Active Learning through combination of project-based learning with problem-based learning in Engineering Education*

Ziwei Chen
Electronic Engineering College
Chengdu University of Information Technology
Chengdu, China
czw@cuit.edu.cn

***Abstract*— This paper takes embedded system teaching as an example, firstly introduces critical issues in engineering education in China. Then active learning through combination of project-based learning with problem-based learning is adopted according to the characteristics of course and different types of teaching, i.e., problem-based learning to theory and basic concept, and project-based learning to experiment and curriculum design. The practice shows that integration of project-oriented problem-based learning approach in teaching and learning environment can enhance students' learning initiative and abilities of active learning, innovation, communication and teamwork. The obtained results are a starting point to other authors willing to use active learning methodologies within the framework of engineering degrees.**

Keywords—active learning; pedagogical methods; embedded system; problem-based learning; project-based learning

I. Introduction

Active learning is a form of learning models based on competences wherein students are asked to learn in an active manner by assessing them on how much they evolve in terms of competences. With the development of constructivism and the popularization of Humanism pedagogical theory, active learning shows more and more important theoretical and practical value, which has been favored by the world education reformers. It has become one of the most important and the most influential methods in engineering education.

Engineering education contains rich exploration soil. It often presents some unmet human needs as the starting point, adopts this engineering problem to motivate students to apply knowledge they have learnt, and then carries out conception and design engineering projects in various constraint conditions. Broad exploration space in engineering education is determined by the particularity of engineering activities [1]. Engineering activities are always embedded in the specific natural, social and cultural environment, and project decision-making, planning, design and implementation must consider the impact of constraining factors. With the progress of engineering project, there will emerge some unexpected events, which will impact on the intended project goal. In the field of engineering, the number of work areas will be very extensive and somewhat not much predictable. Engineers are able to work in lots of different designs and projects, management issues, operations, development, sales, etc. For this reason, it will be essential to identify the competences necessary for the forthcoming broad and changing employment context. In this scenario, a change in teaching methods will be necessary; new methods of work must not be based on teaching (focusing on the lecturer) but in learning (student-centered). The final aim will be learning to learn, as essential step for continuous learning (lifelong learning).

POPBL approach, namely combination of project-based learning (PrjBL for short) with problem-based learning (PrbBL for short), is an instructional methodology that organizes teaching & learning (T&L) activities around projects. The POPBL approach is basically adopted from PrbBL pedagogy model [2, 3]. Thus, the POPBL concept is derived from the PBL's basis that comprises three perspectives: problems, project, and team-work components [4].

The Incorporation of POPBL in T&L activities would allow students to apply knowledge in learning how to solve "real world" problems [5] through teamwork project regardless of one-way lecturing for instructors to complete the syllabus in time [4,6,7]. The adopted POPBL active learning environment not only exposes students to technical skills relevant to the solving real cases issues; but at the same time should also develop non-technical skills such as: cooperation and effective communication, critical and creative thinking, as well as efficient management and planning for the project [6,8,9].

The rest of the paper is structured as follows. Section II describes briefly critical issues in engineering education in China. A case study of ES (Embedded System) course in Chengdu University of Information Technology (hereinafter called "CUIT") is analyzed in Section III to illustrate the POPBL implementation. Section IV presents the students' acceptance on the POPBL implementation, and final section presents the conclusions and future work lines.

II. Critical Issues in Engineering Education

So far, teaching method widely used in China is still the traditional educational paradigm. This traditional approach based on the one-way transmission of large quantities of

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knowledge (e.g. lecturing, or "chalk and talk") is still useful because it allows fast transmission of information from an emitter (the lecturer or teacher) to multiple receivers (students) and because student can benefit from the teacher's experience. However, it is a method with serious drawbacks [10]: the students remember little of what they learn; the knowledge acquired is reduced to facts and data, but there is no reflection or criticism; and the relationships with other facts or circumstances are completely absent. All the students receive the same information, and learn in the same way and at the same rhythm; there is little room for innovation. Further, traditional approach tends to emphasize text-book problems, made up to illustrate theory in the particular discipline. Students are therefore accustomed to getting neat right-and-wrong answers in the back of the book or from teachers. Therefore, this type of teaching has suffered a slow but unstoppable process of alienation from the real needs of industry and society.

Single problem solving classes and practical sessions aim to overcome these shortcomings but often they just are not enough. To prepare for engineering practice, students must also encounter the world of "real" problems, which usually cross discipline boundaries, are complex, ill-defined and contain tensions and contextual factors. Creating solutions to real problems thus requires making interpretations, estimations and approximations. By carrying projects all the way through to actually implementing and testing solutions, students are made more comfortable in translating between models and physical reality, in understanding the implications of assumptions and estimations, and becoming accustomed to standing with one foot in the analysis and the other foot in the workshop [11]. As this relationship is what engineering is fundamentally based on, this practice is a necessary component of engineering education.

