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Teaching Requirement Engineering Using Industrial-Infused Project-Based Learning

Adisak Intana
College of Computing
Prince of Songkla University, Phuket Campus
Phuket, Thailand
adisak.i@phuket.psu.ac.th

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***Abstract*—This paper reports the result of an exploratory study conducted to assess (1) the achievement of learning outcomes (LOs) and (2) the perceived effectiveness of students' learning from Industrial-Infused Project-Based Learning (II-PrBL). The experiment and evaluation were made on the Software Engineering (SE) students in second year who enrolled in the 977-271 Requirement Engineering and System Modeling (RESM) course, semester 1/2019. The result shows that the students were able to think, analyse, integrate and apply the knowledge and skills achieved from the lecture to the real practice in problem-solving based on the industrial case study. They were able to achieve the necessary LOs for the RE course in both specific (hard) and generic (soft) skills. Furthermore, this II-PrBL resulted in the high perceived effectiveness of students' learning and the strong level of satisfactory teaching.**

Keywords*—*Industrial-Infused Project-Based Learning, II-PrBL, Case-Based Learning, Industrial Problem-Based Learning

I. INTRODUCTION

Requirement Engineering (RE) is one of the most important stages in SE that results in the successful software development [1]. It is the first stage of the development process in which enables software engineers to really gain better understanding of users' needs, be able to extract and analyse, define and validate requirements in order to create the software specification [2]. The main goal of RE is the high quality of Software Requirement Specification (SRS) document [3] which is used in the next stage of software development. However, based on several SE research and practices [4], [5] one of the main causes of software failures is from the software specification created from the requirement activities. The root cause of this is a lack of appropriate skills and knowledge for managing RE activities. Therefore, RE in the 21st Century requires not only the scientific knowledge and skills to analyse the problem and find the solution to solve the problem [6], but also the skill and ability of brainstorming, critical and logical thinking, analysing the complex problem in detail with multiple point-of view and finding the best suitable solution [7].

Traditional teaching RE courses use the lecture-based instruction approach where the instructor delivers a verbal lecture using a projector, visualiser and the written word in the university classroom [8]. The learning outcomes from this teaching approach are promoted via the use of practice questions and exercises. In the current RE teaching, the active learning approaches have been integrated with the traditional approach. As a result of this, students gain much more interest in learning and it allows them to achieve greater skills especially discussion, teamwork, brainstorming, critical and logical thinking skills [1]. In recent years, project-based learning (PrBL) has been integrated into the active learning activity which engages the student, gaining a deeper knowledge and skills by the active exploration of real-world challenges and problems. However, most case studies used in the project are not the real but simulated [4]. Therefore, teaching and learning RE in the 21st century education needs industrial project-based learning based on the realistic case study.

This study aims at implementing Industry-Infused Project-Based Learning (II-PrBL) approach into RE course. We conducted the experiment and evaluation of this implementation in the 977-271 RESM course offered in semester 1/2019 for the second year SE student, Prince of Songkla University, Phuket Campus. To accomplish this, we replaced the simulated case study used in the term project in the previous semester (1/2018) with the real case study, Hospital OS system, from Open Source Technology Co., Ltd. company. The contribution of this paper is the exploration and evaluation of the effectiveness of II-PrBL in teaching and learning RE by assessing students' LOs and the course achievement. This also compares with the achievement of PrBL based on the simulated case study conducted in semester 1/2018.

II. RELATED WORK

Recently, the integration of Industrial Problem-Based Learning (i-PBL) with Project-Based Learning (PrBL) has been introduced in engineering education programs [9–11] as it creates a constructive learning environment in which students develop knowledge and skills of sustainable design to solve engineering problems. For example, [9] applied this integration approach to the undergraduate final year industrial projects in mechanical engineering at Universiti Teknologi Mara Malaysia. In [11], an i-PBL framework was implemented for the improvement of software design and development skills through the collaboration with the industrial company. This framework was conducted with the first year students of Information Technology program, in Mae Fah Luang University, Thailand. Unlike our study, we contribute II-PrBL and assess students' learning outcome and course achievement in another SE field that is RE. The II-PrBL concept was locally

developed by Elkhart County's Business-Education to bring the industry sectors to the classroom [12].

III. Exploratory Research Study

This section presents the elements used to implement and evaluate the effectiveness of II-PrBL in teaching and learning RE.

A. Research Questions

Three research questions are formulated to address the goal of this study.

RQ1: "Does II-PrBL increase the degree of student learning outcome achievements in the RESM course?"

RQ2: "Does II-PrBL increase the degree of course achievements in the RESM course?"

RQ3: "What is the satisfaction level of II-PrBL from the students in the RESM course?"

