PRACTICE ON INQUIRY TEACHING MODE BASED ON CDIO INITIATIVE: AN EMBEDDED SYSTEM TEACHING CASE STUDY

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ABSTRACT

Inquiry teaching mode accordswith the CDIO “integration” idea. It meets the requirements of CDIO standard 8 and is inherently embedded in the CDIO syllabus. Partial intended learning outcomes required by the CDIO syllabus can be realized by using inquiry teaching mode. This paper took embedded system teaching as an example, firstly introduced the differences between traditional teaching mode and inquiry teaching mode, and inquiry teaching mode was how to meet the CDIO syllabus. Then different inquiry pedagogical approaches were adopted according to the characteristics of embedded system course and different types of teaching, i.e., case-based learning to lecture classes, problem-based learning to theory and basic concept, and project-based learning to experiment and curriculum design. Finally the effectiveness of proposed method was evaluated through the course’s exit-survey. The learners gave average 3.94 in 5-point Likert-scale, which showed that the learners' responses/feedbacks to proposed method were positive and promising and inquiry teaching mode can enhance students’ learning initiative and abilities of active learning, innovation, communication and teamwork. It can be used as effective carrier for CDIO engineering education reform, and provided references for solving some existed problems in engineering education.

KEYWORDS

Inquiry teaching, Pedagogical methods, Embedded system, Standards: 3, 7, 8

I. INTRODUCTION

Inquiry teaching (or called research learning) is a form of teaching mode wherein students are asked to learn in an active manner by assessing them on how much they evolve in terms of skills. It was first proposed by an American famous scientist, professor Joseph J.Schwab in 1961. Inquiry teaching includes many pedagogical approaches such as problem-based learning, project-based learning, case-based learning, etc. With the development of constructivism and the popularization of Humanism pedagogical theory, inquiry teaching shows more and more important theoretical and practical value, which has been favored by the world education reformers. Traditionally, inquiry teaching is more suitable to science education (Hu, 2014). However, in view of inquiry teaching experience of embedded system (hereinafter called “ES”) course in Chengdu University of Information Technology (hereinafter called “CUIT”), engineering education is provided with rich inquiry soil, and inquiry teaching is also applicable to cultivating innovative engineering talent. At the same time, the CDIO approach is designed to raise the quality of engineering education programs (Crawley et al., 2007), and most of the CDIO features are related to experiential learning (Crawley, et al., 2008). CDIO enables students to be exposed to the experiences that they will encounter as engineers during their professional lives. Besides, the CDIO syllabus contains significant elements of inquiry learning (Hu, 2014), so it can also provide a full range of support for the development of inquiry teaching.

A. Applicability to Engineering Education

Engineering is a step-by-step planned implementation that meets public demands. It integrates multi-disciplinary knowledge and need conform to standard requirements. Broad exploration space in engineering education is determined by the particularity of engineering activities. The aim of science is to find the truth, yet the aim of engineering is to create artifacts which can satisfy human needs. 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. This need engineer to make corresponding response, adjustment and innovation of construction, and to reconsider implementation scheme under some new constraint conditions, which determines engineering knowledge with uncertainty (Schutz, 2001).

B. Effective Way for CDIO Implementation

Inquiry teaching reflects the requirements of CDIO standard 8 (Active Learning), which demands to implement teaching & learning (hereinafter called “T & L”) based on active experiential learning methods. As initial motivation and challenges of learning, the real uncertain problems whose structure is not clear, is no permanent and no unique correct answer, but it can arouse students' desire of active inquiry and of seeking various solutions to solve, and can build a connection and demand to continue learning. Inquiry teaching contributes straight to CDIO standard 3 (Integrated Curriculum) and CDIO standard 7 (Integrated Learning Experiences). Inquiry teaching mode requires students to actively participate in various exploration activities, not only to observe and think, but also to operate and express. Meanwhile it should be encouraged in teaching and integrate theory with practice to arouse students interest, make engineering education be closely to real practice.

