

Development of Problem-Based Learning in an English-Mediated College Science Course: Design-Based Research on Four Semesters Instruction

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Universities in Korea have driven universities' new attempts to adopt more learner-centered and active learning in English. Problem-based Learning (PBL) is one of the well-known constructive teaching and learning methodologies in higher education. Our research goal was to design and develop the optimal PBL practices for a college physics course taught in English to promote learning and course satisfaction. For four semesters, we have tried and adjusted PBL components, and looked at the trend of the exam scores and group work achievement in each semester. We found that the number of problems and the duration of problem solving are the critical factors that influence the effect of PBL in a college physics course taught in English by going through iterative implementation. The iterative process of applying, designing, and constructing PBL to physics classes was meaningful not only in that we have found the optimal PBL model for learning a college physics course, but also in that we have been reflecting on the continuous interaction with learners during the course.

Keywords : Problem-Based Learning, English-Mediated Instruction, College Science Education, Design-Based Research

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Introduction

Problem-Based Learning (PBL) has been one of the most noticeable student-centered pedagogical approaches in the 2000s in Korea. Theretofore educational research in North-America and Europe has reported the effectiveness of PBL in specific disciplines, such as medicine, business and economics (Barrows, 1996; Stinson & Milner, 1996; Bossche et al., 2004). Others have recommended scenarios and guidelines for implementing PBL (Harden & Davis, 1998; Raine & Symons, 2005). Such research also reported that PBL is an effective teaching and learning method for enhancing the communication and interaction with instructor and among students. Therefore PBL can change the nature of classroom interactions and increase students' connectedness, engagement, motivation, or pro-learning attitudes (Klem & Connell, 2004; National Resource Council, 2003).

Globalization policies have engaged almost all levels of the Korean society. The exposure and active use of the English language strive to improve the English communication skills and induce students to acquire knowledge in English. Many Korean universities have created and extended the number of English-mediated courses to establish and retain English exposure in education. Instructor-centered and lecture-based teaching, which was the most dominant method in Korean universities, is not the optimal teaching and learning method, in particular when learning depends primarily on knowledge transfer through the English speaking skills of the instructor and listening skills of the students. Also, lectures are hardly a proper way to teach English-mediated courses because students are absent from the process of constructing knowledge in English.

PBL is an appealing alternative in that it can help overcome expressive language issues of the students, encourage students develop English speaking and writing skills, and provide students with their own knowledge-constructing experience in English. Adopting PBL in an English-mediated college science course has benefits, but also limitations.

Effects of PBL

Several meta-analysis studies have reported the effects of PBL, but it is difficult to conclude that PBL is effective to acquire declarative knowledge. According to Hong(2008)'s study, which meta-analyzed 85 studies on PBL, PBL was effective in improving the learning effects regardless of learner's character, subject, or learner's school age. PBL was also highly effective in improving achievement, problem solving ability, ICT using ability, creativity, self-directed learning ability, learning motivation, learning attitude, and cooperative attitude. In another meta-analysis of the effects of PBL, Dochy, Segers, Van den Bossche, and Gijbels (2004), when it compared PBL students with those in traditional curricula on measures of knowledge application showed a moderate effect size favoring PBL, but there was no effect of PBL on declarative knowledge tests.

In a carefully controlled crossover study of MBA students, Capon and Kuhn (Capon & Kuhn, 2004) randomly assigned students to either PBL-first, lecture-second or lecture-first, PBL-second conditions for two different concepts. The students constructed more integrative explanatory essays for the concepts that they had learned using a PBL approach. However, on measures of declarative knowledge, there were no differences between the conditions.

Drawbacks of PBL

In natural sciences and mathematics education PBL has not been successful in constructing a logic framework for effective learning. Klahr and Nigam (Klahr and Nigam, 2004) unambiguously demonstrated the advantages of direct instruction in science, and their claims are supported by others. Kirschner, Sweller, and Clark. (2006)'s research summarized the limitations of PBL as follows:

A series of reviews by the U.S. National Academy of Sciences has recently described the results of experiments that provide evidence for the negative consequences of unguided science instruction at all age levels and across a variety of science and math content.

McCray (McCray et al., 2003) reviewed studies and practical experience in the education of college undergraduates in engineering, technology, science, and mathematics. Gollub (Gollub et al., 2003) reviewed studies and experiences teaching science and mathematics in high school (Kirschner, et al., 2006).

