Volume 25, Number 1, 2023

Global Journal of Engineering Education

Lessons from on-line and off-line PBL in an engineering economics course under the Covid-19 pandemic

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ABSTRACT: The application and effects of the project-based learning (PBL) model have been carried out in various majors and courses, and the results analysed in several studies. This study was focused on the Covid-19 pandemic period from 2020 to 2022 to discuss lessons and effects of applying an on-line and off-line PBL model to engineering economics courses for engineering students in 2021 and 2022 compared with a simple on-line course in 2020 without PBL. Project teams consisting of three-four students carried out on-line collaborative learning to solve open-ended problems through a four-step PBL procedure including presentation of the final result. Except for this PBL application in 2021 and 2022, textbooks, lecture contents, assignments and tests were implemented in the same way for each semester over these three years. Through lecture evaluation and a simple survey for students, the semesters with PBL showed higher effects in inducing student-led learning and lecture satisfaction compared to the semesters without it. Further, it was established that the PBL application to the course and the evaluation method were more appropriate than the approach in other semesters. It is expected that the PBL method and operation procedure outlined in this article could be utilised as a best practice for various on-line and mixed courses in student-led collaborative learning activities to achieve better educational effects and satisfaction.

Keywords: On-line and off-line project-based learning (PBL), engineering economics course, Covid-19 pandemic

INTRODUCTION

Covid-19, which has been sweeping the globe since the beginning of 2020, has had a huge impact on human life in all fields, including politics, economy and culture. The field of education is no exception. In most educational institutions, lectures have been converted to on-line held classes, and interaction between instructors and learners, and among learners has also been conducted mostly on-line. The history of on-line education is very long, and many educational institutions have been conducting various lectures through on-line mode. In addition, many studies have shown that the educational effect and learners' satisfaction with on-line delivery are not lower than those of off-line lectures.

However, it is still true that the number and type of on-line lectures are very small compared to overall lectures for various majors. In particular, interaction between learners through experiments and practice, instructor-learner interaction, team assignments, etc, are very important learning activities, and there are many limitations to on-line classes in engineering education that impact on educational effects. Therefore, compared to other majors, there are many difficulties in organising and operating on-line classes in engineering. However, under the ongoing pandemic, it is absolutely necessary to continue on-line teaching and learning activities engaging instructors and learners, and there is a need for an on-line method that would have a learning effect comparable to that of off-line classes.

Considering the current background, this case study was aimed at the industrial and management engineering (IME) students of Hankuk University of Foreign Studies (HUFS) in Yongin City, Republic of Korea, to engage them in an on-line- and off-line-based curriculum of the project-based learning (PBL) model, which is widely recognised for its student-led learning effect. More specifically, engineering economics students' performance and satisfaction in 2021 and 2022 were compared with a simple on-line course in 2020 without the PBL application when the pandemic began.

RELATED STUDIES

The capability to transmit and receive a wide variety of voice and video information regardless of time and place due to the development of information and communication technology (ICT) is rapidly changing the physical space of the classroom into a virtual space, catalysed by the Covid-19 pandemic. For a long time, on-line learning has already started in the form of including on-line courses in existing off-line curricula in most universities for various reasons, and is spreading to numerous curricula in various forms [1]. However, there is a variety of different studies and opinions as to whether the on-line curriculum is superior to the off-line one in terms of its educational effect or educational satisfaction.

First, there are studies showing that on-line education is more effective, including a study in which students who took on-line courses in advanced science education showed better grades than students who took off-line courses [2]; and similarily in a mathematics and physics curriculum, the educational effect of on-line delivery was also good [3]. Further, in an on-line introductory physics course, through on-line tools, repeated access to lecture contents, frequent discussions and regular access to course materials for assignments have helped improve test scores [4].

In the recent Covid-19 situation, there have been quite a few studies showing that the on-line curriculum has high educational effects or learners' satisfaction. For example, Kim established that on-line courses operated in a capstone design and engineering accounting curriculum are better than off-line ones [5][6]. Also, in the analysis of learners' perceptions of non-face-to-face on-line practice classes in basic electric circuits, the learning effect of this practice subject, learning convenience, interaction and satisfaction were relatively good [7].

