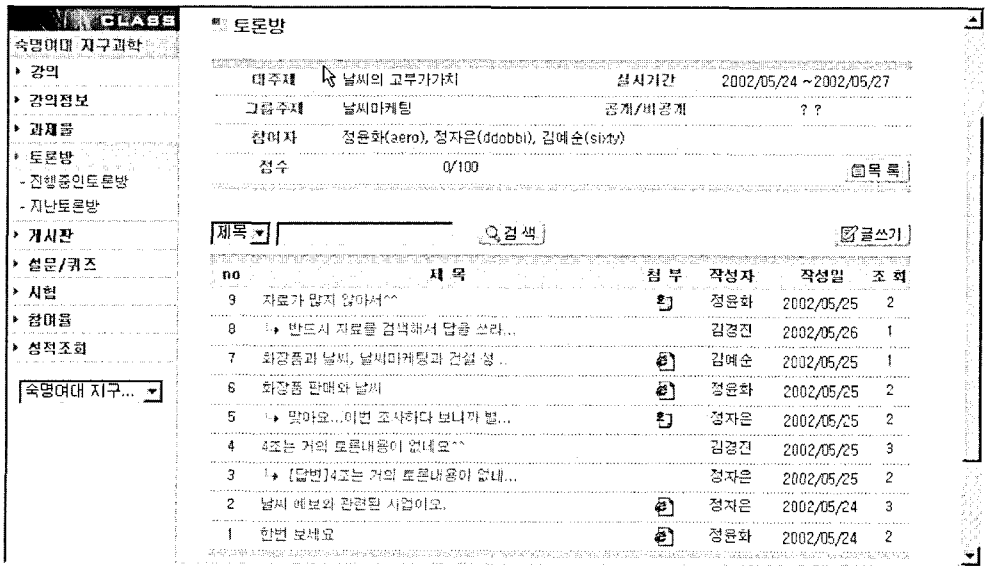


**Fig. 2.** An example of classtown's discussion room.

**Table 7.** Students' preference about the projects

| The project title | The number of answer | The reason |
|---|---|---|
| Project 1: Can extraterrestrial exist? | 4 | Individually interesting field<br>Fresh theme students had never thought |
| Project 2: Should we continuously promote the plan to establish dams? | 4 | Theme relative to environment |
| Project 3: About the value added weather | 6 | Theme relative to current daily life |
| Project 4: Nuclear power generation, should it be established continuously? | 0 | |

**Table 8.** The most difficult project

| The project title | The number of answer | The reason |
|---|---|---|
| Project 1: Can extraterrestrial exist? | 2 | The first theme to carried out and not being accustomed to this method.<br>It was difficult to search for the evidence in extraterrestrial existence |
| Project 2: Should we continuously promote the plan to establish dams? | 4 | It was difficult to tune diverse team members' opinions<br>It was difficult to search for the right answers |
| Project 3: About the value added weather | 2 | It was difficult to determine the right answers<br>Unfamiliar theme, that is, it is not well-known, marketing field |
| Project 4: Nuclear power generation, should it be established continuously? | 6 | It was difficult to understand the materials including the special knowledge<br>It was difficult to determine the right answer |

town's discussion room.

Whenever one project is completed, students should evaluate the project. First of all, students wrote down their thoughts about the teacher's problems. Second, each individual in the group reviewed her group activities and stated what the group did well and how the group needed to change or improve to function better. Next, each individual in the group rated the effort of herself as a team member. Last, each student chose two groups of which she thought as two best groups among groups but her own group based on final project reports and also provided the reason. Best two groups were put their names on the bulletin board.

Information about lectures and projects and students' evaluations about projects were conducted through 'Classtown'. Questionnaires were provided through 'Classtown' at the end of the course work. Students were asked to answer the questions about their perceptions of the projects and the course using PBL. Interviews were conducted to inquire the way how students implement PBL. All the class students were interviewed at the end of the course work. And the questions are: (1) how they implement PBL with group works, and (2) the dissatisfied points about group works.

## Results and Discussion

The project preference of students is shown in Table 7. 43% (6/14) students responded the third project was the most interesting. The third project is related to current daily life and most students did not hear of weather marketing. It may stimulate the students' curiosity. The responses to the first and the second project were the same. Students do not usually come in contact with the theme of the first project scientifically. The combination of individual concern and originality seems to attract students' motive. The second and the fourth project are in relation to environmental issue. But, the reaction is to the contrary. No one chose the fourth

**Table 9.** Students' perception of the course using PBL

| | | |
|---|---|---|
| Question 1. | View about Earth Science after attending class | 3.9# |
| Question 2. | Improvement of critical thinking through PBL | 3.9† |
| Question 3. | Improvement of information literacy through PBL | 3.8† |
| Question 4. | Improvement of communication skills through PBL | 3.5† |
| Question 5. | Improvement of self-directed learning through PBL | 3.8† |
| Question 6. | Degree of working hard | 4.4‡ |
| Question 7. | Degree of student-teacher discussion | 3.3‡ |
| Question 8. | Degree of stimulating student to high intellectual effort | 4.1‡ |
| Question 9. | The amount of dealing with factual knowledge | 2. ‡ |

# 1 = very negative, 5 = very positive
† 1 = definitely false, 5 = definitely true
‡ 1 = large in lecture class than in PBL, 5 = large in PBL than in lecture class

**Table 10.** The types of proceeding activities in PBL

| The way students implemented PBL | The number of answer |
|---|---|
| Not assigned work in advance, each member searched for the materials freely and one of the team members synthesized the data uploaded in the discussion room and finished the project report. | 9 |
| Assigned work to each member, each uploaded the materials in the discussion room, met together later and finished the project report | 3 |
| Not assigned work in advance, each member searchrd for the materials freely and met together later, finished the project report | 2 |

project opposed to the second project.