Pedagogical method we proposed, which project-based learning combined with problem-based learning, is an effective strategy in our teaching practice view. It supports students in developing their attitude to knowledge by exposure to open-ended problems.

III. POPBL Methodology and Pilot Study

A. Embedded System Course in CUIT

The targeted student group was composed of thirty-four students from electronic and information engineering specialty in CUIT. The students studied embedded system in the fall semester of third academic year as a compulsory course. The delivery of the embedded system topics was achieved in sixteen 90-minute lectures, another 16 hours to arrange five experiments. Students finished curriculum design entirely in extracurricular time. The course had following assessment methods: class attendance, 15%; lab performance, 25%; homework / discussion questions, 30%; curriculum design and related documents (including public presentation and defense), 30%.

B. Problem-Based Learning to Theory and Basic Concept

Pedagogical approach of problem-based learning was exploited when course instructor taught theory and some basic concepts. In order to master key knowledge for students, teachers raised mainly some problems, e.g., the concept of embedded system, the practical problem about processing button jitter, etc., with respect to our pilot course before students might give themselves a hard time over combining fundamental theory and basic concept with actual system or project.

Some specific problems were specified by the course instructor. Instructor arranged students to inquiry these problems in advance, then students discussed with each other, worked in teams over a period of time to develop solutions to these problems in spare time, designed the experiment schemes and verified them after students actively learn and autonomously explore. At last, students presented results that they acquired, exchanged learning experience and the method how to solve the problems in the following class.

C. Project-Based Learning to Practical Training

Through problem-driven teaching, students only acquire knowledge needed to be mastered, but can not reach the extent that knowledge acquired is effectively applied to the practice. So some practical training will need to be provided for students. As has been mentioned, practical training that we provided, which contained experiment and curriculum design, was PrjBL oriented. The aim was that students did not simply memorize what was explained in lecture classes. Instead, they should acquire the skill required by program outcomes, e.g., time and resource management, teamwork, communication, etc., which would be demanded by companies in their new workers.

Each experiment was organized as a small PrjBL activity such as chronometer controlled by matrix keyboard, thermometer with temperature record, etc., as can be seen from Table I. Each of this small PrjBL activity was related to more than two of the topics of the course. In this way, students had the opportunity to put into practice what was explained in lecture classes, improving their skill of applying their new acquired knowledge to real problems, rather than simply memorizing it.

TABLE I. Proposed Mini-Project for Each Experiment Session

	Laboratory Project Tasks	***Related Topics***
1	Creation of different visual effects by means of four LEDs (changes from one effect to another are forced by pressing the button)	Lecture 2,4,6
2	Digital Frequencymeter (range: 10-20000Hz)	Lecture 3,5,7
3	Chronometer controlled by means of matrix keyboard and with a LCD display	Lecture 1,4,7
4	Data-logger of the information sent by the PC (serial communication)	Lecture 3,5,7
5	Temperature measurement (sensor controlled by I2C) and storage of the results in an external memory. The stored data will be sent to a PC when demanded (serial communication)	Lecture 1,3,5,7, 8

Students can analyze, reflect and experience in the process of experiment, but not enough to have a thorough engineering concept, so it required a curriculum design project, for instance, MP3 player, simply digital photo album, remote-control toy car, electronic keyboard, PID thermostat, signal acquisition and display system, long distance control system, etc. Project management, such as time management, version management, design specification, and so on, should be incorporated in curriculum project design. We arranged a number of project topics at the beginning of the curriculum teaching in terms of the students' experiences, knowledge, level and interests. In order to promote the acquisition of certain skills such as teamwork and task management, students were freedom combined into a number of working groups about three to four individual.

But students that just started the project could not possibly take everything into consideration, especially some of the details, and it would let the students produce a sense of frustration, and lose interest in learning if students got prematurely into the details of the design [12]. Therefore, experimental scenarios should let students focus on innovative design in the project design rather than too much on the details of hardware. We offered a series of function modules, and students need only combine organically those modules according to project requirement, and apply them in the premise of understanding of function module. In addition, experiment was designed as one module of project, as well as curriculum design projects were increased in difficulty on the basis of experiment.

