Design and Implementation of a Learning Platform for a Computer Science Capstone Course based on Project-based Learning and Creative Thinking

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1   INTRODUCTION

The undergraduate/postgraduate programs at the Department of Computer Science and Information Engineering at the National Chung Cheng University have undergone accreditation by the Institute of Engineering Education Taiwan (IEET), an official member of the Washington Accord since 2008. In the accreditation of undergraduate engineering education programs, Capstone course has already become an important and required criterion [1],[2]. A Capstone project is an important curriculum to fulfil the accreditation criteria. A Capstone course is a one-year long-term project that is used to assess a student's proficiency in the acquisition of culminating academic knowledge and skills, and the readiness for future career. In the past, Capstone courses faced

several criticisms, in particular the quality of execution [3]. Students usually formed a group, sought for an advisor, discussed with the advisor the project topic, and then developed a software or hardware system. When Capstone projects become a formality, the department does not provide a clear guideline on how to execute a well-designed project and teaching strategies to inspire students' creativity. In addition, advisors usually do not make much effort on guiding students to follow software engineering processes or the Project Based Learning (PBL) pedagogy [4]. As a consequence, the quality of a Capstone project could be superficial with low educational values. To improve the quality of Capstone projects, we conducted a reform process that emphasizes on improving the execution quality of Capstone projects based on PBL, while leveraging on the novel design of instructional strategies that promote students' creative thinking. A research team with professors from multiple disciplines was formed to collaborate on this process. The reform process consists of four components, including a PBL platform, a group of experimental Capstone projects, instructional design and creativity assessment method, and learning profile analysis. In this work, we present the design and implementation of the learning platform for Capstone projects based on PBL.

In recent years, many colleges have developed courses using web-based PBL strategy [5], but very few of them tried to combine PBL with creative thinking learning. On the other hand, several courses have been reported to use the creative thinking strategy for course design [6], but they are not based on PBL. This study implemented a learning platform based on PBL and creative thinking for Capstone courses in engineering college.

2   LITERATURE REVIEW

As aforementioned, the reform process consists of PBL platform, Capstone projects, creative thinking, and learning profile analysis. Thus literature analysis on PBL, Capstone course, and creative thinking is described as follows.

2.1 Project-based learning

Project-based learning (PBL) is a model that organizes learning around projects and an opportunity for students over an extended period of relatively autonomous work; and finally the development of real products or demos [7]. The projects can be complex tasks on the issue or challenging issues, involving students of design, problem solving, decision making, or investigative activities [8],[9]. Project-based learning activities help students to have a self-monitoring, to clarify the topic, establish goals, planning tasks, information searching and organization, cooperation and sharing, progress control, completing the works, showing works. Teachers can take advantage of this teaching model to encourage students to engage in case studies, and to assist school-based curriculum development.

Project Learning makes students learn through self-discovery of issues related to everyday life, to find target questions, and then engage in investigative activities, and to seek answers to target questions together with teachers, peers, and experts. For students from Computer Science (CS) department, PBL drives them to come up with real products, which is a very unique feature achieved by applying PBL in a Capstone course in the CS department. It is active learning, so more able to maintain motivation effectively [10].

Therefore, the implementation of project-based learning must be comply with the following.

(1) Compliance with the principles of integrated curriculum interdisciplinary: Learning activities are not limited to the boundaries of a single discipline, but rather constitute

cross-disciplinary knowledge of an application and construction to solve real problems or issues.

(2) Stresses the authenticity of the teaching activity: Learning cannot be out of context, the learner must be involved in real situations, through a series of activities, exploration, and problem solving so as to gradually reach the planned goal.

(3) Cooperative Learning: The cooperative learning model can be used to further promote the inter-exchange of knowledge and skills among peers.

(4) Use technology as cognitive tools: The use of technology helps to stimulate students' motivation to learn and to help students explore and present investigation findings.

