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Development and effect of a Web-based problem-based learning system for an accounting course in engineering education

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ABSTRACT: Various combinations of Web and PBL have increasingly been suggested. To improve students' practical problem-solving abilities and active knowledge construction, the author suggests a Web-based problem-based learning system (PBLS), develops it for an engineering accounting course, and examines its effects through students' evaluation scores on six dimensions based on students' evaluations of educational quality (SEEQ) that were collected before and after the use of the system. There were statistically significant effects of the system mainly on students' efficient knowledge construction and appreciation of practical learning experience. Also, the system developed was more effective in increasing the learning effects of students with more prior knowledge than a general PBL. However, the effects of interaction and self-learning were not significant. The PBLS made students become better problem solvers, because it helped students' knowledge acquisition and construction more than PBL, but it needs to be more effective to stimulate mutual interaction and self-learning.

INTRODUCTION

In any education community, it has become more and more important to increase students' practical problem-solving abilities [1]. A number of teaching strategies and methods have been suggested to reduce the incongruence between the real world and the classroom. Among those, one solution is problem-based learning (PBL), defined as learning that results from the process of working towards the understanding of the resolution of a problem, implying that it is a part of the shift from the teaching paradigm to the learning paradigm [2]. The focus is on what students are learning rather than on what the teacher is teaching. Operationally, given carefully designed, but loosely structured real-world problems, students collectively attempt to solve problems. Teachers stimulate students' initiative, provide guidance and information, encourage interactions and, thus, turn students into active learners [3]. Simply put, PBL is a way of preparing students to achieve active interaction, identify learning resources and seek solutions to real-world problems.

The effects of PBL have been examined from a variety of angles. Most significantly, a robust positive effect has been found with regard to both active knowledge acquisition and problem-solving ability, implying that students undertake active development of knowledge in response to real-world problems [4]. It is evident that PBL should increase a variety of problem-solving abilities including conceptual understanding, analytical thinking and knowledge resource identification [5][6]. Furthermore, several scholars argue that PBL is superior not only with respect to students' attitudes and abilities, but also to most measures of academic achievement [7]. In light of all these factors, PBL should be of great help to students in terms of attitude, ability and performance.

However, PBL has been challenged on two fronts. The first challenge comes from the increasing use of e-learning. Since the 1990s, the use of information technology has been revolutionising teaching, as well as the learning process [8]. As demonstrated by some earlier studies, Web-based learning increases students' interest and intrinsic motivation for learning and further facilitates intra- and intergroup collaboration [9][10]. Not surprisingly, many educational researchers and practitioners have regarded the Web as a potential tool for improving PBL [11]. Recent studies suggest several varieties of Web-assisted PBL, including on-line discussion support [12][13], on-line flexible educational resources [14], a Web-based PBL game [15] and blended PBL assisted by the Web [16]. A recent study even compares Web-assisted PBL with other methods in terms of achievement, knowledge acquisition and critical thinking skills [17-19]. However, an ideal combination of Web and PBL has not yet been found, which signifies there is much room for improvement.

Also worth noting is the fact that real-world problems have become more interdisciplinary in nature, thus, compelling students to acquire and use knowledge from a variety of disciplines [11]. Hence, with an increasing number of interdisciplinary courses being offered by institutions of higher learning, PBL is also required to provide students with a way of acquiring knowledge not only from courses, but also from a variety of sources [20]. The Web enables students to access vast knowledge resources and further participate in synchronous and asynchronous communication to overcome time and spatial constraints [21]. Considering these advantages, it could be expected that Web-based PBL will be an appropriate approach for interdisciplinary courses.

Considering these, a new Web-based problem-based learning system (PBLS) for interdisciplinary courses is suggested. The system has three distinctive features: 1) virtual environment; 2) collaborative group judgment; and 3) semi-automatic hint system. Virtual reality has been created in several previous studies, including automotive electrics mechanism [22], software engineering project [23] and electronic network [24]. These are governed by clear rules and principles and, thus, are predictable with few uncertainties. For instance, the electrical circuit design does not work, if it violates some basic principles. Taking a step further, a virtual environment has been created. Students take the optimised behaviour based on bounded knowledge, make mutual interactions with one another, create a business environment and, then, react to changes in the environment, as well as other students. This is an extended virtual reality, making both problems and solutions more real.