Each of these and other publications amply document the lack of evidence for unguided approaches and the benefits of more strongly guided instruction. Most provide a set of instructional principles for educators that are based on solid research. These reports were prepared, in part, because of the poor state of science and mathematics education in the United States. Roblyer (Roblyer et al., 1997) reported that teachers have found discovery learning only successful when students had prerequisite knowledge and underwent some prior structured experiences.

Recently research on PBL in college science education has appeared, but without consensus on its effectiveness. For a test case of PBL in a small (17 students) introductory thermodynamics course Kampen (Kampen et al., 2004) concluded that the students' learning, motivation, enthusiasm, and performance improve. Other research on PBL in basic science education is skeptical (Sahin & Yorek, 2009) and even negative (Carlson, 2005). The discord may lie in the fact that the common PBL guidelines are at odds with the characteristics of basic science college education, which emphasizes a broad knowledge base in order to solve assignments. In engineering education research on misconceptions suggests that PBL not always automatically leads to constructing the 'right' knowledge and the correct scientific understanding (Perrenet et al., 2000). Critics therefore fear that PBL is not appropriate for disciplines rooted in a hierarchical knowledge base (Kirschner et al., 2006). Hence education experts are confused about the effectiveness of PBL in basic science education (Klahr and Nigam, 2004; Hong, 2008).

Design-Based Research

Given the controversial outcomes of PBL in science education, it was not

obvious from the start whether PBL was the most appropriate teaching method to achieve our educational goals. We adopted the Design-Based Research (DBR) in Figure 1 as our research methodology to find out what aspects of PBL disrupt the effectiveness of it in science education. This study applied PBL to college physics courses repeatedly over four semesters, analyzing the results and revising the PBL model continually. DBR was first introduced by classroom-based intervention researchers who studied learning in the process of complex educational interventions, and it aimed at testing instructional interventions designed to facilitate learning in the educational context (Yoon, 2014).

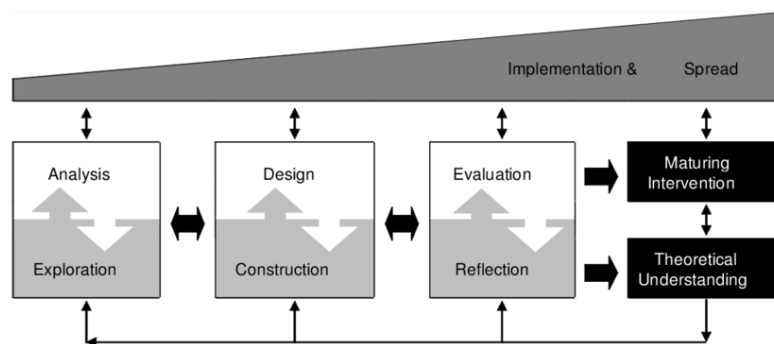


Figure 1. Generic Model for Conducting Educational Design Research (McKenney & Reeves, 2014)

By adopting DBR, our research on PBL could design and test it in the real educational setting, and study learning as more context-dependent and domain-specific in light of the specific circumstances, which is an English-mediated international instructor's college science course.

We set out on a PBL exploration by an international instructor in an attempt to avoid critical language issues and to enhance knowledge acquisition and construction in an EMI course of basic physics to freshmen at a Korean university. We have applied PBL over a period of four semesters in eight basic physics classes.

The purpose of this study is designing and testing PBL in an English-mediated science course with an international instructor. From the perspective of EMI class,

students can have more chances to express themselves to understand and solve problems with peer students and international instructor during PBL. From the perspective of a science class, the minimally guided instruction of PBL could hamper students to acquire and construct organized science knowledge.

Therefore through the experiences during four semesters of PBL we wanted to find answers to the following questions:

- How to design and construct PBL as a maturing intervention based on iterative practice and reflection?
- How does the learning outcome of students change over PBL practices?
 - How do the exam scores of students change over PBL practices?
 - How does the group work achievement of students change over PBL practices?
- How does students' EMI course satisfaction change over PBL practices?