2.2 Creative thinking

Creative thinking is a process to create new solving methods for problems and surpassing learned principles [11]. It can be used on a conceptual level or applied to solve real technical problems. According to Young [12], creativity "is the skill of bringing about something new and valuable." Furthermore, "Creative people diverge from familiar patterns, but then they converge on new solutions." Over the past decade, creative thinking has been greatly promoted and integrated into curriculum design in Taiwan, from K-12 to higher education. In the literature, many creativity tools have been designed to help learners come up with new ideas, develop new inspiring and surprising thoughts, force learners to think in an arbitrarily different way or break through fixed ways of thinking. However, many research studies also pointed out that the creativity process or session should consist of both divergent phase and convergent phase. Thus, the creativity process usually consists of problem formation, divergent phase, clustering or categorizing phase, and convergent phase. While open-minded is required in creative thinking, the coordinator (instructor) shall utilize creativity tools carefully such that the four stages of the creativity process is conducted step-by-step.

Many creativity tools have been proposed, e.g., brainstorming, creative writing and storytelling, SCAMPER, six thinking hats, checkerboarding, morphological synthesis, metaphorical thinking, TRIZ, etc. In the first year, as a starter, we supported two commonly used creativity tools on the learning platform. Learners can have brainstorming with their advisor via a video conference or on-line text chat. Or the instructor can add an activity module, named SCAMPER, into the course design such that learners can use the SCAMPER tool to create new ideas in their projects.

SCAMPER is an acronym for seven thinking techniques that help those who use them come up with untypical solutions to problems. It was first proposed by Alex Osborne in 1953, and then further developed by Bob Eberle and noted in his 1971 book, SCAMPER: Games for Imagination Development. The seven thinking techniques are briefly described as follows:

S Substitute

Remove some part of the accepted situation, thing, or concept and replace it with something else.

C Combine

Join, affiliate, or force together two or more elements of your subject matter and consider ways that such a combination might move you toward a solution.

A Adapt

Change some part of your problem so that it works where it did not before.

M Modify (also Magnify or Minify)

Consider many of the attribute of the thing you are working on and change them, arbitrarily, if necessary. Attributes include: size, shape, other dimensions, texture, colour, attitude, position, history, and so on.

P Purpose (Put to other use)

Modify the intention of the subject. Think about why it exists, what it is used for, what it is supposed to do. Challenge all of these assumptions and suggest new and unusual purposes.

E Eliminate (also Elaborate)

Arbitrarily remove any or all elements of your subject, simplify and reduce to core functionality. In case of elaborate, add more details to your subject.

R Reverse (or Rearrange)

Change the direction or orientation. Turn it upside-down, inside-out, or make it go backwards, against the direction it was intended to go or be used. In case of rearrange, modify the order of operations or any other hierarchy involved.

Traditionally, SCAMPER is exercised in a face-to-face class or discussion session. When the SCAMPER is available on the learning platform, it has the advantage that instructor and learners need not to be in the same place, face-to-face, instead they can have synchronous discussion over the Internet via on-line chat or video conferencing. More importantly, as they go through the SCAMPER steps, all statements in the course of the discussion can be stored on the learning platform, thus making the discussion and summarization (convergent phase) easier. All of the portfolio stored on the learning platform could be helpful for the later run of discussion.

2.3 Capstone course

Capstone courses are very important for engineering education and should be well embedded into the curriculum of undergraduate colleges of engineering. The term capstone is widely used to describe a vertex process or provide students the opportunity to apply the knowledge and experience acquired in their undergraduate degree programs, relates to the ability to integrate and graduate employability [13]. The Capstone courses are often the last step for college education to add value to students' learning and the last year of college experience should include four functions [14]: (1) Integration: college students study for a set of independent courses, as a consequence, content maybe too be specialized and fragmented. Capstone course provides opportunities for students to learn how to integrate acquired knowledge such that learning in the university is not just to accumulate credits, but knowledge of individual courses can be assembled into a meaningful whole learning experience. (2) Closure: Capstone course usually uses cumulative learning and draws upon the whole of the learning experience in the university [15]. It is usually designed for students to take during their last year learning in the university. (3) Reflection: By Capstone course, students reflect on what they learned and what the deficiencies are. (4) Transition: through output of finished products, it allows the specific learning outcomes to help students experience and smooth transition after graduating from university career, and prepare for the future.

3   THE EMPIRICAL STUDY

3.1 Course setting

The Capstone course under study is a one-year, targeting senior college students from computer science department. Most of the students take this course from the second semester of their third-year study to the first semester of their fourth-year study.

3.2 Participants

There were 82 students registered for the Capstone course. Every student enrolled in the Capstone course was required to design one project by team work with three to six members. At the end of the course, all groups were requested to present their work, which were evaluated by two external expert reviewers.