B. Learning Outcomes

Learning outcomes of the RESM course, both Specific LOs (SLOs) and Generic LOs (GLOs) are derived from the standard of RE defined as ISO/IEC/IEEE 29148 [3] as follows:

(SLO1) Collect and formulate requirements, (SLO2) Analyse and model requirements, (SLO3) Document requirement specification, (SLO4) Validate requirements, (SLO5) Manage requirement change, (SLO6) Apply requirement methodologies, techniques, and tools and (*SLO7) Transform requirement specification to implementation*; *(GLO1) Manage team and (GLO2) Develop the communication and presentation skills*

C. Subjects

The subjects were 58 second year undergraduate students in major SE enrolled the 977-271 RESM course as a compulsory course in semester 1/2019.

D. Assessment and evaluation tools

Three assessment and evaluation tools are used to explore and evaluate the effectiveness of II-PrBL.

(1) SRS Checklist Form for assessing the SRS document. It consists of a checklist corresponding to the SRS characteristic identified in IEEE Standard and Rubric for marking guidance [3].

(2) Learning Outcomes Questionnaire Form

(3) II-PrBL Evaluation Form as students' satisfactory with II-PrBL

IV. II-PrBL Execution and Data Collection

Fig.1 shows an overview of our study for observation and evaluating the effectiveness of II-PrBL in teaching and learning RE. This overview is divided into three steps.

Step 1: Term project preparation: the before-semester meeting was set up between the lecturer and industrial facilitator to choose the case study for the term project and its corresponding learning outcomes with the assessment checklist and rubric criteria.

Step 2: II-PrBL execution: at the beginning of the class, the lecturer introduced the course outline especially addressing teaching, learning and

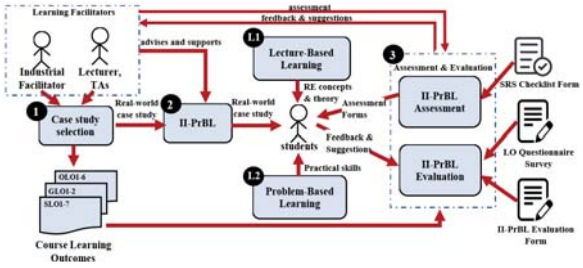

Fig.1. Overview of the study of observing and evaluating the effectiveness of II-PrBL in teaching and learning RE

assessment methods of II-PrBL. Before II-PrBL activity started, lecturers delivered the RE concepts through verbal lecture-based learning. Students also were prepared for II-PrBL activity with group discussion via practical problem-based learning activity (*L1-L2*). The lecturer and teaching assistants changed the role to be learning facilitators to facilitate the guideline and advice to students. Students worked as a group consisting of 5-6 members on the real project from the company. During doing the term project, the progress presentation was set up by learning facilitators. In each progress activity, the feedback and suggestions were delivered to students for improving their term project work.

Step 3: II-PrBL assessment and evaluation: at the end of the II-PrBL activity, the final work product of term project was presented to learning facilitators. The final feedback and suggestions were given directly to students after they finished presentation for final product revision. This term project was marked as 25% by both company and university facilitators. Finally, the questionnaire and evaluation form were sent to students to assess their achieved LOs and evaluate II-PrBL activity.

V. Result and Evaluation

The analysis result related to the research questions are described with important contribution.

A. RQ1: Does II-PrBL increase the degree of student learning outcome achievements in the RESM course?

The analysis result of learning outcome questionnaire is shown in Fig.2. In semester 1/2019, the most learning outcomes from II-PrBL achieved by students is *"SLO3: Document requirement specification"* together with *"SLO1: Collect and formulate requirements"* that is the second most common of achieved LOs. By comparing the achieved learning outcomes in semester between 1/2018 (using the simulated project) and 1/2019 (using the real industrial project), the use of industrial case study leads significantly to an increase in the high level of achievement in specific learning outcome *SLO1*. In semester 1/2019, students also achieved *"SLO6: Apply requirement methodologies, techniques, and tools"* which did not appear in the achievement in semester 1/2018. We have discovered from our class observation that the complex problem in the real project case study also motivated students to find the suitable requirement methodologies, techniques, and tool for implementing the solution.

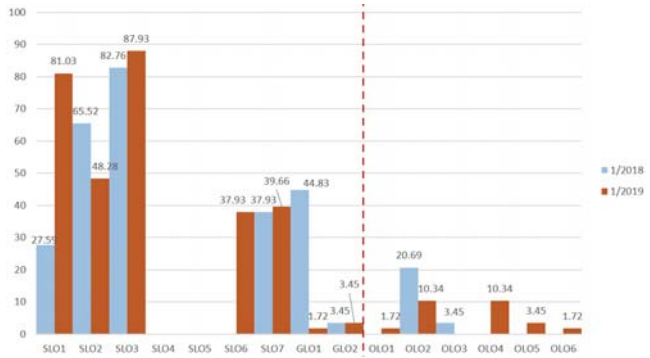

Fig.2. Comparison of achieved learning outcomes in between semester 1/2018 and 1/2019

