IMPROVEMENT OF CDIO SKILLS BY USING INQUIRY LEARNING

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ABSTRACT:

Although the CDIO tenet is to make students to get a deeper theoretical knowledge and better CDIO skills, the effectiveness of this pedagogy is challenged by teaching methods. This study investigated how CDIO skills of students were improved in “Civil Engineering Materials” (CEM) course by using a new “Three stage learning method” which was built on the basis of inquiry learning pedagogy. The students’ assessment and their awards were displayed. It can be seen that students were interested in this new learning method, and the ability, knowledge and personality of the students were effectively enhanced through such course reform.

KEYWORDS:

CDIO, Inquiry learning, Civil Engineering Materials, Three stages teaching method

1. INTRODUCTION

As economic reform in China has made a significant progress in the last 30 years, there is an urgent need to reform higher education system to better serve the increasing needs of society and industry. Shantou University has adopted CDIO education framework to re-design Civil engineering program since 2005 [1]. The syllabus schedule of Civil Engineering Materials” (CEM) course based on CDIO has been re-designed. In this course, CDIO competencies were cultivated mainly through completing a team project with a repeat CDIO processes for producing a concrete with certain special indexes. In practice, for sophomore, a rational mix design for a special concrete is the biggest obstacle to perform their project.

It is well known that wide domain knowledge is the most essential requirment to successfully design a special required concrete [2]. However, sophomores have little prior knowledge about concrete, moreover, most students in civil engineering were uninterested in CEM and unwilling to active-learn. As a result, the team project could not be completed well, leading to a failure to cultivate students’ CDIO competencies.

To ensure sophomores successfully perform their team project, a new “three stages learning” (TSL) method shown in Table.1 was proposed on the basis of inquiry learning pedagogy. Inquiry learning pedagogy emphasizes that learners should be active agents of the learning processes. Inquiry learning pedagogy can lead to a deeper and more meaningful understanding about a domain [3]. According to educational psychology the relationship between domain knowledge and the interest are: 1) The more domain knowledge learners possess, the more competently they will be able to process new information from the domain in a strategic and efficient manner. 2) Along with domain knowledge, another variable important in academic development is the interest in the subject matter. 3) As the interest in an area of study increases, recall of new information from that domain also increases. 4) When one is knowledgeable about a domain, one is necessarily motivated to know more about this subject [4].

Table 1
Sketch of “three stage learning method”

Stage	Course	Learning Method	Project
1. NATURAL STAGE	Theory knowledge (basic & narrow)	Instruction	
		Instruction + group discussion + self-study	A simple project (CDIO)
2. UN-NATURAL SCIENTIFIC STAGE	Theory knowledge (deep & wide)	Instruction + group-discussion + self-study	
		Instruction + class-discussion + self-study	A slight complicated project (CDIO)
	Theory knowledge (more deep & wide)	Study on the individual problem	
3. SCIENTIFIC NATURAL STAGE		Self-study and discussion to Discover & solve problems	A complicated project
	Theory knowledge (professional)	A problem solved through researching	
			Expert

The hope was placed on that the CDIO skills may effectived be developed by using the TST method. For natural stage, students are just becoming acquainted with CEM. During this stage, learners are characterized by a limited amount of domain knowledge within CEM. In addition, this limited knowledge tends to be fragmented and disorganized. Moreover, students often show a low level of interest in the domain. Their interest is also rather transient and short term and as such is highly situational. A simple project would be especially helpful to increase interest in learning. Some CDIO skills such as practical ability, communications skills and ability of forming effective teams are improved in the natural stage.

In un-natural scientific stage, students have developed a relaively richer and more coherent foundation of knowledge of CEM, their interest becomes stronger than those students in natural stage. A complicated project is suitable for improving abilities of the critical thinking, problem identification, judgment and balance in resolution as well as utilization of knowledge in design. However, in unnatural scientific stage, students may still be attracted to the more situational arousing details. To keep students’ interest, teachers should guide them to go through an entire CDIO cycle.

For scientific natural stage, students hold a rich and well-organized network of domain knowledge as well as a deep-seated interest in the subject. They demonstrate a high level of persistence and remain interested even when facing some hard difficulties. In this stage, students display some characteristics of experts and have a certain level of innovation ability and the skill of knowledge application.

2. DESIGN AND PROCEDURE

2.1 Design

The curriculum schedule of CEM course were redesigned based on TST method, and the significant differences before and after reform are shown in Table 2 .

Table 2
Contents, methods and schedule of CEM course before reform and after reform

	Before reform		After reform	
	Contents	Learning Method	Contents	Learning Method
1st-4th wks	Theoretical knowledge	Instruction	Theoretical knowledge (Basic & applicable)	Instruction
5th-8th wks	Theoretical knowledge	Instruction	A simple project (Including Conceive, Design, Implement, Operate)	Instruction; Discussion; Self-study
9th-12th wks	Theoretical knowledge	Instruction	Theoretical knowledge (Deep & wide)	Instruction; Discussion; Self-study
13th-15th wks	A complicated team project	Instruction	Project being modified	Instruction; Discussion; Self-study
16th week	Display and Debate	Instruction Self-study Discussion	Display and Debate (Including Conceive, Design, Implement, Operate)	Self-study; Discussion; Instruction;
17th week	Classroom examination		Classroom examination	
Assessment	1) Classroom examination 2) An experimental report at the end of the semester		1)Classroom examination, 2) Design report and display of products as well as routine performance	
Grade standard	80% , writing examination 20% , experimental report		40% , writing examination 60%, Design report and display of products as well as routine performance	

It is well known that the theoretical knowledge is the most important key for the successful project implementation. Based on this idea, the schedule before reform shown in Table 2 is reasonable, but there are three negative characteristic:

1) Students lost their interest during a continuous twelve weeks theoretical teaching in classroom.
2) CEM is a domain rich with concepts and mechanisms. Moreover, the structure of theoretical knowledge for students is disordered in a short and intensive studing period. As a result, students often cannot process efficient information to design their project.
3) The team project before reform was too complicated which also led to loss of self-confidence.