Among the 82 students, 30 of them joined the experiment group. They were divided into 6 groups. PBL platform and creative thinking strategy were introduced to them.

For the control group students, their advisors supervise their Capstone project via face-to-face project meetings.

3.3 Design and Implement the Learning Platform

Taking the point of view on information technology, the use of innovative technology to construct a learning platform is rather easy to reach the target, but from the theoretical point of view for education, whether the learning platform can play its role to improve the teaching quality and learning effect or fulfil the pedagogical design is a great ordeal. Issues and challenges on how to improve teaching quality and facilitate effective learning are faced by the learning platform. Therefore, in the design of our learning platform, self-regulated learning process is introduced such that learners are aware of specific tasks to be performed. The platform allows learners to form groups, set their learning goals, objectives of their projects, and schedules of their tasks using grant chart or Work Breakdown Structure (WBS). In such a way, learners are aware of their progress and tasks to be finished. On the other hand, the project advisors can define the stages of a project and documents required for each stage, monitor the status of each group, and perform formative and summative evaluations on the platform. With the platform, a group of learners are able to define the goal of their project which is required to be a real problem with innovative solution, plan the software life cycle of their project, implement and present their project, revise their work based on the evaluation results of external experts as well as peer reviews, and finally turn in their final report. During the one year of project based learning, learners can use tools to share documents, discuss ideas, collaboratively edit documents, solve technical problems, spark creative ideas, fulfil the implementation of the project according to the requirement of software engineering procedure, practice conclusion and reflection of their project at the end of the course. The platform also serves as a scaffolding tool where the stages of PBL are built as scaffold and project advisors help learners explore the breadth and depth of the background knowledge of the project, provide creative thinking strategies to help learners find creative solutions, and provide software engineering tools to improve the software quality of the project implemented by learners.

Specifically, the design goals of the learning platform include (1) to provide precise step-by-step guidelines with a scheduler for advisors and students to follow: by implementing the PIPER five stages; (2) to keep students learning profile: by providing document repository for project team members; (3) to provide tools for collaboration among team members: by developing network resource modules, video conferencing, e-mail service, version control system, etc; (4) to provide teaching strategies and

assessment method for creativity: by implementing the SCAMPER creative thinking module.

Our learning platform is built based on Moodle. To provide precise step-by-step guidelines for PBL, we designed the learning process on the platform based on the PIPER model [5]. Specifically, the Capstone project activities on the platform were designed to consist of five stages: Preparation (P), Implementation (I), Presentation (P), Evaluation (E), and Revision (R). The detailed task, workflow, the required support from the learning platform of PIPER is showed in Figure 1.

