A COURSE of ENGINEERING SYSTEM DESIGN FOR CIVIL ENGINEERING STUDENTS

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ABSTRACT

Being one of four main courses from “*Abilities-Attitudes-Knowledge*” integration teaching system, at ShanTou University（STU）, a course called “Engineering System Design” for Civil Engineering students was first time built up in China in 2009. This is a PBL for the 4th year students. 3~4 persons composed of a team. Based on their earlier finished Project Planning, Architectural Design, Structural and Geotechnical Design result for a project, each team continued to do a Construction Organization Design. And then the following task was Project Evaluation including the analysis on the market, financing, financial & national benefits and risk. A Summary-report to review the whole project work and amend mistakes was required as one part of the project work. In order to more effectively promote CDIO engineering abilities, each teaching-procedure was detailed as workable “actions” in the syllabus. As learning results, it showed that the project practice is the key point to promote students’ abilities in their service to the real engineering society system. This paper studied teaching method and learning outcomes. The existing problems and the future improvements were discussed as well.

KEYWORDS

CDIO, Engineering system design, Teamwork Project, “Abilities-Attitudes-Knowledge” integration teaching system

1. INTRODUCTION

In engineering field, it contains an all-inclusive of technology, social development, market value, management pattern, economic, traditions and morals. Within CDIO program, the objective of engineering education is to prepare students who are deeply knowledgeable of the technical fundamentals and broadly prepared with the pre-professional skills of engineering. In Civil Engineering Department (CED) at STU, educators have challenged engineering education to do a better job at meeting this objective in a modern, team-work and real engineering-society system based environment [1].

As one of outcomes for CDIO education reform in CED at STU, a new course called “Engineering System Design (ESD)” was set in 2009. This course was designed for the 4th year students, after they finished some of relevant courses’ study of “Architectural and Structural Design”, “Building Construction”, “Construction Cost Evaluation”. “Project Management”, “Engineering Economics”. It was the first time in china to build up this *Project Based Learning* (PBL) course that embodied the composite knowledge applications of economics, management, politics, laws & rule and related technical fields for a teamwork project called “My Dream-town, Wuqiao Island—an old town reconstruction”. The ESD aimed to improve students’ abilities on multidisciplinary comprehensive application, economic concept, teamwork and simulation of a real project implementation.

In this paper, the learning processing was reviewed and analyzed as the main body. The learning goals, syllabus, teaching content and method, assessment were given. And identified aspects of the rationale for teaching engineering in the context of CDIO idea was analyzed. They were all based on emulation of professional practice, support of skills learning and theories as applied in engineering and higher education.

Finally, from students’ feedback, this paper evaluated the learning effects. The existing problem and further improvements were discussed at the end.

2. The CDIO PROGRAM BASED TEACHING GOALS AND SYLLABUS FOR ESD

(1) CDIO program & its rationales

To follow CDIO program, in year 2009 four related PBL courses [see figure 1] had been built in Civil Engineering Department (CED) at STU and its learning goals were [2]:
① Knowledge system;
② Personality and professional abilities;
③ The abilities of Communication and cooperation;
④ The abilities of project implementation in the enterprise-social context.

These four goals are integrated in a way that the 4th level based on the other threes. The primary objective was to consolidate and promote students engineering abilities, especially for the abilities of project implementation in the enterprise-social context.

Practice is the best way to enable students to master their engineering knowledge. In Civil Engineering Department at STU, when students started their project work, some of civil engineering related courses might not yet be provided to them. At that stage, some of the engineering knowledge which students initially applied on a project was just from their feeling, as we called students were at “original natural-stage” to the scientific[3].

Once students went through detailed work, soon they could find the big difference between their “poor” or “original” cognition for engineering and the real knowledge. It resulted in encountering numerous problems during project implement, so that students could hardly carry on their work without further study. At this time they were at an awkward “scientific un-natural stage”. However, because of this awkward “un-natural”, in order to complete their work, students have been “forced” to approach a solution by all means of study, such as: consulting, team-discussion, literature study and so on. Through repeat the procedure of “problem-study-solving”, bit by bit students had formed an “active learning” habit as required refer to CDIO standard 8 [4].

Based on the CDIO standard 7 [4] of “integration learning experiments”, the primary learning aim for the 4th project of “Engineering System Design” was to implement all round and systematic CDIO “*Abilities-Attitudes-Knowledge”* program, especially for the level 3 and 4 [see table 1]. To accomplish this learning goal, continuing to do “Building Construction” and “Project Evaluation” for the project. Ultimately, students could be able skilfully to do a project with comprehensive applications of engineering technology, economics, politics, traditions, and become a highly experienced pre-engineers as they have reached a “scientific natural stage”.