By comparison, the schedule after reform has positive characteristic as follow:

1) Being droved by curiosity, change and difference, the students' learning interest are aroused adequately by simple and applicable theoretical instruction and project implementations.
2) Instructing theoretical knowledge from narrow to wide is helpful to form a well-structured knowledge system, and implementing project from simple to complicated make students successfully to process information and to implement project.
3) After reform, students firstly implement their project including a CDIO process, then modified their project according a further learning which include one or two CDIO process. During more than two times of CDIO process, the students' innovative ideology, analysis ability, teamwork spirits, system thinking, experimentation and knowledge discovery as well as knowledge of CEM are expected to be effectively enhanced.

2.2 Procedure

From 1st to 4th weeks, students were arranged to learn a little basic and necessary theoretical knowledge at classroom such as basic performance and principles of civil engineering materials, with a special emphasize on cementitous materials.

At 5th week, the students were divided in groups, and each group was made up of four or five students. Each group was designated to to complete a primary level team project with a C-D-I-O process for developing a material only required to "take good advantages of local materials".

From 5th to 8th weeks, each team was operated a middle level project. They conceived and designed their project by reading some references, discussing in team, or consulting teacher or schoolmate. When finishing mixture plan, group began to test their product in laboratory, and then analyse the results and reach conclusions for the selected item. Finally, each group displayed their products, and whole class would then evaluate the design and give their comments on the design. The team displaying the design needed to defence or debate or accept the comments.

From 9st to 12th weeks, students were asked to learn more theoretical knowledge at classroom as follow: 1 Production and application of civil engineering materials considering social and resource problems; 2 Fundamentals on environmental friendly insulating materials.

From 13th to 15th weeks, each team was appointed a high level project with one or two C-D-I-O process for developing a material. The material should satisfy the request of "having high-performance, or having multifunction, or being an environmental friendly insulating material". Each team needed to revise its design according to the comments and the requirements from teachers, and put forward another discussion, design and practice process.

At 16th week, each group displayed their products again, and whole class would then evaluate the design and give their comments on the design. The team displaying the design needed to defence or debate or accept the comments.

The assessment was also changed from "according to classroom examination and an experimental report at the end of the semester" to "the design report and the product display, as well as classroom examination." Then, the standard of grade was also changed. Before reform, writing examination and experimental report were made up 80% and 20% of the total grade respectively. And after reform, redesign process (including performance during design and final report) and writing examination were made up of 60% and 40% of the total grade respectively. The abilities of working independently and learning independently, as well as team spirit and communication skills were emphasized in this reform.

3. REFORM EFFECT ACCORDING TO RESPONDSES OF STUDENTS

Based on the faculty observations through the project process, the students' abilities and learning efficiencies were significantly enhanced after this reform.

A student wrote in a personal reflection, "Through this project I further realize the virtue of CDIO approach. In the approach we learned how to study, how to communicate and how to cooperate. I have gotten a deeper appreciation of a civil engineer. I realize that we need not only to possess a rich, comprehensive professional knowledge, but also, more importantly, to be professional in learning and conduct".

Another student wrote in his personal reflection: “It is true that do more, learn more. We should pay more attention to practical abilities, such as independent thinking self-learning. Teamwork is not a work easy to be done; each member of a team must have his own unique insight in order to complete the project perfectly. How to communicate effectively, how to screen the useful knowledge, and how to use knowledge are all great challenges for us. It is true that practice is the sole criterion for testing truth.”

One student reported: “The teamwork redesign project of CEM makes us really go into the construction practice. We resisted at first doing this project because we thought the experiment being hard, dirty and tired. However, during the project process we really felt the joy of the harvest of working hard, and understood the knowledge more deep-set through learning from practice. Here, I show my thanks to Teacher Li for providing us the good guidance, and I also thank my classmates for their good ideas to amend my project.”

Moreover, the big achievement of this reform is that students use their development material to participate several competitions, and the awards obtained by them are shown in follow:

1. Fig.1 shows that one team using their “green heat insulating material” got the Best Poster at the 7th CDIO International Conference - CDIO Academy.
2. Another group receved a second prize of the 11th Guangdong Provincial “Challenge Cup” Competition for College Student’s Academic Research Work.
3. One group obtained the 7th Guangdong Provincial “Challenge Cup” Competition for College Student’s Business Plan.
4. One group as shown in Fig.2 got the “Best Venture Exhibit Award”, “Recognition of Environmental Concerns Award”, and “Best Team Synergy Award” at the 10th Mai Bangkok Business Challenge.

Figure 1. The prize certificate at the 7th CDIO International Conference

Figure 2. Poster Presentation at the 10^{th} Mai Bangkok Business Challenge

4. CONCLUSION

This study investigated the influence of the “three stage teaching” method on the development of CDIO skills for students. Students hold a rich and well-organized network of domain knowledge as well as a deep-seated interest in the subject of CEM by using “Three stages education” method which was built on the basis of inquiry learning pedagogy and educational psychology. Using this method, the CDIO skills of self-study, innovation, communication and team cooperation are enhanced. Students also learn enough theoretical knowledge and problem solving ability for perparing to be a qualified engineer.

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