Another study can also be mentioned that confirmed the possibility of co-operative product development practice based on a completely non-face-to-face product data management system in product development practice subjects [8].

However, in early studies, on-line students' satisfaction with on-line lectures tended to be lower than off-line lectures [9][10]. In particular, the biggest concern for professors is whether the on-line curriculum is as educationally sound as its off-line equivalent. As is well known, not all students prefer on-line courses [11].

About 23% of leading universities have perceived that on-line courses are not better than off-line courses [12], and on-line courses do not outperform traditional off-line courses in a variety of curricula in terms of learning outcomes. For example, in psychology [13] and linguistics [14], students' academic performance was poor in on-line courses, and their grade point averages in on-line courses were also lower than those in off-line courses [15]. In addition, in the evaluation and experience analysis of 48 professors in the College of Engineering at Korea University, Seoul, Republic of Korea, for on-line classes, most instructors negatively evaluated the effectiveness of non-face-to-face on-line classes [16].

On the other hand, there are also studies that report no significant difference between on-line and off-line lecture effects. For instance, there was little difference in the learning outcomes of on-line and off-line students demonstrated by Neuhauser [17] or Brown and Park [18], and no difference between on-line and off-line lecture methods, especially in the learning outcomes based on credit standards were reported by Cavanaugh and Jacquemin [19]. In addition, no differences between the two methods could be found in test scores, grade distribution and students' attitudes toward chemistry in a recently deliverd introductory inorganic chemistry course [20]. Further, in regard to on-line students' lectures, except for the high level of satisfaction in the algebra-based physics curriculum, there was no statistically significant difference in the learning outcomes of students taking the two methods [21].

More generally, it seems that there is no difference in terms of learning outcomes or educational effects between on-line and off-line courses in existing studies, and no strong indication that on-line courses are inferior. In particular, in a study comparing the same lecturer, the same lecture material and the same test and assignment on-line and off-line, it was found that there was no difference in the learning effect of the two methods [19][21]. However, in the context of the Covid-19 pandemic, research on on-line education has shown that student participation has decreased [22], and furthermore, despite the advantages of on-line education using ICT to remove time and space constraints, the lack of interaction between instructors and learners has paradoxically also been revealed [23].

In a study on the perception of on-line education in engineering colleges in the first semester of 2020 in Korea, the need for instructors to design structured classes suitable for on-line education was emphasised [24]. In addition, an in-depth interview study of instructors who conducted on-line classes showed that in the process of redesigning off-line classes into on-line classes, in the case of courses based on face-to-face learning situations, such as experimental courses in engineering colleges, the transition to the on-line class environment emphasised the need for special teaching and learning strategies, as well as the need to find various ways to improve learning effects. That means the student-centered learning model needs to be applied to on-line courses as well.

Engineering economics, which is the target of this case study, is an interdisciplinary subject between engineering and social sciences, and it provides a systematic framework for evaluating the economic aspects of several competing engineering solutions [25].

It is widely held that the PBL model can develop problem-solving skills through student-led collaborative learning, teamwork and communication, while utilising various advantages of on-line learning is the best practice alternative. As PBL is considered a teaching/learning approach in the curriculum [26], it seems more suitable during the Covid-19 pandemic in regard to on-line and off-line lectures.

In the study presented in this article, were examined the classes and effects from experiences of on-line and off-line PBL during three fall semesters of an engineering economics curriculum from 2020 to 2022.

Engineering Economics Curriculum

The necessity of economics subjects in engineering colleges has been pointed out in several studies. Understanding and applying economic principles to engineering have never been more important. Engineering is more than a problem-solving activity focusing on the development of products, systems and processes to satisfy a need or demand. Beyond function and performance, solutions must be viable economically. A great solution can die a certain death if it is not profitable. So, engineering economics provides a systematic framework for analysing the economic aspects for competing design solutions for all speciality areas, such as chemical, civil, computer, electrical, mechanical and industrial engineering [25]. The IME of HUFS offers engineering economics as a required course for freshmen, and as the number of students from other major's increases through double majors and minors, the course is divided into two classes. Class A is open only for first-time students who are freshmen majoring in IME, while class B is open for students from other departments and re-takers. Through the 16-week class, students learn the systematic evaluation of alternative investment opportunities. For class A, the same textbooks, assignments and instructors were involved during the three fall semesters under consideration, from 2020 to 2022.