Also, the semi-automatic hint system provides automatic hints for simple mistakes and errors, and allows students to get optimised hints only when they are completely stuck in the problem-solving process. This mixed approach is expected to increase the efficiency of problem-solving, and is different from fully automatic or manual hint systems [25][26]. Finally, negative biases of face-to-face group judgment (such as the bandwagon effect) are reduced trough on-line discussion.

An engineering accounting course was exemplified to illustrate the application of the Web-based PBLS. A Web-based PBLS was developed and run for one semester in two groups including a control group. Students' course evaluations were measured through surveys and interviews, before and after, and its net effects were analysed using the paired *t*-test.

WEB-BASED PROBLEM-BASED LEARNING SYSTEM (PBLS)

Concept of Web-based PBLS

The concept structure of the PBLS is as shown in Figure 1. It has three components: lecturer, student and Web-based platform. The PBLS is designed to maximise interactions among the three components. In typical PBL, when students are given a problem, they find solutions through direct interactions with a lecturer. As noted in previous studies, direct interaction often frustrates students and lecturers [3]. Lecturers are often conflicted, because they tire of inefficient interactions. Similarly, students often lose confidence as a result of such interactions.

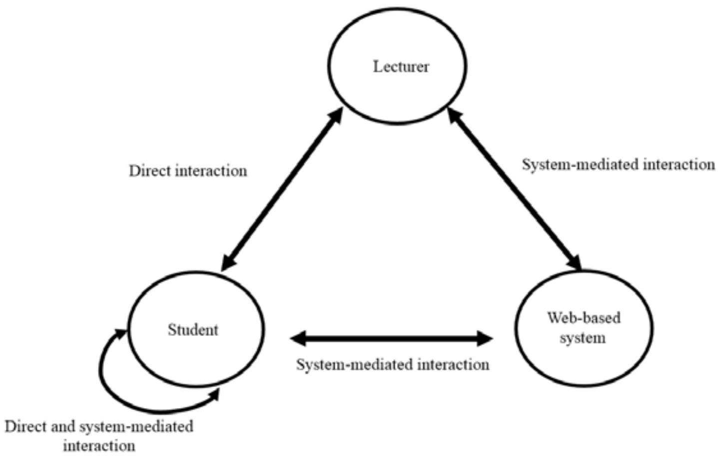

Figure 1: PBLS concept structure.

Thus, for more systematic and effective interaction, the Web-based system is made to play an intermediate role between lecturers and students. Needs, complaints, feedback and measures of student knowledge are automatically collected, selected and transferred to lecturers and other students. Lecturers apply several criteria to filter out useless information. Reviewing these, lecturers and students improve the system and share useful knowledge. Through iterative interactions, students gradually interact more efficiently and effectively not only with lecturers, but also with other students. Mediated by the Web-based platform, teachers and learners communicate in greater depth with one another. Direct interactions are allowed only in classroom lectures.

At first, lecturers let students keep key course objectives in mind. They, then, introduce the operation of the Web-based PBLS and guide students into the problem-solving process. Students build virtual companies on the system, face various accounting problems and solve those. Lecturers interact with students via the Web-based system, encouraging students to solve problems independently. Also, with due regard to the overall progress of each group, intra- and intergroup interactions are coordinated, while bottlenecks and system inconveniences are eliminated. Students form groups and build virtual companies on the system. Companies produce goods and services, make transactions and generate accounting problems. Team members collectively solve these problems. If necessary, several teams can collaborate and also obtain some knowledge from lecturers. Students also interact with lecturers and other teams through the Web-based system. When a team solves a problem, the results are organised logically and, then, presented to the other teams and lecturers. Then, the team receives questions and comments on every aspect of problem-solving including knowledge acquisition, logical thinking, methodology and others. The final component of the PBLS is the Web-based system. On a computer, lecturers and students go to the homepage, sign up and log into the system. Students run their companies, create and solve accounting problems, share information and make discussions. Lecturers monitor the progress of teams, make discussions, give some information to teams and manage the system. The Web-based system is a virtual space, where virtual companies create accounting problems, students solve those problems and various interactions are made.

Overall, the Web-based PBLS aims at maximising positive interactions among three components (lecturer, student and Web-based system). Brief descriptions of the key components, interactions and functions of the Web-based PBLS are given in Table 1.

Table 1. Description of the Web-based PBLS.