When a working group had finished one of the proposed projects, its members explained their solution to lecturers, justifying the design decisions they made. Also, they had to answer the questions asked by lecturers, who acted as contractors of the working group. Besides, a report had to be handed over by every student. In this practical report they had to explain their solution and answer to a questionnaire with practical and theoretical questions related to the corresponding topic (but not necessarily to the project proposed for that topic). In this way, students need to study what had been explained in lectures in order to do the practical report. Hence, not only the mentioned skills were promoted, but also plagiarism was prevented or, at least, was easily detected and the appropriate measures can be taken [13].

IV. DATA ANALYSIS AND DISCUSSION

To further clarify the effect of teaching reform and evaluate pedagogical method we proposed, the course's exit-survey with Likert-scales: 1 (min) to 5 (max) points was introduced. We made a survey in 34 students who attended ES course. These students were required to complete a short questionnaire about the proposed method, which were listed below [14].

1. Overall, active learning through POPBL methodology was better than the traditional method;

2. The POPBL teaching method allowed me to become more involved in the learning process and enhanced my learning initiative;

3. The use of POPBL teaching method in embedded system course encouraged me to attend lectures;

4. Problem-based learning helped me in understanding the theoretical contents of the course;

5. Complementing every topic with a practical training helped me in understanding what is explained in lecture classes;

6. The POPBL teaching method allowed me to practice certain non-technical skills such as collaborative work, public presentation, etc.

7. The use of POPBL teaching method in embedded system course improved my ability to learn actively the material;

8. I wish the professors in my other classes would use POPBL teaching method;

To answer the questions a scale from 1 to 5 was given where 5 equals "strongly agree" (SA), 4 equals "agree" (A), 3 equals "indifferent" (I), 2 equals "disagree" (D) and 1 equals "strongly disagree" (SD).

The assessments were done anonymously and the survey results obtained for each question were shown in Table II and Fig. 1. The quantities in bold represent the preferred choices.

TABLE II. SURVEY RESULT

# QUESTION	SA	A	I	D	SD
1	**56%**	44%	0%	0%	0%
2	38%	**44%**	12%	6%	0%
3	35%	**50%**	3%	9%	3%
4	21%	**53%**	6%	15%	5%
5	24%	**59%**	3%	11%	3%
6	15%	**44%**	18%	15%	8%
7	18%	**53%**	20%	9%	0%
8	29%	**44%**	24%	3%	0%

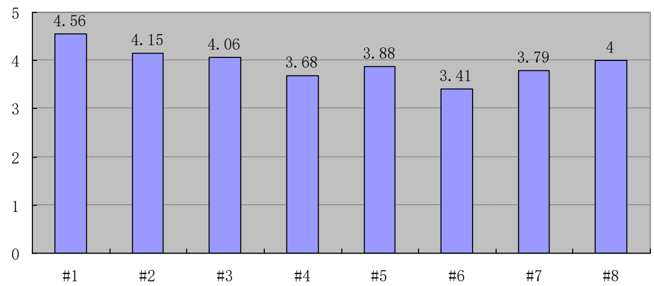

Fig. 1. The average of values for each question

The learners' responses/feedbacks gathered from the survey were positive and promising. In terms of their overall assessment from question 1, 100% of the students stated that the POPBL method had helped them to learn the contents as well or better than a traditional method; nobody declared that the implementation of the contents in a traditional way would have been better that the POPBL method. They also considered that this method resulted in knowledge that was more deeply seated than the traditional method.

In overall, most of the learners agreed that the POPBL teaching implementation in the taught courses improved their non-technical (communication, leader/peers with team working and planning) and their technical skills to creatively solve the real-world problems of the given application systems for the case study projects according to the result of question 6.

Through the input of students from question 3, 4, 5 and 8, majority believed that the POPBL teaching method had not only helped them understand the course materials, but also liked the frequency of the use, and believed it encouraged participation.

The result of question 2 and 7 showed that students' learning initiative and abilities of active learning were also covered by the proposed methodology.

V. CONCLUSIONS

Active Learning through POPBL methodology is one of T & L pedagogy model that incorporates the project-orientation and team-working settings to solve replicated real-world case study problems with aims to develop learners' soft skills and technical skills through "learn by doing", which is in common with the education philosophy constructivism advocated [15-16].

Our pedagogical practice, namely integrating the combination of project-based learning with problem-based learning into embedded system teaching in the framework of active Learning, shows that POPBL methodology can enhance students' learning initiative and abilities of active learning, innovation, communication and teamwork, and promote students' engineering quality. It can be used as effective carrier for engineering education reform, and provides references for solving some existed problems in engineering education, which was of great practical significance.

In future, we hope to produce more extensive analysis in comparing the results of student achievement between sections of the same courses, which do not implement POPBL methodology in their T&L activities. This should give us better reflections on whether the POPBL pedagogical implementation is contributing towards the improvement in traditional T&L environment.

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