As seen in Table 8, 43% (6/14) participants responded that the fourth project was the most difficult. To solve the problems in the fourth project, students needed to use many technical and professional terms and information. Therefore, students had difficulty in interpreting such technical terms. It implicates that difficulty level of the terms and information should be examined and considered when developing for problems for PBL.

14% (2/14) students stated that the first project was difficult because they were not accustomed to PBL. 86% (12/14) students felt comfortable with PBL and did not experience any difficulty. The third project was reported to be difficult because of unfamiliar field, marketing field. Interestingly, one of the objectives of this course is to make students experience about various academic fields related to Earth science. Instructor should have explained and shared this objectives clearly.

Students stated that it was difficult to work with open-ended problems. If students learn to elicit conclusion through conversing various ideas of team members and tuning diverse opinions, it will be one of the important advantages of PBL.

Table 9 shows the student perception of the course manipulated by PBL. The Question 1 probed degrees of interest in Earth science. Most students became more interested in Earth science after attending the class. Question 2 through 5 have relation to PBL. Most students perceived PBL hardly affected the improvement of communication skills relatively. The reason can be inferred as follows: While critical thinking, information literacy and self-directed learning were viewed to be related to problems, communication skills are abilities including expressing ideas and tuning diverse opinions and making a decision in a group works and it can not be improved without the activity of team work. Furthermore, communication skills were not seen as directly connected with solving problems. Web-based course tool was used to implement PBL in this course. But, students could not make use of Web-based tool effectively in communicating with the other team members.

Table 10 reported students perceptions regarding

the way they worked with activities. Many students have cooperated and communicated in this insufficiently. Also, most students answered interactions among team members were deficient. Siegel *et al.* (1986) reported that the interaction of computer-mediated groups in the decision-making process was less observed than of face-to-face discussion groups. If partial of the lecture class would offer on-site meeting, communication between team members would be more activated and cooperation would be better. The joint of off-line and on-line activities would be desirable.

Question 6 through 9 in Table 9 are items focusing on comparison between LBL (Lecture Based Learning) and PBL (Problem Based Learning) in this course. Students thought that they worked harder in PBL than in LBL and they participated in the process of implementing project actively. Daniel *et al.* (1996) reported that positive cooperation of students and active participation is the conclusive factor whether project results in success or not. Meanwhile, the larger the number of writing in a discussion room of web page, the more organized and the deeper thinking the submitted report showed. According to the responses on the question 8, students felt that PBL stimulated them to make higher intellectual efforts than LBL.

However, students perceived that there was little difference in student-teacher discussion between PBL and LBL. They also thought that the amount of knowledge dealt with is larger in LBL than in PBL. Elizabeth (2001) reported the significant difference of student evaluation between PBL and LBL in a course for junior-level dietetics majors. In her studies, PBL students perceived that the amount of knowledge dealt with was smaller than LBL students. And LBL students achieve higher scores of the final exam slightly than PBL students, but the significant difference between scores of LBL and PBL students was not shown. Kaufman & Mann (1999) also argued that traditional class scored higher on the knowledge test in medical school than did the PBL class but knowledge differences found in PBL class after two preclinical years have disappeared at the end of fourth year, that is, basic science knowledge of PBL students may continue to grow throughout the clinical experience.

The important thing is that assessment should not focus solely on the knowledge outcome but should be tailored to the goals of PBL. The goals of PBL in this course were critical thinking, information literacy, and communication skills, being the basis of self-directed and life-long learning. Generally, students' attitudes towards the course were more positive in PBL than in LBL. According to the data in this study, most students achieves the goals of PBL except communication skills.

## Conclusion

In this study, Application of PBL to a college Earth science course shows positive effects: (1) Students participated more actively in PBL than in LBL, (2) more students involved in self-directed learning to solve the problems, and (3) students responded that they used more higher-order-thinking skills in PBL oriented projects. On the other side, PBL in this study did not contribute to the improvement of communication skills. The key to complement this problem is how to activate communication among team members. The combination of off-line and on-line activities seems to be desirable. And student journaling about activities would be helpful in watching group activity over all.

Themes of the projects in this study were related to application of scientific knowledge rather than acquiring scientific ideas. For example, the themes, such as, extraterrestrial, environmental issue, weather marketing increase student's interest and motivate them to probe for deeper and wider understanding of real world. An important finding of the study is that PBL can contribute substantially to the student led and directed activities in Earth science courses at college level.

In the future, research studies on the effects of PBL on students' acquisition of Earth science concepts or principles are needed. Assessment methods and instruments to measure changes in cognitive and affective aspects after implementing PBL should be devised and administered to discover the effectiveness of PBL.

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