Phase I : Initial Design and Exploration of PBL

Course background

We adopted PBL in a basic physics course in which each semester about 1200 freshmen students register as part of their basic education. The majority of students were native Korean, but the university regulations prescribed English as the language of instruction in all classes. Students have various majors, different high school pre-education, and a diverse competence in physics and English language. During four semesters and over a period of two years (2011/2012) the same instructor applied PBL in eight basic physics classes, i.e. two classes per semester. The students spent 2.5 hours per week in the classroom and most of the class time was used for the PBL group discussions.

The instructor's first encounter with PBL was through a series of workshops organized by the Center for Teaching and Learning of the university. This was followed by a two-week intensive PBL training at Maastricht University (famous for applying PBL in all disciplines since its foundation). After learning about the general principles and practices of PBL, the instructor took the challenge to find out in what form PBL could be applicable in a basic physics course where English is the language of instruction.

None of the students had ever experienced PBL before and also this physics class was the only exposure to PBL among their course selection. Therefore we thought it necessary to prepare a detailed syllabus that explained the new way of teaching and learning and the unfamiliar class organization. In practice most students ignored the lengthy syllabus, but instead learned 'how to do PBL' by going through the first PBL problem, which served then as the de-facto guidance to the students about what to expect and what was expected from them.

The two authors have had different stakes in the onset of this work. As the instructor of the physics classes, Lahaye mainly designed PBL problems and learning activities to convert his lecture-based classes into a more effective and interesting learning experience for the students. As the educational researcher, Lee provided the guidance for the PBL models, assessment rubrics, and its implementation without attending classes.

Development of PBL problems and assessment rubric

A basic physics course has a typical hierarchy of topics and concepts. We used this order as a guide to designing an appropriate sequence of PBL problems. An important aspect of a PBL problem is its ill-defined description that leaves room for different interpretations in order to enforce a discussion on suitable assumptions and relevant physics. As a consequence the various student groups likely create different types of solutions for the same PBL problem. A PBL problem also should try to relate to a real life or realistic situation. Students can

then use and apply their own experiences, which is an important skill to comprehend for future academic and professional careers.

The instructor used online resources, such as University of Delaware Clearinghouse website (2010), John Abbott College website (2010), “Case Collection” by the University of Buffalo (2010) and the “Cases Online” by Emory University (2010), which provide an online collection of real life cases with narratives that are nice templates for PBL problems. From the online resources we have, for example, adopted a car accident investigation, the planning of a highway exit, and the design of a bungee jumping act.

Figure 2 is an example of a PBL problem on the dynamics of a rotating hollow cylinder. The problem asks the students to design a spinning cylinder as a new attraction for a local amusement park. There are no specific details given, except the land area. The text concludes with three questions of economic interest, but which require important physics insights and the answers depend on the design choices. The problem is ill-defined in that few details are given in the text and important features are left out. For example, friction between the cylinder wall and the passengers is an essential detail, but is not mentioned in the text; or the danger from a too fast spinning cylinder is intentionally omitted from the description. The main learning objective is rotational motion, but equilibrium, friction, and energy conservation are equally important.

The PBL problem in Figure 2 thus embraces a range of key course topics, while the students must give each topic its place in their solution. In addition students can use their own real life knowledge of the existing amusement park and other experiences in Korea. For example, students addressed specific safety issues based on their own visits to amusement parks, or the opening times of the park helped determine “how many people per day can enjoy a ride?”, and some groups used the actual price of a kWh electricity in Korea to calculate the costs of the required energy.

One of the concerns in our PBL schedule was the number of problems students should deal with in order to comprehend all the essential concepts of the course.

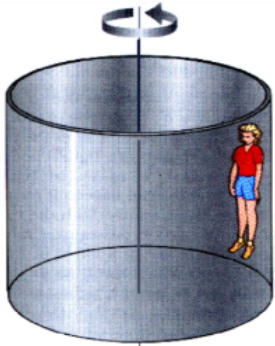
To cover the contents of the textbook imposes new concepts almost every week, and therefore we started the PBL experiment with an equally intensive scheme of one PBL problem per week. However, reflecting students' feedback throughout the semester, the number of problems was reduced in sync with the 4 to 6 PBL problems per semester as reported by others (Kampen et al., 2004; Carlson, 2005).

The management of Seoul Grand Park has decided to replace an old merry-go-round by a new, more exciting facility in order to boost the number of visitors to the amusement park. The merry-go-round covers a 300 m^2 area (that includes also the ticket booth, a space for queuing, and an area for spectators). The new facility cannot exceed this area.