Component	Interaction component	Objective	Function
Lecturer	Student	Make students solve problems by themselves; maximise positive interactions; maximise student performance	Guidance; encouragement; monitoring; coordination; knowledge supply; discussion; evaluation
	Web-based system	Make the system efficient and effective	Problem design; system maintenance; system improvement
Student	Lecturer	Get appropriate help	Discussion; knowledge acquisition; system usage guidance; system usage feedback
	Student	Solve problems	Team organisation; role allocation; responsibility allocation; discussion; knowledge acquisition; knowledge sharing; knowledge construction; collective thinking; teamwork building
	Web-based system	Conduct efficient and effective interactions with others	System use; system improvement
Web-based system	Lecturer	Make lecturer manage and coordinate interactions	Knowledge collection; knowledge filtering; knowledge delivery; interaction mediation
	Student	Make students interact effectively and efficiently	Knowledge collection; knowledge delivery; interaction mediation

Development of Web-based PBLS

The system development proceeded through four phases: analysis, design, implementation and testing, in that order. A number of similar commercial applications were reviewed and analysed, but no programme with systematic open-ended problem creation or an interactive problem-solving process could be found. Thus, through the analysis of the needs of stakeholders, system objectives and key components were derived. Then, the overall architecture was designed and broken down into sub-functions including a market transaction algorithm, open-ended problem generation and an accounting operation process. With due regard to the interoperability among programs, the Web-based system was implemented using JAVA as the main language.

The Web-based system is composed of tutorials, and main and monitoring programmes. Students can use tutorials and the main programmes. Lecturers can use all programmes. Additionally, students can access system-usage help, a fundamental accounting term dictionary, a course evaluation criteria guide and a notice board. They can also ask questions, write answers and share knowledge through the user community board.

The main menu structure of the Web-based system is shown in Figure 2. Of importance is the fact that the monitoring programme is linked to other programmes and, thus, helps lecturers to monitor the progress of each team and to perform various tasks including evaluation, communication and system management. Using the evaluation programme, lecturers evaluate all outputs, such as knowledge acquisitions, problem-solving processes and accounting records. Lecturers communicate with students via interaction functions including messaging, open discussion boards and knowledge sharing. If the progress of any team is too slow, lecturers can encourage them to keep up with the overall pace. In the tutorial programme, a maximum of 25 virtual companies conduct transactions and generate simple, but practical accounting problems. The tutorial programme plays a role in preparing students to solve open-ended problems.

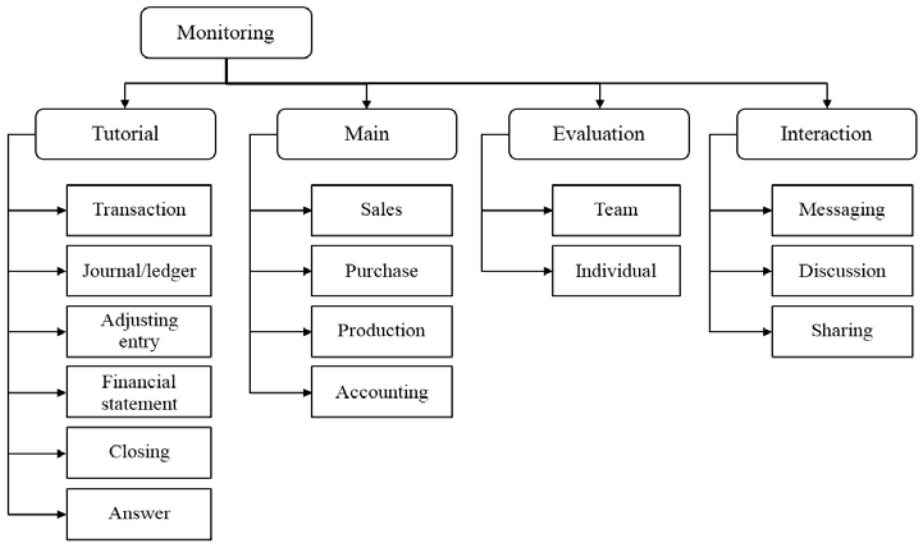

Figure 2: Main menu structure.

The main programme is an extended version of the tutorial programme, focusing mainly on open-ended problem-solving. Its menu structure is shown in Figure 3. Once a team creates its virtual company, it is registered with the system and, then, classified as either a manufacturing or a service company with the associated initial accounting specifications. All teams conduct transactions, record accounting information and convert the figures into a financial statement. A variety of corporate accounting problems occur, and these compel students to solve those problems for their companies. The main programme is a small virtual economy involving various pseudo/real economic activities and problems. Using this programme, students are able to not only perform simple accounting, but also advanced financial analysis to make transactions more favourable for their own companies. All this implies that the PBL open-ended problem-solving process is well-implemented in the system.