However, the achievement level of learning outcome *"GLO1: Manage team"* decreases dramatically from semester 1/2018 to 1/2019. This is because students focused on finding the solution for the real project instead of team collaboration and management. We have planned to improve this by adding a team building and management activity for the term project in the next semester. Some students in both semesters gave the opinion that they achieved *"GLO2: Develop the communication and presentation skills"*. None of students in both semesters did not mention "*SLO4: Validate requirements"* and *"SLO5: Manage requirement changes*. This is because these learning outcomes are for the later steps of RE after SRS documentation which students did not reach in their term project. We measured these learning outcomes from the examinatio instead.

Moreover, students in both semesters discovered the other learning outcomes including *"OLO2: Develop systematic thinking skill"*, *"OLO1: Manage the software project"*, *"OLO3: Manage time"*, *"OLO4: Understand and explain the system workflow"* and *"OLO6: Develop personal skills"* e.g. *"develop circumspect, self-discipline and detailed oriented skill"* that are necessary skills for SE career paths, especially in documentation. Finally, students in semester 1/2019 specified that they achieved *"Apply the knowledge to the real case study (OLO5)"* that did not mention in the previous semester.

B. RQ2: Does II-PrBL increase the degree of course achievements in the RESM course?

Teaching and learning method in II-PrBL enabled students to achieve a good grade. As in Table I, the majority of students (89.66%) in semester 1/2019 achieved the grade above level *C(Fair)* and no students achieved grade below level *Poor(D+)*. Furthermore, the students in 1/2019 had proficiency in the practical skill instead of theoretical knowledge as the exam marks of students in this semester is lower than that of 1/2018. This resulted in the number of students achieving grades A and B+ in 1/2019 is slightly less than those in 1/2018. This also affects students to gain better understanding of and be able to focus the problems on users' requirements very quickly. This leads to an increase in the term project mark (25%) to raise significantly as in Table II. There is no difference in the mean of this mark for both semesters. However, the values of the mark in 1/2019 is less spread out than that in 1/2018. This means that the value of the mark in 1/2018 is further from the mean (higher deviation) comparing that in 1/2019. The minimum of the term project mark in 1/2019 is much higher than that of in the previous semester using the simulated case study. Based on the statistic information, we conclude that the use of real industrial project consequently results in the high degree of learning achievements in this course.

TABLE I. CLASS ACHIEVEMENT IN 1/2018 AND 1/2019

Grade	1/2018			1/2019		
	Criteria	Number	Percentage	Criteria	Number	Percentage
A	80-100	2	5	80-100	2	3.45
B+	74-79	7	17.5	74-79	6	10.34
B	67-73	10	25	67-73	13	22.41
C+	60-66	8	20	60-66	13	**22.41**
C	53-59	5	12.5	53-59	18	**31.03**
D+	46-52	4	10	47-52	6	**10.34**
D	40-45	2	5	40-46	0	**0**
E	0-39	1	2.5	0-39	0	**0**
W	-	1	2.5		0	**0**
Total		40			58	

TABLE II. ACHIEVED MARKS OF TERM PROEJCT

Semester	Number	Average	S.D.	Max	Min
1/2018	40	20.17	2.34	23.58	14.74
1/2019	58	21.28	1.29	23.46	18.99

TABLE III. SATISFACTORY QUESTIONS

Question	Type
1. Achieved knowledge and experiences	
Q1.1 The objectives of this activity are clearly specified in the course outline	Likert scale (Mandatory)
Q1.2 This activity follows the course contents.	Likert scale (Mandatory)
Q1.3 After this activity finishes, it helps students to gain better understanding in the relevant course contents	Likert scale (Mandatory)
Q1.4 The activity enables students to achieve more experiences from feedback and advices from facilitators	Likert scale (Mandatory)
Q1.5 The activity enables students to achieve the knowledge and experiences in addition to textbooks and classroom.	Likert scale (Mandatory)
2. Achieved advantages	
Q2.1 Students can adopt the achieved knowledge and experiences from this activity to the industrial work after graduation.	Likert scale (Mandatory)
3. Importance	
Q3.1 Departments should cooperate the learning activities in the university with the industry/companies	Likert scale (Mandatory)
Q3.2 Industrial-Infused Project Based Learning is very important for students in the future	Likert scale (Mandatory)
4. Suggestions	
Q4.1 Comments and Suggestions for activity improvement	Open-ended question