The idea is the following: a large cylinder is hollow inside and has a floor at the bottom, so that people can position themselves inside the cylinder when it is at rest. The cylinder starts spinning after the people stand with their back against the wall. When the cylinder is spinning fast enough, the floor suddenly moves away, but the people in the cylinder stay in their positions.

Your team is asked to make a design for this facility, explore its possibilities and risks, and estimate answers to following questions:

- How many people per day can enjoy a ride?
- What are the daily energy requirements for operating the facility?
- What safety measures prevents danger to people inside the cylinder?



The diagram shows a 3D perspective of a hollow cylinder. A vertical axis passes through the center, with a circular arrow at the top indicating rotation. A person is standing inside the cylinder, leaning against the inner wall. The floor of the cylinder is shown as a flat surface at the bottom.

Figure 2. An Example of a PBL Problem about a Hollow Rotating Cylinder

The PBL problems and report rubric aimed at a stepwise strategy to discuss and understand the context of authentic problem, identify the crucial pieces of information and knowledge, prepare a strategy to solve the problem, study the physics relevant to the problem independently, fill in the gaps of information by reasonable solutions, discuss for group solution with group members, and finally formulate the answers supported by the assumptions and physics theory. Figure 3 shows the procedure of PBL during a period of one problem solving, which is a modification of the 7-steps PBL model of Maastricht University for this study.

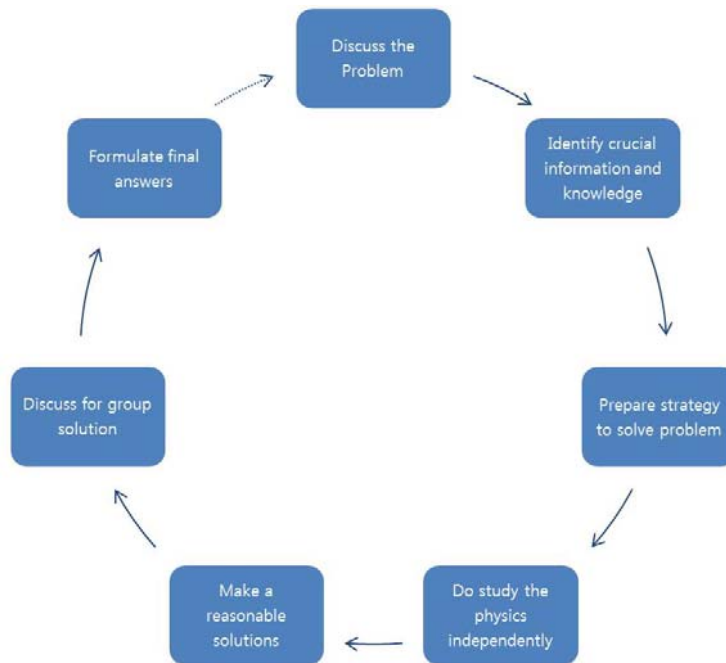


Figure 3. PBL Model during a Period of One Problem Solving

Table 1. Rubric Used for Evaluating Group Reports and Presentations

Components	Description	Score
Front page	▫ A separate sheet with a title, group picture, and member names.	10 points
Introduction	▫ Rephrase the problem and sketch the solution strategy.	10 points
Explanation of applied physics	▫ List of relevant physics used in the report together with an explanation of the physics	20 points
Solution	▫ Creativity: interesting and/or novel ideas ▫ Logicity: logical flow of arguments ▫ Explanation: explanation of assumptions, approximations etc.	30 points
References	▫ List of references to data and facts to support assumptions and used physics.	10 points
Summary	▫ A brief summary of the report	20 points

The assessment of the PBL group work was in the form of group reports, group presentations, and peer member evaluations within the group. The instructor evaluated all group reports and presentations according to a 6-items rubric shown in Table 1.

PBL groups and tutors

The students worked in groups of five with the intention to leave the groups unchanged for the rest of the semester, similar to McMaster's PBL design (Woods, 1996). At the beginning of the semester the groups were carefully crafted by the instructor in order to optimize the diversity according to pre-university education, age, and gender. If the groups were to be rearranged during the semester, then the new groups were such that students would not meet with former group members (i.e. orthogonal regrouping).