Our platform and course design is based on PIPER, except that creative thinking and software engineering technique are embedded in the first two stages, for example, use of SCAMPER tool for creative thinking in the preparation stage and exercise software development methodology in the implementation stage.
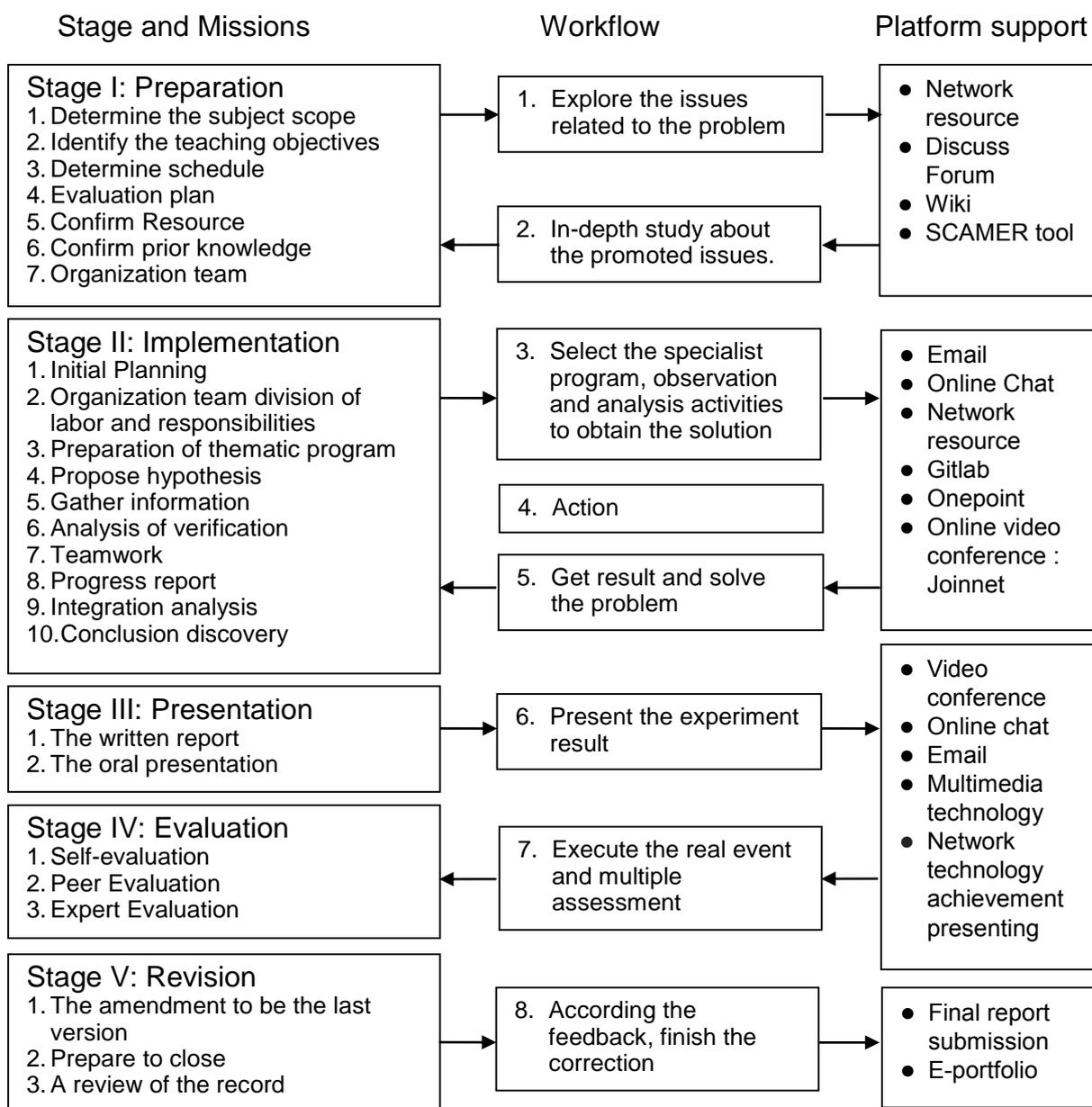
Stage and Missions	Workflow	Platform support
Stage I: Preparation 1. Determine the subject scope 2. Identify the teaching objectives 3. Determine schedule 4. Evaluation plan 5. Confirm Resource 6. Confirm prior knowledge 7. Organization team	1. Explore the issues related to the problem 2. In-depth study about the promoted issues.	• Network resource • Discuss Forum • Wiki • SCAMER tool
Stage II: Implementation 1. Initial Planning 2. Organization team division of labor and responsibilities 3. Preparation of thematic program 4. Propose hypothesis 5. Gather information 6. Analysis of verification 7. Teamwork 8. Progress report 9. Integration analysis 10. Conclusion discovery	3. Select the specialist program, observation and analysis activities to obtain the solution 4. Action 5. Get result and solve the problem	• Email • Online Chat • Network resource • Gitlab • Onepoint • Online video conference : Joinnet
Stage III: Presentation 1. The written report 2. The oral presentation	6. Present the experiment result	• Video conference • Online chat • Email • Multimedia technology • Network technology achievement presenting
Stage IV: Evaluation 1. Self-evaluation 2. Peer Evaluation 3. Expert Evaluation	7. Execute the real event and multiple assessment	
Stage V: Revision 1. The amendment to be the last version 2. Prepare to close 3. A review of the record	8. According the feedback, finish the correction	• Final report submission • E-portfolio

Fig. 1. The modified network project-based learning model PIPER.

The preparation stage consists of seven sub-stages, namely, determine the scope of the project, determine the project objectives, plan the project schedule, finalize the title of the project, secure needed resources, equip with prior knowledge, and organize a team. Activities used to exercise these sub-stages include discussion board, wiki editor, resource sharing (repository folder), etc. Furthermore, in this stage, inspiring students' creativity is very important. Therefore, the platform provides some tools to facilitate advisors to guide students to explore their creativity, e.g., SCAMPER and six thinking hats. The Capstone course learning platform homepage was shown in Figure 2, and Figure 3 showed the implemented SCAMPER creative thinking strategy step-by-step carry out page.