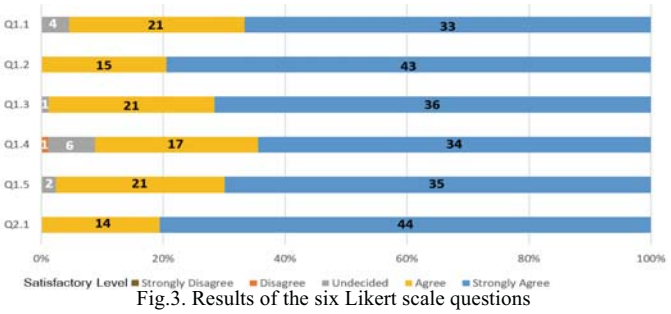

Fig.3. Results of the six Likert scale questions

C. RQ3: What is the satisfaction level of II-PrBL from the students in RESM course?

Table III shows the questions used in a satisfactory evaluation form and the analysis result as in Fig. 3. Most students agreed that II-PrBL enabled them to gain more knowledge and experiences to them (with average of Q1.1-1.5, 62.41% of them strongly agree). Furthermore, all students agreed (75.96% of them strongly agree, Q2.1) that they can adopt the achieved knowledge and experiences from II-PrBL to the industrial work after graduWation. Considering the analysis result of the relationship between II-PrBL (Q3.1) and importance for future

application (Q3.2) illustrated as three dimensions of the bubble graph (Fig.4), approximately 87.94% of students agreed that they will be able to apply the knowledge and experiences gained from II-PrBL in their future. Only 12.06% felt possibly about this issue. Furthermore, students also gave the feedback in the questionnaire (Q4.1). Most complained that *"the term project required much time"*. As the facilitator from the company offered to arrange the activity in overtime or at the weekend, some students suggested that *"Working with the company is a good activity giving us a lot of experiences but should not arrange the activity in overtime"*.

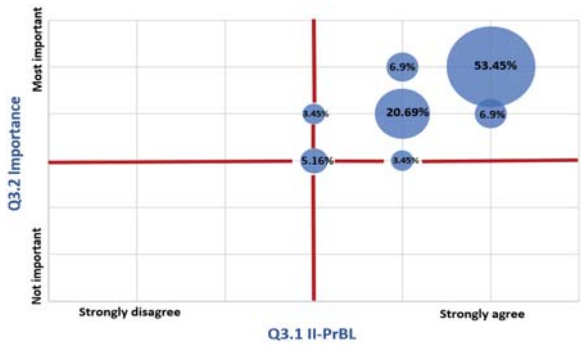

Fig.4. Relationship between II-PrBL and importance for future application

However, we have found that II-PrBL provides the students with an important skill necessary for this course, in that the student can capture and visualise the complex problem. This consequently leads them to develop fully learning and experiences as the comment of *"I felt so tired, but I have gained a lot of experiences in requirement engineering. Also, using the real case study from the company I can capture and visualise the problem of the case study very clearly."* In addition, most of students suggested that they still want this kind of activity in other future courses such as *"It was such a good activity"*, *"It was a fun activity and motived me to learn more"* and *"I would like the teacher to arrange this activity again in the future"*. We will use all feedback and suggestions from the students to improve the future teaching and learning activity. Overall, students were mostly satisfied in II-PrBL.

VI. Discussion and Lessons Learned

From the study results, we have discovered that II-PrBL motivates the student in the RE class to gain better and deeper understanding of the complex problem. This is because students can capture and visualise the problem very clearly instead of imagination. Furthermore, similar to [1], using real case study from the company engages a lot of students' interest. For example, as we observed in the II-PrBL activity, after students knew that they are going to work with the real case study that the company will use their proposed solution in the future, they were motivated and intended to accomplish the term project to commit the goal. These challenges and motivation cause students to be able to apply the achievement of thinking and analysis skills to solve specific problem efficiently and effectively. Therefore, II-PrBL consequently results in the high achievement level of LOs in RE. for both specific and generic LOs. Moreover, surprisingly, students have discovered the other useful LOs by themselves during doing II-PrBL activity. These LOs are systematic thinking, software project management, time management, logical thinking and personal skills (e.g. self-discipline and detailed oriented).

However, during observation, we found that in the beginning of II-PBL activity, students focused on finding what is the correct answer for this specific complex problem rather than searching for a suitable way to solve the problem. After the progress activity, learning facilitators explained and suggested that the student to find the suitable way leading to the discovery of the best solution instead of looking directly for the right answer. For the teaching improvement in the future, this will be explained to students at the beginning of activity.

VII. Conclusion and Future Work

The main objective of this study is to explore and evaluate the effectiveness of II-PrBL in teaching and learning RE. The results have shown that students in the RESM course have developed the necessary LOs for RE and gained the high achievement of their study. They are able to analyse, apply and integrate the achieved knowledge and skills to solve the problem in the real industrial case study. Furthermore, the satisfaction of II-PrBL activities is considerably high. We expect the results of this study can be used as a guideline in other courses of the SE curriculum.

Refeernces

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