PBL guidelines often recommend the use of specific roles for group members, such as a discussion leader, a scribe, a facilitator, etc. At first we encouraged the use of roles in a group by supplying the members with role labels and by requesting to state each member's role in the final report. However, in practice students preferred not to act according to a role, but rather freewheeled through the discussions. Possibly the cultural context or lack of PBL experience made the students feel uncomfortable with the roles, but also other PBL research has recognized that students rather do without formal roles in group discussions (Kampen et al, 2004; Alves et al, 2012). We quickly abandoned this idea and the absence of formal roles did not seem to impair the PBL process.

The instructor and a teaching assistant acted as floating tutors in the classroom. During class time the tutors visited each group at least once for checking on the general progress and otherwise were available 'on-call' for assistance and answering questions. The intermittent tutoring scheme meant that student groups were working independently most of the class time. No tutoring scheme was scheduled for outside the classroom.

Phase II: Implementation and Construction of PBL

Table 2 shows the eight classes during the four semesters and their respective PBL schedule. The numbers of PBL problems per semester were stepwise reduced from the first to the fourth semester. Reduction of the number of PBL problems required a redesign of the problems, such that the new problem set would again comprehend the full range of course topics. Hence, fewer problems meant that each was to have a wider scope in terms of physics concepts. Also notice that Table 2 shows a decrease in student enrollment, which was not under our control and most probably, was a result of an increasing number of students deciding not to enroll in the PBL classes.

Table 2. Overview of the Eight PBL Classes during Four Semesters

Semester	Class	Number of students	Number of groups	Number of problems	Weeks per Problem solving
1 st	A	65	13	11	1
	B	65	13		
2 nd	C	49	10	6	2
	D	38	8		
3 rd	E	31	7	6	3
	F	56	12		
4 th	G	31	7	3	4
	H	25	5		

Academic Achievements and re-design of PBL

In basic physics course the conventional flow of topics has a linear and hierarchical structure, where new concepts are construed from previous ones. The course syllabus prescribed new concepts every week. In the first semester we followed the syllabus to set up an intensive PBL scheme with weekly problems. The problems were introduced in class and most of the class time was dedicated to the

PBL group discussions. The groups would have to meet again out-of-class in order to finalize their solution reports, which were due before the end of the week. Students showed a remarkable effort at handling the demanding timetable.

However, in the first semester the students' performance in the individual exams was too low compared to the other classes which did not adopt PBL. In reflection on the first semester's exploration, such as exam scores, interview results, and group work achievement, we concluded that the heavy workload did not give the students enough time to comprehend the newly learned concepts and to deepen their individual understanding. We inferred that the workload had to be reduced and in the next two semesters we halved the workload to two weeks for one PBL problem. Those two semesters the students' individual exam performances are much better and the quality of the reports improved significantly. This development was important for the continuation of our PBL experiment.

The performance upsurge in the second and third semesters did not cease the complaints on the workload. In the fourth semester we relaxed the PBL scheme even further (see Table 2) in the hope that the performance of the students would continue to improve. The anticipated improvement did not happen, but instead students made little progress at first and rushed into conclusions in the end. At last we realized that we had attained an optimum condition in the second and third semester with two weeks for each PBL problem. Therefore in our PBL design the overloading or underloading of the students severely impacted the effective learning through PBL.

Students' Responses and re-design of PBL

In the first semester an informal meeting took place between the educational researcher and 10 random students from the PBL classes. We intentionally excluded the instructor to let students freely express their experiences without the risk being intimidated by the instructor's presence. The consensus from the meeting

was that the students liked the novel teaching style, but were displeased by the workload. Students expressed their frustrations as follows:

"I have to do a lot of work alone. This is almost self-taught. To solve a physics problem that requires application, I need to know the knowledge exactly which is needed. Since there is no instructor's explanation, I am asking to myself whether I know the right thing and I am not sure."

"I've thought a lot about the advantages of this class. It's good to have and think about problems which are related to real life. I had thought about problems even when there's no class. But there wasn't much time to solve them. It was hard for me to take another project-based course in this semester. Anyway, it would be helpful to problem solving."