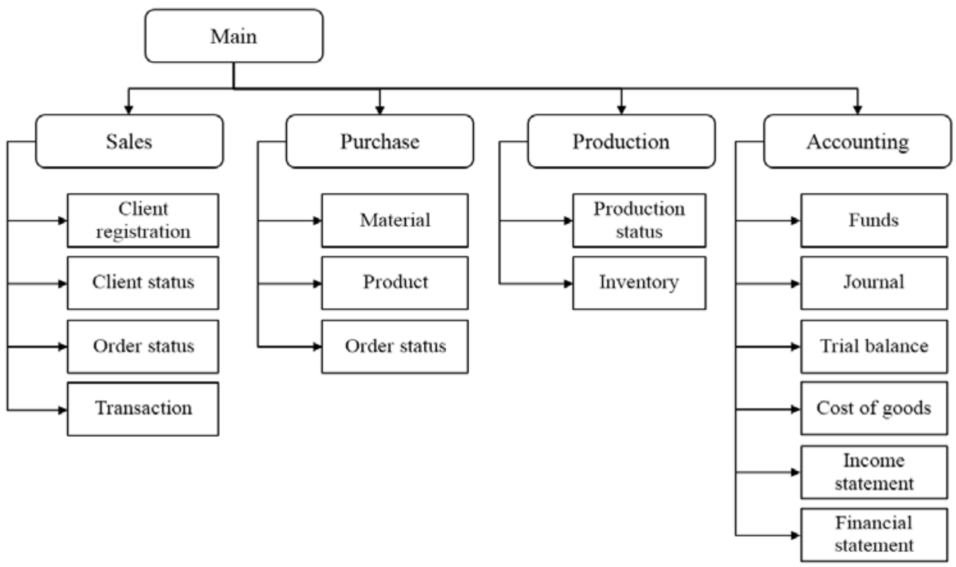

Figure 3: Menu structure of the main programme.

EFFECTS OF WEB-BASED PBLS

Methodology

Above all, it should be noted that the Web-based PBLS aims to satisfy students' need to be equipped with practical problem-solving abilities. Considering this, its effects should be measured by industry practitioners' satisfaction with graduates or students' satisfaction with courses rather than on the basis of academic achievement. Unfortunately, the first cannot be measured unless graduates of these courses get jobs. Thus, by focusing on students' evaluation, the effects of the system can be examined. As has been noted in previous studies, the use of the system to evaluate student satisfaction remains controversial and problematic, because there are numerous factors associated with the rating that are outside lecturer control [25]. However, recent studies argue that the process should be reliable if students and lecturers have similar views about what constitutes good teaching [26]. The system is based on students' needs and, thus, is best evaluated by students.

Teaching/learning effectiveness is by nature multifaceted, implying the multidimensionality of students' evaluations. Thus, it is important to choose appropriate dimensions that are to be carefully examined. Reviewing a number of previous studies and evaluation schemes, such as students' evaluations of educational quality (SEEQ), the author selected six dimensions comprising:

1) learning/value;
2) enthusiasm;
3) organisation;
4) group interaction;
5) breadth of coverage;
6) workload/difficulty [27].

The standard questionnaire has been modified with regard to characteristics of the Web-based PBLS and the engineering accounting course and was used to survey students before and after a lecture series.

Course Context and Data

A total of 58 senior undergraduate students (24 female and 34 male) enrolled in an engineering accounting course at Hankuk University of Foreign Studies (HUFS) in South Korea participated in this study. All participants received two weeks of instruction on both problem-solving projects and system usage. Then, for 14 weeks, they received lectures on fundamental concepts and theories for 50 minutes once a week and met in the Web-based PBLS for 100 minutes twice a week. During the lectures, students were provided with relevant knowledge about problem-solving and fundamental accounting knowledge. Based on these lessons, students freely conducted transactions in the PBLS system, while managing and recording accounting. When students failed to solve problems or gave wrong answers, lecturers encouraged them to recall the knowledge relevant to the problem, to identify the mistakes they made and to come up with possible new solutions. Although students received individual lectures, they were directed to work in groups to solve problems, requiring them to communicate with one another to acquire relevant knowledge. This is a simplified version of the problem-solving process outlined by Utterback and Abernathy [28]. The lecture proceeded in parallel with the problem-solving projects and, thus, students continually applied newly learned theories and methods to the accounting problem.