Inquiry teaching mode is inherently embedded into the CDIO syllabus in the form of competence, which covers all steps of inquiry teaching mode. That is to say, on the one hand, CDIO syllabus actually put each process and each step of inquiry teaching as a kind of competence to train, and refine teaching implementation. On the other hand, partial intended learning outcome required by CDIO syllabus can be completely realized through inquiry teaching mode. Engineering students are explicitly asked by CDIO initiative that they should be able to actively explore and learn.

II. THEORETICAL BACKGROUND

A. Case-Based Learning

Case-Based Learning (CBL for short) is a promising pedagogical technique, which first was advocated by the America Harvard Business School. It mainly is used in the combination of theory and practice. Cases are important for bringing real world problems into a classroom ensuring active participation and leading to innovative solutions to problems. The engineering case can be derived from engineering practice, or it can be fabricated if it is difficult to get the actual engineering examples, but whatever it takes, it should reflect real engineering practice in complex environment. Educators choose to use CBL in their courses, which involved students with real life situations and developed their decision-making skills. Literature (Ktoridou & Dionysiou, 2011) shows that instructors who integrate CBL observe that their students are further engaged, interested, and involved in the class. It is stated that many universities are promoting case-based learning as it teaches important concepts and facts within the context of authentic or real-world situations (Oliver,1999).

B. Problem-Based Learning

Problem-Based Learning (PrbBL for short) technique was devised in 1969 at McMaster University in Canada. As the name indicates, PrbBL is a teaching method in which the education process is focused fundamentally on the resolution of problems and in which critical enquiry is the main action that guides the learning process. PrbBL takes the problem as research objects in students' learning process, presents how to acquire and apply knowledge, how to identify and collect effective data, how to systematically analyze, explain and answer problem, and how to communicate, inspect and evaluate through understanding, exploring, studying and debating to problem.

Engineer training, using PrbBL techniques, requires educators to define complex problems that should be solved in collaborative work and to prepare a scenario that is suitable for the correct execution of the activity. It must always present a situation that contains a problem (if possible, a real one) and preferably the situation should not be very structured, but rather a generally open scenario, with a low level of specification (Pardo, 2014). PrbBL integrates engineering training with soft skills acquisition. Skills such as communication, research, self-evaluation and group work, among others, should therefore be addressed in a PrbBL environment (Cunha, et al., 2013).

C. Project-Based Learning

Project-based learning (PrjBL for short) is a teaching method in which students are given realistic problems characterized by not having a single correct answer. Guided through a process of analyzing the problem, researching alternatives, arguing for and against them, the students present a recommended solution. PrjBL is characterized by authentic investigation, collaboration among peers, the use of technology to support inquiry processes, and delivery of an end product. Through their active participation in the project execution process, students are encouraged to form original opinions and express individual standpoints. The project fosters students' awareness of the complexity of systems they would tackle and encourages them to explore the consequences of their own values (Wengrowicz, et al., 2014). Proponents of the PrjBL method clarified that it provided real-world and real-time learning opportunities that replicate the type of problems students would encounter and solutions they would use throughout their academic and professional lives (Dori & Silva, 2010).

D. Relationship between CBL, PrbBL and PrjBL

As has been mentioned above, PrbBL, PrjBL and CBL, which are one of inquiry pedagogical methods, are learner-centered and face real-world problems, and emphasize on participation of students, exploration of study, active learning and collaboration learning. There are some obvious differences between each other. More specifically, CBL emphasizes the case as a guide of learning process, inquiry problems are presented in the form of case; PrbBL represents a working philosophy in which critical enquiry is the main action that guides the learning process. Its inquiry problems are presented in the form of problem; PrjBL, in contrast, is concerned with guiding the learning process through the search for a viable solution to a project. Inquiry problems of PrjBL are presented in the form of product or program. The objectives of PrjBL are really very similar to those of PrbBL. The main difference is that PrjBL focuses on the application of knowledge, while PrbBL focuses on the acquisition of knowledge.