The differences in curriculum management for each of the three years are as follows. In the case of 2020, due to the Covid-19 pandemic, all lectures were delivered in real-time as on-line lectures. There were 37 students in 2020. Grades were evaluated based on evaluation standards, such as attendance and a terminology quiz (15%), on-line midterm examination (40%), practical problem-solving task (20%), and the on-line final examination (25%). The biggest difference in 2021 was that the four-step on-line PBL model was introduced as a way to strengthen students' on-line learning activities based on the experience of 2020 and increase their participation in on-line lectures. As for the lecture method, all classes were also delivered as real-time on-line lectures, and the grade evaluation was based on attendance and a terminology quiz (13%), on-line midterm examination (39%), the four-step on-line PBL model (22%), practical problem-solving task (6%), and the on-line final examination (20%). Although the evaluation criteria were similar to those of 2020, the evaluation weights were significantly modified according to the introduction of on-line PBL.

The number of students for the 2021 academic year increased slightly to 42 students. In the fall semester of 2022, due to the lessening of Covid-19 restrictions, the lecture mode was changed to face-to-face. As a result, both lectures and tests were changed to face-to-face, but PBL was conducted on-line, off-line or a mixed method by a team. The grade evaluation for 39 students in 2022 was attendance and a terminology quiz (13%), off-line midterm examination (39%), the four-step on/off-line PBL (22%), practical problem-solving task (6%) and the off-line final examination (20%). Table 1 below summarises the characteristics of the engineering economics curriculum by year.

Table 1: Characteristics of the engineering economics curriculum from 2020 to 2022.

	2020	2021	2022
Lecture type	On-line lecture without PBL	On-line lecture with on-line PBL	Off-line lecture with on/off-line PBL
Lecture content	Economic analysis methods and cases	Same as 2020	Same as 2020
Evaluation criteria (proportion)	Attendance and a terminology quiz (15%), on-line midterm examination (40%), practical problem-solving task (20%) and the on-line final examination (25%).	Attendance and a terminology quiz (13%), on-line midterm examination (39%), the four-step on-line PBL (22%), practical problem- solving task (6%) and the on-line final examination (20%).	Attendance and a terminology quiz (13%), off-line midterm examination (39%), the four-step on/off-line PBL (22%), practical problem-solving task (6%) and the off-line final examination (20%).
Course target/number of participants	Freshmen/37	Freshmen/42	Freshmen/39

On-line and Off-line PBL Operation and Procedure

On-line problem-based learning can be defined as the main process of existing problem-based learning in an on-line environment [27]. Thus, on-line project-based learning (PBL) can be defined similarly. The on-line environment has its advantageous for learners as they can use various resources required in PBL to improve their problem-solving ability, and problem solving is possible through on-line co-operative learning [28].

Under the Covid-19 environment, it is necessary to organise PBL, so that all possible courses based on PBL can operate on-line. Figure 1 shows the operation procedure of on-line PBL. As shown in the figure, all processes of PBL are performed using several on-line services and tools. HUFS eClass - a learning/teaching management system (LMS/TMS) provided by Hankuk University of Foreign Studies, and Webex, an on-line lecture system, have become core tools. Students search for and communicate information and data needed in the problem-solving process, write meeting minutes and reports. Uploading is also possible on-line by using personal on-line tools (mobile SNS, Google Meet, Zoom, etc), eClass or Webex. However, off-line activities may also be required depending on the content of the project to be solved. Considering the characteristics of the engineering economics curriculum, the project was designed and developed, so that it could be solved through on-line team co-operative learning. In the case of the fall semester of 2022, as the class was switched to face-to-face, PBL activities could also be conducted on-line or off-line as needed.