In subsequent semesters we conducted anonymous surveys for collecting the students' responses. The complaints about the workload of the PBL group work continued throughout the four semesters in the survey answers as follows:

*"Too much work", "Time-consuming", "Stressful",
"Insufficient time for self-study", "Reduce the number of problems",
"Unsure if I gained the knowledge",
"One week is not enough to solve such difficult assignments",
"I wish we were given more time to solve the assignments".*

We sympathized with the students for the truly heavy burden of weekly assignments in the first semester. The stepwise workload reduction in the following semesters did silence most of the harsh outcry, but even in its most modest form in the fourth semester students still mentioned workload as the critical downside of PBL. We believe that students actually were comparing the required efforts in the PBL classes with those in regular lecture-based classes. In lecture-based classes the students could obtain a similar grade without the "incessant and strenuous assignment pressure" in the PBL classes. Despite the high appreciation of the PBL classes, the gradual drop of students registering for the PBL classes (Table 2) is a

sign of students carefully weighing their options.

Concluding the PBL problems with a report helps the students organize and present the results of the discussions in the group work. Despite the detailed rubric for scoring the reports and presentations, the evaluation and feedback proved to be a demanding and ungrateful task for the instructor. Following the guidelines of the rubric, the scoring had to distinguish the good from the mediocre. Despite the special care for a fair and open scoring process, too often students were disgruntled by the apparent discrepancy between their efforts and the score. Some of the rough scoring edges were removed by the peer evaluations, which were used to convert the group score into individual scores.

Phase III: Testing results of PBL

Students' individual examination scores

In order to compare results of PBL classes, we have used the results of common midterm and final exams which students from all basic physics courses take simultaneously. The questions in the common exams were based on traditional textbook problems. The regular lecture-based classes focused mostly on this type of questions, whereas the students in the PBL classes spent their class time on the PBL problems. The students in our PBL classes were thus exercising different problem solving skills.

Table 3 shows the results of the midterm and final exams for the four PBL semesters. In the first two semesters only one PBL class took the common exams and in the last two semesters two PBL classes did so. The exam scores of the PBL classes indicate a slight upward trend in the first three semesters, but the last semester shows a significant drop.

In the common exams, students from PBL classes could not demonstrate their

subtle skills learned through PBL. Moreover, the PBL skills aim at long-term benefits, which are not revealed by textbook questions in ‘short-term’ exams. In the PBL classes the students are given more responsibility for their own learning than in the lecture-based classes. The lack of conventional lectures implied that students had to study and prepare for the exams by themselves, whereas in the lecture-based classes the students could concentrate on proper exam preparation during regular class time. The large group of students from the regular lecture-based class always had average scores of about 50 and Table 3 demonstrates that we can achieve the same results with PBL.

The exam performances in Table 3 also indicate an optimal condition during the second and third semesters, where the exam results of the PBL classes are mostly steady at around the average of 50. The first and fourth semesters, on the other hand, are significantly below the 50-average. We believe that overloading or underloading the students with PBL problems in the first and fourth semester respectively had a negative impact on the learning. The more adequate “dosage” in the second and third semesters constructed a balanced condition for individual learning.

Table 3. Results of the Midterm and Final Exams (perfect score is 100)

Semester	Class	Number of students	Average of Midterm exam	Average of Final exam
1 st	A	65	N/A	N/A
	B	65	44	38
2 nd	C	49	N/A	N/A
	D	38	49	51
3 rd	E	31	41	49
	F	56	50	54
4 th	G	31	43	34
	H	25	28	29

Students' PBL Group Work Achievement

For each PBL problem the group members had to submit a group report, which should contain a list of elements according to the rubric in Table 1. The rubric assisted the students in categorizing the ingredients of the report and put the outcome of the group discussion in a logical order. It also emphasized the importance of adding proper explanations to the solution process, which is quite different from the general habits of answering textbook questions.

Occasionally students were startled by the multitude of possibilities in the solution to a problem. Nevertheless all students were able to quickly adapt to this new approach to physics and over time the majority of groups could seamlessly make the appropriate connections between the textbook physics, a real world situation, and their own assumptions.

We have taken the quality of the reports as a measure of how well the student groups dealt with the PBL problems. The total number of reports during a single semester varied with the number of problems in that semester and with the number of groups in the classes. We have taken the average scores of all the reports in a semester and Table 4 compares semester by semester. The report scores in the second and third semesters are significantly higher than those in the first and fourth semester.