III. COURSE DESCRIPTION AND CURRENT PROBLEMS

A. Characteristics of the Embedded System Course

ES is attracting more attention nowadays because embedded devices can be found in almost all the information and communication technology areas, such as telecommunications, networking, automotive, and consumer electronics, etc. ES are dedicated systems. Under the condition of meeting system requirements, ES are simplified and optimized in order to improve the system efficiency and reduce power consumption and storage size. In the design of ES, special programs for external equipment drivers and applications need to be written according to the specific requirements. In order to write the drivers such as LCD, touch screen, we must understand the corresponding hardware principles and technologies.

From the above it can be seen that “ES” is a relatively difficult course because it requires students to have a solid knowledge of pre-requisite courses in both the theory and practice (Fan, et al., 2012). ES and software & hardware research studying and learning require broad perspective, multidisciplinary tradeoffs. Therefore, it mainly focuses on the multidisciplinary capabilities cultivation for students so that the students could deeply recognize the importance of process of software engineering, grasp the knowledge of substantiated ES development method, master ES design and usage of typical development tools like IDE and testing tools.

B. Current Practice and Critical Issues

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 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 (Pardo, 2014): 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 pace; there is little room for innovation. Students are 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.

IV. PROPOSED 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 ES in the fall semester of third academic year as a compulsory course. The delivery of the ES topics was achieved in sixteen 90-minute lectures, another 16 hours to arrange five experiments. Students finished curriculum design entirely in extracurricular time.

B. Case-Based Learning to Lecture Classes

The knowledge associated with actual engineering project can attract more students to actively participate in the project (Du, et al., 2013). They will enter the process of learning experience with problem in order to obtain better learning effect. A complete project rather than a fragment is in more favour of fostering systematicness and integrality of constructing knowledge to students. This can be realized by designing some independent learning topics (or modules) which were each other interaction but slightly different, when a complete project was divided into several small cases. Every topic completed one or several modules. According to this idea, classroom teaching used lectures on special topics, and decomposed project came from the fields of engineering into some small cases, which were reasonably assigned to each topic, as shown in Table 1. In the decomposition of the project, it should pay attention to combine with theoretical knowledge, and to maintain certain integrity of project functions. Moreover, the case should follow from simple to difficult and gradual manner, which can gradually stimulate the student's enthusiasm and interest in learning, thus avoid posing psychological resistance when students encounter difficulties. For example, project case of "remote control automatic curtain" was adopted in our pilot course, which let students conceive through analyzing system requirements and system components; introduced memory structure problem and the concept of Harvard structure by the LCD font loading problem; explained the role of relays in digital circuit and control knowledge of GPIO by motor start-stop control; introduced the application of interrupt by keys, real-time communication and real-time control problems; explained the use of timer by timing controlling curtains; presented the communication mechanism of the peripherals by automatic remote controlling curtains. So 1~2 cases were run through each lecture topic, which guided students to solve one after another practical problem and to learn related knowledge with the goal of solving practical problems, and finally teachers would summarize all theory knowledge, and add knowledge points that were not involved in.

Table 1. Proposed Case and Problem for Each Lecture Class

	Lecture Topic	Relevant Knowledge	Discussional Case	Exploring Problem
1	Introduction to embedded system and architecture of Cortex-M3	1.Characteristics of embedded system 2.Introduction of ARM and cortex-M3 3.Memory and bus architecture 4.Bit-band manipulation 5.Low power mode	C1.Remote control automatic curtain C2.LCD font loading	Q1.Understanding of embedded system Q2.Meaning and role of bit-band
2	Development tools and programming model	1.Composition of ARM project 2.Project template 3.Use of integrated development tools 4.Common methods for debugging and commissioning method 5.Joint Debugging of MDK and Proteus 6.On-chip flash programming	C3.LED cycle flash display	Q3.Functions of project template and its preparation method Q4.programming model
3	Firmware library and	1.ARM assembly language program structure 2.STM32 firmware library	C4.Operation status indication	Q5.Difference between embedded