On-line (in 2021)/off-line (in 2022) PBL activities		On-line tools
Announcement and introduction of on-line and off-line PBL	↔	Webex/eClass
↓		
Organising projects for student autonomous teams (three or four students)	↔	Individual on-line tools like SNS /eClass
↓		
Assigning individual projects to student teams	↔	eClass
↓		
On-line problem-solving activities by student teams in 2021 On-line and off-line problem-solving activities by student teams in 2022 (data gathering and analysis, collaborative learning, team meetings, instructor Q&A, etc)	↔	Individual on-line tools like SNS /eClass
↓		
Step-by-step project report and meeting minutes upload to eClass Instructor evaluation and feedback	↔	eClass
↓		
Final presentation of student-team projects and instructor evaluation (including student peer evaluation on eClass)	↔	Webex (in 2021) and face-to-face (in 2022) (eClass)

Figure 1: On-line and off-line PBL procedure in the 2021 and 2022 fall semester.

On-line and Off-line PBL Problems and Evaluation

In order to design an open-ended project problem considering the purpose and educational effect of PBL, the problem was constructed by searching from an information source for solutions to the problem, so in reverse. In other words, since the final educational purpose of engineering economics is to support problem solving or decision making at various business sites, utilising various data of companies, such as current and new product development information, accounting data, organisational information, etc, is appropriate. Project problems, which were geared to analysing business feasibility were developed based on three real companies, such as Ortec Inc. and Daeyang Inc. both in Korea, and Given Image in Israel. Students performed team-based co-operative learning activities to solve project problems at each stage shown in Figure 2 by utilising the company's business information provided by the instructor, included in textbooks, company Web site and various Internet resources, etc.

The student project team was autonomously composed of three-four students considering the total number of students, with each team selecting a specific company and type, and each team member was assigned problems in each step through team discussion. The problem-solving process was carried out through individual learning activities of team members and co-operative learning process within the team, and when necessary, they interacted to obtain advice or assistance from the instructor using eClass. In 2021, 42 students formed 11 teams and in 2022, 39 students formed 10 teams. The problems to be solved in the project were structured problems, ill-structured problems and open-ended problems that could be solved by applying various methodologies learned in engineering economics. As shown Figure 2, the PBL process consists of a total of four steps, and up to step 3, the learner is expected to apply main methodologies of engineering economics to present problem solutions, and the last step (step 4) is combined to present solutions, including sensitivity analysis on the learner's own scenario.

Out of the 22% PBL evaluation weight, up to step 3, the project was evaluated by the instructor with a total weight of 13%. Each project team reported up to step 4 through meeting minutes summarising the discussion contents conducted within the team during the step-by-step problem-solving process. In particular, meeting minutes were found to be effective in suppressing *free-riding* within the team, improving teamwork and managing project schedules. The evaluation in step 4 accounted for the largest proportion that is for 9% of the 22% of the PBL evaluation. In particular, 7% of instructor and 2% of student peer evaluations were reflected. The weight of 2% of student peer evaluation seems relatively small, but it was very effective in attracting other students' participation despite the student presentation on-line. Specifically, students' on-line peer evaluation was conducted in eClass, many students added their reviews, and it is believed that the interest and participation in the PBL course has increased beyond the existing face-to-face presentation.

Step 1: Engineering Economics Project - Assignment #1

(The role of each team member is detailed in the team meeting minutes, and the team leader collects and submits the assignment in the form of a report (MS Word file). Uploaded to eClass by 11:59 on 4 October 2022.)

Investigate, analyse and organise the following in relation to the target case company and prepare a report (there is no limit on the report size, but it must be written with the participation of all team members):

1. A table of contents with the information specified below must be included first after the front cover.
2. General status of the target case company.
3. Example - company history, major domestic and international businesses, company assets, sales, employee status and trends, major related companies, etc.
4. Detailed status of products (or services) of target case companies.
5. Example - it is recommended to use various data, such as the Web site of the target company, portal data, such as Google and Naver, economic newspapers, etc, for sales, net profit, price trends, and product manufacturing costs, alternative products or services and related technology trends for the past three to five years.
6. Status of the industry or market structure to which the target case company belongs.
7. Example - market or industry scale (domestic or global total sales, etc), competitive structure (domestic and foreign major competitors and competitors' size and competitiveness, etc), target industry or company-related tax (corporate tax rate), regulations (depreciation method, etc), economic indicators (interest rate, etc).
8. In addition to the above topics, it is necessary to allow for variable adjustments, sensitivity analysis and decision support needed for the implementation of stage 4 of the project (it requires knowledge of the entire stage 4 project topic by the team in advance). Create tables, figures, etc, and edit them in a format that is easy for readers to understand.