Table 2: Course information and learning outcome.

	Experimental group (Web-based PBLS)	Control group (PBL)
Organisation, course title, number of students	HUFS, engineering accounting, 58 (24 females and 34 males)	Sungkyunkwan University, engineering accounting, 50 (18 females and 32 males)
Contents	Introduction; financial statements; merchandising; managerial accounting; fraud, ethics and control; taxes, dividends and bonds; departmental accounting; budgeting; cash flow analysis	
Grading	8 PBL problems (80 pts); participation (20 pts)	
Learning outcome	Collect and organise appropriate accounting data; write and analyse financial statements in an appropriate way; identify appropriate managerial issues to analysing accounting data; use appropriate analytical tools to analyse accounting data; use clear communication to convey accounting information to others; apply appropriate principles to ethical issues	

To compare students' evaluations before and after the course, the author conducted two surveys. The first was conducted after the introduction and the second at the end of the semester. Based on the six dimensions previously mentioned, questions were formulated using a five-point Likert scale from: strongly agree - 1; agree - 2; undecided - 3; disagree - 4; and strongly disagree - 5. Additionally, to examine the influence of prior knowledge, the students were asked to list their previous relevant classes and to provide profile data including age, student identification number, and so on.

To measure the net effects of the Web-based PBLS against the PBL, the author included a control group composed of 50 senior undergraduate students (18 female and 32 male) enrolled in an engineering accounting course in Sungkyunkwan University in South Korea and had them complete the same pre- and post-tests. The general PBL was applied to this group, meaning that students freely communicated and interacted directly with other students, and also with a lecturer. The same educational contents and problems as were given to the test group were provided.

Results

First, as shown in Table 3, the author compared the before and after student evaluations of the Web-based PBLS using the paired-samples *t*-test. The decreasing incongruence between classroom lectures and practical accounting is notable.

The larger mean differences for *Learned something valuable* (0.86) and *Learned subject* (0.71) compared to those of the other sub-factors provide strong support. Note that the mean score of *Learned something valuable* in a classroom lecture over the last three years is 3.40, almost the same as the before-mean score (3.34) in Table 3, but 0.92 units greater than the after-mean score (2.48). Another thing to note is the effect on the clear lecture organisation with statistically significant mean difference (0.44), implying that Web-based problem-solving is useful for understanding objects, concepts and techniques in engineering accounting. This is also evidenced by the mean difference of *Practical details* (0.39). In the *Group interaction* category, improvement on knowledge sharing is mainly due to systematic interaction and quality management of knowledge. *Enthusiasm about learning* increases slightly.

Some weaknesses were also found in the proposed system. A Web-based PBLS cannot motivate students to perform extra self-learning. No statistical significance was found for relevant sub-factors including *Enthusiasm about self-learning*, *Course challenge* and *Subject interest*. Another problem comes from weak stimulation effects on the group interaction. Contrary to expectations, the system contributed little to increasing intra-student interactions or interactions between students and lecturers. As shown in a qualitative survey on complaints, it is evident that this lack of interaction is partly due to a poor user interface. Many students complained that the messaging or chatting functions of the system were not user-friendly. Finally, the workload, when using the proposed method, is much more likely to increase, including more time and effort to become accustomed to the system.

Table 3: Paired-*t*-test results of students' evaluation of the Web-based PBLS.

Evaluation dimension	Sub-factor	Before		After		Mean difference	Significance
		Mean	SD	Mean	SD		
Learning/ value	Course challenge	2.49	0.92	2.40	0.84	0.09	0.61
	Subject interest	2.22	0.80	2.20	0.68	0.02	0.88
	Learned something valuable	3.34	0.95	2.48	0.87	0.86	0.00***
	Learned subject	2.73	0.74	2.01	0.85	0.71	0.00***
Enthusiasm	Enthusiasm about learning	2.68	0.92	2.39	0.77	0.29	0.04**
	Enthusiasm about self-learning	2.63	1.03	2.42	0.86	0.21	0.23
Organisation of the course	Clear explanation	2.93	0.86	2.49	0.80	0.44	0.01**
	Clear system usage	3.15	0.80	2.56	0.82	0.59	0.00***
	Objectives stated and clear	2.39	0.71	2.18	0.67	0.21	0.11
Group interaction	Encouraged communication with lecturer	2.86	0.89	2.71	0.82	0.15	0.26
	Encouraged team discussion	2.39	0.80	2.61	0.86	-0.22	0.16
	Students shared knowledge	2.67	0.93	2.04	0.66	0.63	0.03**
Breadth of coverage	Breadth of concepts	2.37	0.76	2.55	0.81	-0.17	0.21
	Depth of concepts	2.73	0.84	2.52	0.77	0.21	0.19
	Practical details	2.87	0.92	2.48	0.68	0.39	0.09
Workload/ difficulty	Concept	2.26	0.69	2.76	0.86	-0.50	0.00***
	System usage	2.65	0.81	2.85	0.61	-0.20	0.04**
	Project workload	3.25	1.01	2.98	0.85	0.27	0.16
	Project difficulty	3.15	0.92	2.95	0.95	0.20	0.15