	programming	3.Cortex software interface standard: CMSIS 4.C language programming in embedded system		C language and C language standard
4	Outputs and inputs	1.GPIO 2.Toggling an output 3.Separating the hardware from the action 4.A simple interface to a button 5.Momentary button press	C5.Motor start-stop control C6.Marquee	
5	Task management	1.Scheduling and operating system basics 2.State machines 3.Interrupts 4.How not to use interrupts	C7.Manual control	Q6.Processing button jitter
6	Timer	1. General timer (TIMx) 2.Pulse width modulation (PWM) 3.Watchdog timer(WDT) 4.Realtime clock (RTC)	C8.Timing control C9.LED brightness control	
7	Communicating with peripherals	1.The wide reach of peripherals 2.Ways of communicating 3.Putting peripherals and communication together	C10.Remote control C11.Temperature detection	
8	ADC and DMA	1.ADC working mode 2.ADC interrupt 3.Sensor 4.Function and structure of DMA	C12.Touch screen C13.Light intensity detecting and signal acquisition	

The key problem of CBL was case design and case selection. Teachers collected data, elaborately designed or selected the case associated with teaching content before teachers started to teach. The characteristics of this case should be familiar content or industry to students without too much workload or difficulty, Otherwise students would fear the difficult and resist the content.

C. 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 ES, the practical problem about processing button jitter, etc., as shown in Table 1 with respect to our pilot course.

The PrbBL strategy had been implemented in different ways, which especially depended on the number of students. Our method was a 8-stage process, as follows: 1)Presentation or reading of the scenario; 2)Arranging problems; 3)Literature retrieval, data collection and active learning; 4)Brainstorming and devising a work plan or experiment scheme; 5)Enquiry and research; 6)Summarizing the results and extracting conclusions; 7)Public presentation; 8)Commenting

D. Project-Based Learning to Practical Training

Through case-driven and problem-driven teaching, students only acquired knowledge needed to be mastered, but can not reach the extent that knowledge acquired was effectively applied to the practice. So some practical training would need to be provided for students. As had 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 the CDIO syllabus, e.g., time and resource management, teamwork, communication, etc.

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 2. 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.

Table 2. Proposed Small Project for Each Experiment Session

	Laboratory Project Tasks	Related Topics	Used Module
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	In/Out ports; Timers
2	Digital Frequencymeter (range: 10-20000Hz)	Lecture 3,5,7	Interruptions; CCP module (Capture)
3	Chronometer controlled by means of matrix keyboard and with a LCD display	Lecture 1,4,7	LCD display; CCP module (Comparison); Matrix keyboard
4	Data-logger of the information sent by the PC (serial communication)	Lecture 3,5,7	USART module (asynchronous communication)
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	SSP module (I2C); USART module; External devices (temperature sensor, EEPROM memory,...)

Students can analyze, reflect and experience in the process of experiment, but not enough to have a thorough engineering concept, Therefore, it required a curriculum design project, for instance, MP3 player, simply digital photo album, remote-control toy car, PID thermostat, 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 students' experiences, knowledge, level and interests. In order to promote the acquisition of certain skills such as teamwork and task management, students were freely divided into a number of working groups with three or four individual in each.

When a working group had finished one of the proposed projects, its members explained their solution to lecturers. 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. 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 practical report. Hence, not only the mentioned skills were promoted, but also plagiarism was prevented or, at least, was easily detected (Arias, et al., 2010).

V. RESULTS 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 the course of "ES". These students were required to anonymously complete a short questionnaire about the proposed method, assessment questions were seen in Table 3 and the results obtained for each question were illustrated in Figure 1.