Table 4. The Average Scores of the PBL Group Reports

Semester	Class	Number of problems	Number of groups	Number of reports	Average score
1 st	A	11	13	286	54.5
	B		13		
2 nd	C	6	10	108	82.9
	D		8		
3 rd	E	6	7	114	70.0
	F		12		
4 th	G	3	7	36	58.1
	H		5		

The time students had for completing the report is four times longer in the fourth semester than in the first semester (1 week versus 4 weeks per assignment). More time for the assignments did not guarantee better reports, but apparently impeded the PBL process. In our experience the optimum conditions for achieving our PBL goals are in the second and third semester, where the students have a time limit of two weeks for one problem. In these two semesters we have been most confident about PBL: the students were able to organize knowledge systematically and work out their thinking in a proper report format despite the minimal guidance by instruction during the PBL sessions.

Students' course satisfaction

Near the end of the semester all students were asked to give their opinion about the lecture delivery, the guidance and Q&A in class, and teaching materials by means of an anonymous course evaluation survey system provided by the university. The survey questions did not specifically address the PBL instruction, but we assumed the answers from the students in our classes were strongly influenced by their PBL experiences. For each class the responses were translated into a percentage point scale. The closer to 100, the more satisfied the students were with the class.

Table 5. The Students' Satisfaction with the PBL Classes

Semester	Class	Number of students	Course satisfaction
1st	A	65	87
	B	65	86
2nd	C	49	90
	D	38	94
3rd	E	31	95
	F	56	86
4th	G	31	88
	H	25	89

The satisfaction of the students in the PBL classes is shown in Table 5. The satisfaction of the PBL classes is somewhat skewed by the decreasing number of students per class. As the news spread among the students about the PBL classes, the students who decided to register for the PBL classes already would have a positive attitude towards this teaching and learning approach, whereas others chose not to register for PBL classes. Consequently Table 5 demonstrates that a substantial group of students remained attracted to PBL and felt content about it afterwards.

Reflection and Lesson Learned

PBL in an English-mediated instruction

In pursuit of a globalized education system the university promoted the use of and exposure to English language in the classroom. The official guidelines for English-mediated instruction call for the use of only English in class by the instructor and by the students. In the strict sense of the policy students had to use English in the group discussions during class time. However, it turned out impractical to uphold the rules for a physics class with PBL. Students naturally switched to their common mother tongue (Korean) for a meaningful group discussion on physics. These concessions on the EMI regulations made the switch to PBL easier for the students. The communication in English with the international instructor still turned the classroom into a bilingual experience for the students. Also the final reports and presentations in English language reminded the students of the global setting of the course.

Unfortunately the reports and presentations were not effective vehicles to achieve an exposure to English language, because the one group member with the best English language skills usually would take the burden of the English writing and talking. Given the diversity of language skills among the students, it was not

realistic to expect and not feasible to enforce an equal share of the language duties. After all, the understanding of physics had to take preference over the improvement of English language.

Afterwards we realized that we had compromised some of the principles of English-mediated instruction in order to ease the course transformation to PBL, because our concerns were focused on physics content rather than language. Nevertheless, the PBL classes were still embedded in an English setting by means of international instructor, an English textbook, and the reports and presentations. The prospect of many Korean universities is a significant increase of international students. We can envision a natural adaptation of the EMI principles with PBL that enhances learning in a globalized classroom.

Interaction with the international instructor and tutors in PBL

Prior to the four PBL semesters, the instructor taught a similar basic physics course in a traditional lecture-based and instructor-centered method. The teaching in the form of plain lectures became a one-directional communication, where the mostly Korean students adopted a passive role in class with only occasional questions privately asked after class. The passive demeanor was probably a combination of cultural habits and the use of a English for instruction. The classroom situation drastically changed in the new PBL setting. The PBL group work urged the students to actively share ideas with group members and the tutors were often called to assist with the group work. From the instructor's point of view there was a lot more personal communication with many more students than in the traditional lecture-based classes. Because the instructor and tutors had to apply "time-sharing" among the groups, the students would carefully prepare the questions before calling a tutor, which very often led to good questions and a meaningful interaction with the tutors. In the private ambiance between group members and tutor the communication was much less hampered by language or culture.