* *p*-value less than 0.10;** *p*-value < 0.05; *** *p*-value < 0.01

Looking into the results of the control group in Table 4, the difference between the Web-based PBLS and PBL is obvious. Above all, the Web-based PBLS increased the value of learning more than the PBL. The mean difference is that the *Learned something valuable* rating (0.31) was far less for the PBL than for the Web-based PBLS (0.86).

Also, PBL's effect on the increase of *Learned subject* was not significant compared to the significant mean difference of the Web-based PBLS (0.71). Notably, PBL decreased students' evaluation on *Practical details* by 0.15, but the Web-based PBL increased it by 0.39. In addition, the Web-based PBL recorded larger mean differences for *Clear explanation* and *Students shared learning* than did the PBL. In sum, the Web-based PBLS improves student learning of both the concept and the practical application of the subject compared to the PBL and, thus, increases the value of the learning.

However, in some respects, PBL is superior to the Web-based PBLS. Notably, the mean differences of the PBL for *Enthusiasm about self-learning* (0.18), *Encouraged communication with lecturer* (0.17) and *Encouraged team discussion* (0.27) are significant at 1%, while those of the Web-based PBL are not statistically significant, implying that the PBL is a better method for stimulating communication and self-learning.

Table 4: Paired-*t*-test results of students' evaluation in the control group.

Evaluation dimension	Sub-factor	Before		After		Mean difference	Significance
		Mean	SD	Mean	SD		
Learning/value	Course challenge	2.81	0.75	2.75	0.77	0.06	0.43
	Subject interest	2.61	0.73	2.63	0.79	-0.02	0.53
	Learned something valuable	3.45	0.88	3.14	0.62	0.31	0.04**
	Learned subject	3.32	0.91	3.26	0.85	0.06	0.25
Enthusiasm	Enthusiasm about learning	3.10	0.62	2.77	0.67	0.33	0.00***
	Enthusiasm about self-learning	2.93	0.76	2.75	0.76	0.18	0.03**
Organisation of the course	Clear explanation	2.90	0.68	2.91	0.60.	-0.01	0.23
	Objectives stated and clear	2.76	0.82	2.66	0.93	0.10	0.15
Group interaction	Encouraged communication with lecturer	3.32	0.98	3.15	0.80	0.17	0.00***
	Encouraged team discussion	3.25	0.77	2.98	0.73	0.27	0.01**
	Students shared knowledge	3.17	0.91	3.02	0.86	0.15	0.00***
Breadth of coverage	Breadth of concepts	3.05	0.81	3.03	0.82	0.02	0.33
	Depth of concepts	2.91	0.88	2.96	0.87	-0.05	0.16
	Practical details	2.87	0.92	3.02	0.68	-0.15	0.07
Workload/ difficulty	Concept	2.38	0.63	2.98	0.58	-0.60	0.00***
	Project workload	2.95	0.75	2.92	0.73	0.03	0.15
	Project difficulty	3.25	0.91	3.18	0.83	0.07	0.13

* *p*-value less than 0.10;** *p*-value < 0.05; *** *p*-value < 0.01

Some argue that the effects of PBL depend heavily on the prior knowledge of students. Also, it is known that the knowledge gap could hamper interactions. In this regard, students were classified into three groups. Students in the first group had previously taken both accounting and management courses, those in the second had taken accounting courses and those in the third had taken management courses. Six students did not take any relevant courses and, thus, were excluded.

Two assumptions regarding prior knowledge were made. First, students were assumed to have acquired the relevant knowledge of the courses taken. The second assumption is that there was no within-group difference of knowledge among students. The paired-samples *t*-test examined the effects of the system on students' evaluation and enabled the author to select some dimensions and sub-factors with statistically significant differences, as shown in Table 5.