Table 3. Assessment Questions

	Assessment Questions
1	Overall, inquiry teaching mode based on CDIO intiative was better than the traditional method;
2	The inquiry teaching method allowed me to become more involved in the learning process and enhanced my learning initiative;
3	The use of inquiry teaching mode in embedded system course encouraged me to attend lectures;
4	Case-based learning and 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 inquiry teaching method allowed me to practice certain non-technical skills such as collaborative work, public presentation, etc.
7	The use of inquiry teaching mode in embedded system course improved my ability to learn actively the material;
8	I wish the professors in my other classes would use inquiry teaching mode

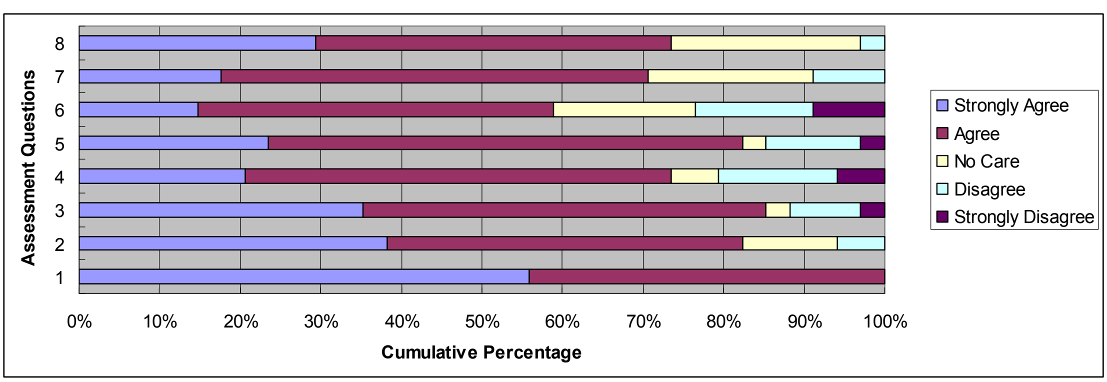

Figure 1. Survey Results

The learners' responses/feedbacks gathered from the survey were positive and promising according to an average of 3.94 points in all questions. In terms of their overall assessment from question 1, 100% of the students stated that the inquiry teaching method had helped them to learn the contents as well as or better than a traditional method; In overall, most of the learners agreed that the inquiry teaching implementation in the taught courses improved their non-technical (communication, teamwork and planning) and their technical skills to creatively solve the real-world problems of the given application systems according to the result of question 6; Through the input of students from question 3, 4, 5 and 8, majority believed that the inquiry 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.

VI. CONCLUSIONS

Inquiry teaching mode based on CDIO intiative 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 CDIO intiative advocated. However, using separately one kind of inquiry pedagogical approaches does not achieve the desired results due to differences in the nature of curriculum and teaching types. Our pedagogical practice, namely integrating the combination of project-based learning with problem-based learning and case-base learning into ES teaching according to the characteristics of ES course and different types of teaching, i.e., case-based learning to lecture classes, problem-based learning to theory and basic concept, and project-based learning to experiment and curriculum design, showed that inquiry teaching mode 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 CDIO engineering education reform, and provided references for solving some existed problems in engineering education.

It should be said that one of the most important points that generates most problems for instructors who follow inquiry pedagogical approaches was finding a real scenario that stimulates students to follow the process. In addition, adopting synthetically inquiry pedagogical approaches in T&L demands immense work, timely preparation and great participation especially in monitoring the team progress, as well as in giving fast feedbacks and suggestion for every submitted deliverables.

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 the synthetic inquiry pedagogical approach in their T&L activities. This should give us better reflections on whether the synthetic inquiry pedagogical implementation is contributing towards the improvement in traditional T&L environment.

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BIOGRAPHICAL INFORMATION

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