The interaction with the tutors fell into two categories of questions. One type of questions addressed a difficulty or misunderstanding of a physics concept. For example, a student group could not distinguish between different types of friction forces and asked for a clarification. The tutor would resolve the confusion and enhance the learning by means of the question-and-answer method in order to find the answers together with the group members. This type of communication was effective in terms of personal learning and often created in-class aha moments.

The other type of interaction was about requests for direct guidance to the PBL problems. A popular and the bluntest one was: “please give us a hint”. Here is the pitfall that the tutor’s answer may channel the group into a specific solution strategy. In the PBL tradition this had to be avoided, because groups needed to search for and discover their own. The tutor’s initial attitude was then to abstain from answering the question, but instead respond with counter-questions in order to help develop a solution strategy. However, students noticeably showed frustration when no straightforward answers were provided.

Group work and group dynamics

At the end of the two years experimenting with PBL we came to the conclusion that the report writing as a group work had two major flaws. Firstly, it is difficult for the instructor to substantiate criticism and for the students to accept the criticism, due to the ill-defined nature of the PBL problems with no clear-cut right or wrong answers. Secondly, it turned out that the students spent an unproportionate amount of time on the textual aspects of the reports: type the story into the computer, get good pictures, and make a pretty layout. The time for report writing could be spent better on learning and understanding physics. Further research may point to alternatives for a more appropriate assessment scheme of the PBL group work.

For one class in the third semester the peer evaluation results revealed that in one-third of the groups the workload was not evenly shared among the group

members. This was a clear message that many students were not at ease with the group dynamics. Immediately after the break for the midterm exam we regrouped the students, such that former group members did not meet again. This class reshuffle gave the students the opportunity for a fresh start in the second half of the semester. The group dynamics did not improved much, but at least the students were relieved of the burden in their first groups. In the fourth semester we continued the regrouping policy with new groups for each assignment. During the four semesters it proved difficult to recognize disharmony among the group members, also because the students tended to conceal trouble among the group members. We believe that the regrouping was a practical solution to mitigate irritation from bad group dynamics.

Starting from the second semester we launched a peer evaluation scheme in the PBL classes. A few times during the semester each student dispensed 120 points to the members as a testimony of their participation in the group work. For an ideal group all members would receive the same amount of points, but a systematic dispersion of the points implied that some group members were more active than others.

Conclusion

We have implemented Problem-based Learning during four semesters in a limited number of basic physics classes within an academic system where instructor-centered lecture-based instruction is the norm. As an international instructor using English with predominantly Korean students, we hoped that PBL could bridge the major language issues and enhance the interaction between the instructor and students. During the four semesters experimenting with PBL we developed a model of PBL that could resonate with the students, without compromising the students' competence in common individual exams.

We designed initial PBL model which show the procedure of PBL during a

period of one problem solving and developed it over semesters by adjusting the number of problems and the duration of the problem solving with the reflection on results. Each semester's different PBL models showed different results in exam scores, group work achievements, and course satisfaction.

The limitations of PBLs in science and math education in existing studies are reported in the unguided instructions. According to this study, when the number of PBL problems for the first semester was 11 and the PBL problem solving period was only one week, exam scores, group work achievement, and course satisfaction were low. Interestingly, when the number of PBL problems for the fourth semester decreased by a quarter and the duration of the problem solving increased by four times, the exam scores, group work achievement, and course satisfaction were also low. Rather, we found that exam scores, group work achievement, and course satisfaction are relatively high when the number of problems for the second and third semester is 6 and the problem solving period is 2 to 3 weeks. These results imply that the appropriate amount and load of learning could affect the effectiveness of PBL in addition with instructors' guidance and direct instruction.

Students' perception in course satisfaction during the PBL was that they welcomed the free and liberal atmosphere in the classroom and were pleasantly surprised that the PBL approach made the physics class taught in English "much less boring." However, course satisfaction showed that the workload in PBL remained an unsolved issue, because students would compare the required efforts in PBL with those in traditionally taught classes. Although the course satisfaction was changed by each PBL model, the number of students signing up for the PBL classes gradually decreased over the four semesters.

It is hard work for an instructor to prepare all the materials for a new PBL course. However, it is rewarding to see the engagement of an entire class of students and it is an interesting experience to approach instruction from a very different students-centered perspective. Although our PBL project terminated after the two years, the instructor still interweaves PBL with other instructional approaches as one of the tools to engage students.

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