Table 5: Selected paired-*t*-test results of students' evaluation with different prior knowledge (n=52).

Prior knowledge (Number)	Evaluation dimension	Sub-factor	Before	After	Mean difference	Significance
			Mean	Mean		
Accounting/ management (19 students)	Learning/value	Learned something valuable	3.52	2.20	1.32	0.00***
		Learned subject	2.72	2.10	0.62	0.00***
	Enthusiasm	Enthusiasm about learning	2.70	2.40	0.30	0.00***
	Organisation of the course	Clear explanation	3.13	2.47	0.66	0.02**
		Clear system usage	3.15	2.88	0.27	0.05*
	Group interaction	Encouraged communication with lecturer	2.92	2.53	0.39	0.08*
		Students shared knowledge	2.75	2.20	0.55	0.04**
	Breadth of coverage	Practical details	2.85	2.40	0.45	0.04**
Accounting (21 students)	Learning/value	Learned something valuable	3.20	2.61	0.59	0.00
		Learned subject	2.60	1.80	0.72	0.00***
	Enthusiasm	Enthusiasm about learning	3.05	2.45	0.60	0.00***
	Organisation of the course	Clear explanation	3.02	2.48	0.54	0.04**
		Clear system usage	3.05	2.50	0.55	0.00***
	Group interaction	Encouraged team discussion	2.60	2.40	0.20	0.08*
		Students shared knowledge	2.73	1.98	0.75	0.00***
	Workload/difficulty	Concept	2.35	2.68	-0.35	0.00***
Management (12 students)	Learning/value	Learned something valuable	2.98	2.70	0.22	0.08*
		Learned subject	2.81	2.26	0.55	0.00***
	Group interaction	Students shared knowledge	2.74	2.52	0.22	0.09*
	Workload/difficulty	Concept	2.25	2.83	-0.58	0.00***

* *p*-value less than 0.10; ** *p*-value < 0.05; *** *p*-value < 0.01

With prior knowledge of accounting and management, the first group was characterised by the largest mean differences for *Learned something valuable* (1.32), *Clear explanation* (0.66), *Encouraged communication with lecturer* (0.39), and *Practical details* (0.45). Based on these figures, it is evident that this group ought to appreciate more greatly the value of the system in terms of practical problem-solving compared to the other students, signifying the importance of prior knowledge. This supposition was supported by their comments in individual interviews such as …*With Web-based PBLS, I feel that I become a better problem solver of accounting problems.* Another thing to note is the lopsided effect of interaction. Through the system, these students found that interaction with lecturers was more valuable than the lectures themselves, but that interaction with other students was of little use due to the knowledge gap.

Students in the second group were less appreciative of practical problem-solving activities than were members of the first group, showing smaller mean differences in *Learned something valuable* (0.59) and statistical insignificance in *Practical details* than the first group. However, they were more engaged in knowledge sharing and intra- and intergroup interaction-based learning, as was supported by relatively large mean differences for *Enthusiasm about learning* (0.60), *Encouraged team discussion* (0.20), and *Students shared knowledge* (0.75). The third group with only prior management knowledge showed weak effects of the system in all dimensions.

Table 6 shows the results of the control group. Overall, PBL increased students' evaluation over four common sub-factors, as shown below, but its effects were smaller than those of the Web-based PBLS. Notably, in the first group, the mean difference of the PBL in *Learned something valuable* (0.23) was far smaller than that of the Web-based PBLS (1.32), showing the obvious effects of the proposed system on students with more prior knowledge. The Web-based PBLS also more often stimulated interactions with the lecturer and with other students than did PBL, although it was not effective in creating more enthusiasm.

The learning effects of the Web-based PBLS were weak in the second group, but the group interaction effects still remained strong, as shown in the mean difference in the *Students shared knowledge* (0.75) between the Web-based PBLS and that (0.24) of the PBL. In the third group, the PBL was better than the Web-based PBLS.

Overall, the Web-based PBLS was shown to be effective in increasing learning and group interaction effects for students with more prior knowledge, but was not very effective for students lacking accounting knowledge. The students with only management knowledge struggled to understand the basic accounting concepts more than the other students and, thus, experienced difficulty in using the Web-based PBLS.

Table 6: Selected paired-*t*-test results of students' evaluation with different prior knowledge in the control group (n = 50).