Step 2: Engineering Economics Project - Assignment #2

(The role of each team member is detailed in the team meeting minutes, and the team leader collects and submits the assignment in the form of a report (MS Word file), uploaded to eClass by 11:59 on 25 October 2022.)

Distribute the following spreadsheet exercises arranged by chapter among team members, solve them using Excel, and then the project manager (PM) collects, edits and uploads them:

1. Chapter 4, p. 215 Spreadsheet exercises: 4-129, 4-130, 4-131, 4-132.
2. Chapter 5, p. 269 Spreadsheet exercises: 5-64, 5-65, 5-66, 5-67 (5-68).
3. Chapter 6, p. 348 Spreadsheet exercises: 6-68, 6-69, 6-70, 6-71.
4. Chapter 7, p. 411 Spreadsheet exercises: 7-57, 7-58, 7-59, 7-60.
5. Chapter 11, p. 549 Spreadsheet exercises: 11-24, 11-25, 11-26, 11-27 (11-28, 11-29).

(If the content of the lecture in Chapter 11 is not completed before 25 October, you do not have to submit Chapter 11. However, there is no deduction to your mark, even if you submit it including the results of the preliminary study!)

Step 3: Engineering Economics Project - Assignment #3

(The role of each team member is detailed in the team meeting minutes, and the team leader collects and submits the assignment in the form of a report (MS Word file). Uploaded to eClass by 11:59 on 15 November 2022.)

1. Discuss and identify among team members the project problem (project step 3) of the business economic analysis case assigned to each team (explore and share related data and information, if necessary).
2. Allocate tasks among team members based on the understanding of the industry, market and business of the company acquired through step 1 and step 2.
3. Each team member shares their analysis of the contents through a team meeting at least one week prior to the submission of assigned tasks, and makes corrections, if necessary.
4. Each team member sends the data to the PM at least three days prior to the submission of stage 3 report, the PM edits the report form and circulates the report to the team members.
5. If there is no problem after the circulation of all team members, the PM uploads the stage 3 project report to the corresponding session of the e-Class team project before the due date.

Attachment: Step 3 of the project - refer to the file related to the economic analysis of XX company.

Step 4: Engineering Economics Project - Assignment #4

(The role of each team member is detailed in the team meeting minutes, and the team leader collects the assignment and submits it as a presentation file (PPT). Uploaded to eClass by 11:59 on 29 November 2022.)

1. Step 4 reflects reality as much as possible by using data from step 1, presenting reasons for various changes or assumptions for different variables (referring to issues in attached files) applied to analysis in step 3, modifying the analysis and re-evaluating the economic analysis validity.

Recommendation 1: It is recommended to analyse by the scenario type. For example, it is advisable to change the related variables or parameters through a team meeting to analyse whether the market situation is optimistic, conservative or pessimistic or whether the manufacturing cost is high, medium or low. It is better to evaluate the impact of interest rates and tax rates through sensitivity analysis.

2. Table of presentation contents (examples and recommendations only, subject to revision if necessary):

- Business environment of XX company.
- Include the contents of step 1, such as the industry trend of the target business.
- Market environment and expected sales trend of XX company.
- Manufacturing cost trend of XX company.
- Economic analysis of XX company (including sensitivity analysis according to variable changes).
- Appropriate discount rate (or the minimum acceptable rate of return - MARR).
- The internal rate of return (IRR) in this project.
- Cash flow by year to calculate the business value of XX company using the discounted cash flow (DCF), business value (net present value - NPV), pay-back period, etc.
- Conclusion: XX company feasibility assessment.

3. Eight-minute presentation per team plus two-minute real-time on-line presentation during the Q&A class using data in PowerPoint (four-person team, including the team's proposal and conclusions, four people must take turns presenting).