The Implementation stage, each team needs to design and implement its Capstone project. Thus, we modified the implementation procedure of PIPER in order to train students to conduct their projects according to the software life cycle model. In this stage, each team needs to exercise project management and software engineering procedure to make sure their finial system meets the deadline and has good quality control. New tools were developed as plug-ins of Moodle or standalone systems to support project management, software version control, and student collaboration, such as OnePoint, gitlab, and Joinnet.

In the presentation stage, each team needs to turn in a written report (include design, development, test cases, user manual, etc.) and make a public presentation. An exhibition of the results of Capstone projects was held to the public. At the same time, to evaluate the proficiency and creativity of each project, two experts from Computer Science field, three experts from creativity assessment field were invited to evaluate the technology readiness and creativity, respectively. During the evaluation stage, the platform also provides an activity for peer assessment within a group as well as cross groups. Finally, in the revision stage, the platform provides activities for each team to turn in its revised final report based the comments from evaluators and advisors. Each team also needs to turn in a review report in which each team addresses the problems they faced, what have been solved, and what needs to be further improved in the future.

Fig. 2. PBL learning platform   *Fig. 3.* The SCAMPER activity module.

4   RESULTS AND DISCUSS

We did a satisfaction survey of participating students, the survey results show that satisfaction of using the platform to understand the steps of PBL, support of cooperative learning, usefulness of document management, practice the life-cycle of software engineering process, and the effectiveness of Capstone project learning are all higher than 80%. The cronbach's alpha value was 0.942, so the internal consistency was excellent. Students provided feedback by answering a questionnaire after the course ended. Due to our intention to keep the questionnaire short we selected six questions.

With 30 joined course students, we finally collected 26 answered questionnaires (87%). Survey questions and responses are provided in Table 1. From Table 1, we do observe one potential problem, that is, the satisfaction of using the platform as the collaboration and communication tool among team members has the lowest score among all survey questions. After reviewing with students, one common answer to why the platform is not very helpful for collaboration and communication is because sometimes face-to-face meeting is more convenient and effective. Team members can easily get together to have face-to-face discussion after class while it needs some arrangements to set up an on-line meeting.

Table 1. Students' feedback to questionnaire survey

Survey Questions	Applies completely	Applies a lot	Applies partly	Applies a little	Does not apply at all
Platform helps you to understand the steps of Project-based Learning	37%	26%	33%	4%	0%
Platform helps you in step-by-step implementation of the thematic	44%	19%	30%	7%	0%
Platform can increase cooperation and communication among team members	33%	19%	37%	7%	4%
Platform helps you to develop a project via software engineering process	37%	33%	22%	4%	4%
Platform helps you organize thematic files	37%	30%	30%	0%	4%
Platform helps you during the Capstone course	33%	33%	26%	4%	4%

Furthermore, students were divided into high and low creativity-level groups by using the Torrance Tests of creativity thinking (TTCT) score with Taiwan normal standards. Table 2 showed the Capstone project scores between experiment and control group for the low-creativity-level students. Together with the exercise of creative teaching strategies to inspire students' creative thinking, it was observed that most students, who obtained lower score in the TTCT score were able to obtain higher score in the creativity assessment of their final projects than the control group students. This result indicates that introducing the creative thinking teaching strategy helps students who obtained low scores in the Torrance creativity assessment improve their creativity in their final projects.

Table 2. t-test of Capstone Project scores evaluated by internal expert for low-creativity-level students

Group	N	Average score	SD	t
Experiment	28	88.82	1.99	2.26*
Control	52	86.74	2.92	

*$p<0.05$

5   CONCLUSIONS

In this study, PBL and creative thinking strategy were simultaneously applied to help engineering college students develop their practical skills of deploying project in a Capstone course. Results showed that the subjects held positive opinions towards the two teaching strategies. The practical and cooperative learning helped students' knowledge construction, and problem solving skills, and made the course more active and lively. The research finding also showed that creative thinking teaching could enhance low-creativity level students' creativity in conducting projects.

Our future work will focus on training teachers and students to handle PBL and creative thinking process efficiently on the platform and deploy and promote the platform to other courses in engineer education.

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