Prior knowledge (Number)	Evaluation dimension	Sub-factor	Before	After	Mean difference	Significance
			Mean	Mean		
Accounting/ Management (20 students)	Learning/ value	Learned something valuable	3.42	3.19	0.23	0.00***
	Enthusiasm	Enthusiasm about learning	3.18	2.91	0.27	0.01***
	Group interaction	Encouraged communication with lecturer	3.42	3.18	0.24	0.00***
		Students shared knowledge	3.20	3.12	0.08	0.04**
Accounting (13 students)	Learning/ value	Learned something valuable	3.46	3.10	0.36	0.00***
	Enthusiasm	Enthusiasm about learning	3.11	2.71	0.40	0.00***
	Group interaction	Encouraged communication with lecturer	3.26	3.15	0.11	0.04**
		Students shared knowledge	3.14	2.90	0.24	0.01***
Management (11 students)	Learning/ value	Learned something valuable	3.41	3.03	0.38	0.00***
	Enthusiasm	Enthusiasm about learning	3.03	2.67	0.38	0.00***
	Group interaction	Encouraged communication with lecturer	3.25	3.14	0.11	0.02**
		Students shared knowledge	3.13	2.90	0.23	0.01***

* *p*-value less than 0.10; ** *p*-value < 0.05; *** *p*-value < 0.01

DISCUSSION AND CONCLUSION

A new learning/teaching model named Web-based PBLS was suggested to take advantage of Web-based learning and PBL with systematic coordination. Its aim is to improve students' practical problem-solving abilities and active knowledge construction composed of knowledge acquisition and sharing through the effective use of various knowledge sources and systematic interaction. The Web-based PBLS was applied to one group, and the general PBL was used in the control group. Using student course evaluations conducted before and after the lecture series, the author examined the effects of the system.

Obviously, students feel that they should become better problem solvers when using the Web-based PBLS than with the general PBL. Based on the interview responses, this is mainly due to efficient knowledge construction under more realistic virtual environment. Given the badly structured real problem in the early problem-solving process, there was little difference between the Web-based PBLS and general PBL. However, as time progressed, the Web-based PBLS encouraged students to acquire and construct valuable knowledge, while decreasing ineffective behaviours, and this caused students to appreciate their practical learning experience.

Having a virtual environment characterised by unexpected movements of competitors, bounded information and strategic interactions also motivates students to be engaged more in the problem-solving process. Automatically collected data about students' problem-solving processes and results enables lecturers to identify the sources of inefficiency and to communicate information about those inefficiencies to students. Using this information, students can continually improve their methods of problem-solving. Such a learning effect becomes clearer in a group of students with more relevant knowledge of accounting and management than is the case in other less learned groups.

Another advantage comes from the synergy effects between theoretical concepts and practical problem-solving. The parallel operation of the Web-based PBLS and lectures was mutually reinforcing in terms of concept clarification. Also, students appreciated the timely hints not only from lecturers, but from team members. The semi-automatic hint system increases efficiency of problem-solving, but does not make students dependent on hints. The provision of optimised hints to the capability of students is a successful strategy in the problem-solving process. The above-mentioned continual monitoring and improvement system seems to contribute a great deal to a positive evaluation.

However, the effects on interaction are relatively weak and vary with the level of prior knowledge. A group with greater knowledge appreciates interactions with lecturers and increases those interactions, but finds little value in intergroup interactions with other students. In contrast, other groups with less knowledge value interaction and knowledge sharing among students are also somewhat motivated by those interactions. Notably, the on-line centred discussion system reduces negative biases including the bandwagon effect and lopsided judgment in groups with less knowledge more than in groups with greater knowledge. Students with ample knowledge cannot share knowledge enough on the on-line system.

Considering the *pros* and *cons* of the approach described here, the system should be of great help in increasing the learning effects of students with more prior knowledge and can, thus, equip students with practical problem-solving abilities. However, the Web-based PBLS has several limitations and weaknesses, and there is much room for further study. Above all, the inter- and intra-team interaction effects are weak and should be complemented by other methods for stimulating and structuring on-line and offline interactions.

Another challenge comes from the disappointing results on students' self-learning. Students did not think that the subject was challenging and, thus, were not motivated to engage in extra self-learning. A method for stimulating students to engage in self-learning should be developed and included in a Web-based PBLS with challenging, but interesting problems. Finally, the differential effects on interactions according to the level of prior knowledge should be taken into consideration in terms of redesigning the system and, thus, to maximise positive interactions among students, lecturers and the system.

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