4. Mutual peer evaluation between teams is scheduled (for this, each individual, excluding his or her own team, must evaluate the rest of the team in this class on a five-point scale. At this time, the evaluation basis can be presented. Ten percent of the overall project evaluation will be reflected in the future).

Recommendation 2: The point to refer to during peer evaluation is to place these changes in more realistic circumstances and give better scores to the team that analysed the changes through different variables.

Attachment: Step 4 of the project - refer to the *XX company economic analysis - variable adjustment and sensitivity analysis* related file.

Figure 2: Four-step project problems.

ON-LINE AND OFF-LINE PBL EFFECTS FROM STUDENTS' LECTURE EVALUATIONS

HUFS's lecture evaluation was based on a five-point Likert scale for a total of 20 questions in four types: three questions for student self-evaluation, 12 questions for curriculum and instructor evaluation, three questions for lecture-based evaluation and two questions for descriptive evaluation (see Table 2).

Table 2: Evaluation of the engineering economics course, including PBL by year.

	Related questions	2020 (35/37)	2021 (37/42)	2022 (37/39)
Conducive to student-led learning	A-a	3.94	4.41**	4.52***
	A-b	3.94	4.38**	4.37*
On-line PBL adequacy	B-a	3.92	4.35*	4.23
	B-b	3.97	4.41*	4.32
Learning effect and satisfaction	C-a	3.97	4.19	4.18
	C-b	3.74	4.22**	4.15*

Note: (number of respondents/number of students), p-value of paired t-test between different years as of 2020: * < 0.10; ** < 0.05; ***< 0.01

The response rate was very high at 92.4% over the past three years, as students had to take course evaluation to check their grades. Although there was no statistically significant difference in the average of the total scores of the 20 lecture evaluation questions in the total course evaluation scores by year, in 2020, when the on-line lectures were conducted, the lowest result was recorded (3.97), and in 2021, when the on-line PBL was introduced, the result was the highest (4.37), and in 2022, when the evaluation system was switched to off-line lectures with on-line/off-line PBL, the result was intermediary (4.29). The obtained figures are similar to the results of research on existing on-line courses. The effect is presented next by focusing on student evaluation of the PBL operation in 2021 and 2022.

Six out of 20 course evaluation items can be seen indirectly evaluating the effectiveness of PBL in 2021 and 2022 compared to 2020 without PBL. First of all, the results of two questions were compared and analysed to find out whether it was the student-led learning process that was the purpose and main effect of PBL. The items are: *I have actively participated in this course (A-a)* and *I have prepared sufficiently for this course before and after classes (A-b).* Also, two items were used to determine the appropriateness of PBL performance and evaluation, such as: *Pedagogical methods employed were appropriate for the course (B-a)* and *Appropriate evaluations for the course objectives and properties were undertaken (B-b).* Finally, to evaluate the learning effect and satisfaction of the PBL-applied course the following two questions were posed: *This course successfully enhanced my competency (C-a)* and *I am generally satisfied with this course (C-b).*

Table 2 shows the results of verifying the difference between the average score and the average score of PBL-related items by year based on 2021 and 2022 compared to 2020 without PBL. The difference between 2021, when on-line PBL was conducted and 2022, when on-line and off-line were mixed, was not statistically significant in all six questions. All evaluation scores in 2021, when on-line PBL was conducted, were high, except for one item on the student-led learning perspective. Compared to 2020, when PBL was not conducted, the 2021 and 2022 evaluation results similarly demonstrate that student-led learning (A-a, A-b) was very well achieved through PBL.

Although no statistical significance was found, the appropriateness of PBL application and evaluation was rated higher in later years than in 2020. In particular, students in the 2021 academic year, where all curricula including PBL were conducted on-line, recognised that the application of PBL in the engineering economics curriculum was an important learning and teaching method, and rated the PBL performance, as very appropriate (B-a, B-b), which accounted for 22% of the credit evaluation. In addition, in the case of 2022, in which face-to-face lectures were delivered, there was no statistical significance, but it was evaluated as appropriate. In 2022, a simple survey of engineering economics students was conducted (response rate 97.5%) through Google, and the results of PBL performance satisfaction were very encouraging.

First, 28.2% were very satisfied, 38.5% were satisfied, 25.6% were average, 7.7% were dissatisfied, 0% were very dissatisfied and 66.7% were more than satisfied. Further, student peer evaluation was introduced in the evaluation process in 2021 and 2022, although the weight reflected in grades was relatively low, but the fact that students directly participated in the evaluation seems to have been effective. Lastly, as a result of evaluating whether students' self-learning ability improved through classes using PBL, there was no statistical significance compared to 2020, but there was a slight improvement recorded (C-a). However, overall satisfaction with courses using PBL showed improvement with a statistically significant difference compared to 2020 (C-b).

As a result, it was also confirmed that the application of PBL, whose effects were emphasised in previous studies, is one of the best teaching and learning methods to encourage student-led co-operative learning, improve problem-solving skills and cultivate overall capabilities to solve real problems of companies.

CONCLUDING REMARKS

This study is a case analysis of engineering economics courses that applied the PBL process in an engineering college curriculum in 2021 and 2022 compared to an on-line course without PBL in 2020 under the Covid-19 restrictions. This study has several limitations. First, it seems to be somewhat unreasonable to apply the effect of on-line PBL of a single course to various on-line courses as it is. Second, even if the study was conducted with first-time students of the same grade in the same department, there is a limit to generalising the comparison results by year. In particular, it seems more appropriate to divide the analysis into a control group (PBL group) and a non-control group (non-PBL group) at the same time, however, this is left as a follow-up study. Lastly, due to the prolonged Covid-19 pandemic, there were several cases in which many students took a leave of absence during the study period compared to previous years, and the actual, remaining students are considered to have a greater enthusiasm for learning than students in other years, and the number of students is relatively small. Therefore, there is a limit to this study's application to general students.

Despite these limitations, the content and effects of this case are worth referring to in a situation where the possibility of further expansion of on-line and off-line mixed courses is likely to increase in the future.

Based on this case study and experience, the following is a summary of what can be helpful for the operation of PBL in various courses in the future.

First, it is necessary to organise a systematic and pre-recognised on-line or mixed PBL course. In this case, the four-step PBL process and various project problems have to be identified in advance and repeatedly investigated using on-line tools, such as eClass, Webex, etc, to help learners understand the need for PBL and to effectively improve their understanding of on-line PBL. It has been a great help in proceeding and managing the courses.

Second, it is necessary to develop a set of on-line PBL problems suitable for a collaborative learning process based on various, vast and realistic data and information. Students' dissatisfaction with PBL in a simple survey in 2022 was about 7.7%. The biggest cause of this dissatisfaction was the difficulty in collecting and using actual data, such as actual production investment and various internal expenses of the team's target company. Therefore, when developing project problems, it is necessary to make the most of realistic data and information, and to investigate ways to collect related data in advance and provide them to students.

Third, since the core goal of PBL is to develop problem-solving ability through collaborative learning under teamwork, instructors need to establish a system in which all team members can participate in the teamwork and collaborative learning process in the PBL course. In this case, periodic and repetitive meetings with minutes for fair assignment of project tasks to team members and systematisation of team learning activities were of great help. In addition, frequent on-line interactions between learners and instructors, such as prompt response to inquiries, detailed feedback on project reports by steps, confirmation of students' meeting minutes, etc, have contributed to students' interest in the course, their continuous participation in the PBL process and their improvement of problem-solving skills.

Last, it is necessary to involve students in the evaluation process to increase the degree of participation and concentration of the PBL process. Since most on-line lecture systems provide a student peer evaluation tool, it is expected that it can be utilised to increase student participation by making the most of it.

In the future, on-line or on- and off-line mixed lectures are expected to become a key educational method in engineering colleges with many experiments and practical work. On-line or mixed PBL is expected to be an effective teaching method in a situation, where on-line lectures are a clear challenge to not only learners, but also instructors in engineering colleges, where securing the ability to solve various problems in the industry is an important educational goal.

ACKNOWLEDGEMENTS

This research was supported by the Basic Science Research Programme through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (NRF-2017R1A2B4005858, 2020S1A5A2A03042307) and Hankuk University of Foreign Studies (HUFS) research fund of 2022.

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BIOGRAPHY

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