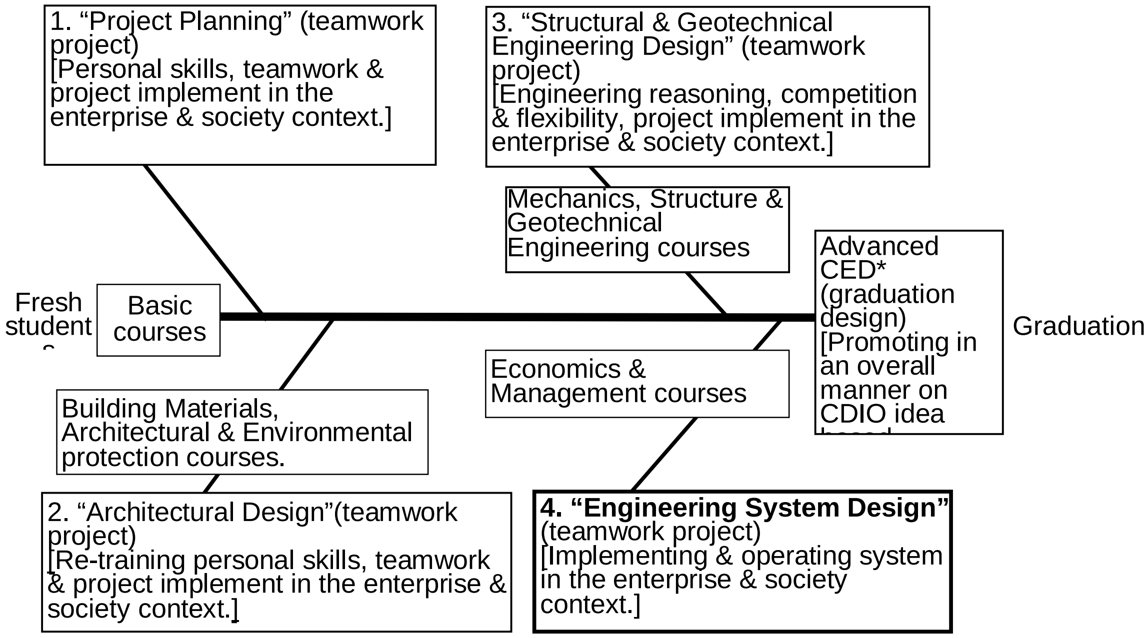

Figure 1, Fishbone diagram of project based “Abilities-Attitudes-Knowledge” integration teaching system in Civil Engineering Department STU
(*: **C**ivil **E**ngineering **D**esign)

(2) “Abilities-Attitudes-Knowledge” Integration Teaching Program

According to a questionnaire’s feedback (from having worked for civil engineering field at about 10 years college graduated students), there was 80% of all answerers believed that the ranks for learning analytical and problem solving skills, the self-study and innovative abilities, communication and teamwork should be on the top of the all. In the other words, it has become a consensus that engineer’s capabilities are more important than knowledge. So that engineering education is necessary to understand the impact of engineering solutions in a global, technology, economics, societal and environmental context [5].

To attain CDIO learning goals from ESD course, a practical teaching syllabus was built, and each teaching procedure has been designed as “fixed actions” [see table 1] in it. It emphasized the abilities of personal, communication and teamwork, the project implement in a real engineering and societal context [6].

Table 1
CDIO Program Based Syllabus For ESD Teamwork Project [condensed]*

序号	**CDIO Syllabus** (main goals)	**Individual Teaching Procedure** (to be fulfilled “fixed actions”)	**Goal Met**		
	1. Technical Knowledge and Reasoning		**Touch**	**Learn**	**Apply**
1	1.3.1: Knowledge of Urban Planning, Architectural & Structural design, Foundation design.	Technical evaluations on project planning, architectural design, structural & foundation designs.	--	C	C
2	1.3.2: knowledge of Building Construction” & Construction Cost Estimation”	Implementing construction design and construction cost estimation to the teamwork project.	--	B	B
3	1.3.3: knowledge of “Project Evaluation” & civil engineering related rules/laws.	Evaluations on technology, economic, politics, risk, rules/laws & etc to a project.	--	B	B
	2. Personal and Professional Skills and Attributes				
4	2.1.1, 2.1.3~2.1.5:	The judgment of project feasibility	--	B	B

	Problem Identification and formulation; Estimation and qualitative analysis; Analysis with uncertainty; Solution and recommendation	from comprehensive analysis of all individual evaluation result. Problem solutions & conclusions from team discussions.			
5	2.2.2: Survey of print and electronic literature	A list of all referred references.	--	B	B
6	2.3.1~2.3.4: Thinking holistically; Emergence and interactions in systems; Judgment and balance in resolution.	Final decision from comprehensively verification on the politics, economics, society, culture, risk and laws/roles.	--	--	B
7	2.4.1~2.4.7: Perseverance and flexibility; Creative thinking & critical thinking; Awareness of one's Knowledge, skills, and attitudes; Time and resource management.	Accomplish project work according to schedule; Consultation, literature-study & group-discussion along with the all teamwork of planning, problem solving, decisions & corrections.	--	--	B
8	2.5.1: Professional ethics, integrity, responsibility, and accountability	Considerations on the effects of economics, environment, humanity, risk and technology.	--	C	B
	3. Interpersonal skills; teamwork and communication				
9	3.1.1~3.1.5: Forming effective teams and team operation; Team growth and evolution; Leadership and technical teaming.	3~4 persons in a team with team-leader's coordination.	--	C	B
10	3.2.2~3.2.6: Written, electronic (/multimedia) & Graphical communication; Oral presentation and inter-personal communications.	Team-discussion records, written report with related tables/charts/photos & drawings, oral presentations & defence to the experts & other groups in a class.	--	B	B
	4. Conceiving, Designing, Implementing, & Operating System in Enterprise & Societal Context				
11	4.1.1~4.1.4: Roles and responsibility of engineers and the impact of engineering on society; The historical and cultural context;	The judgment of project feasibility from comprehensive analysis of all individual evaluation in enterprise & societal context.	--	B	C
12	4.2.4: Working successfully in organizations.	Statement of processing of problems and solutions in the written & oral report.	--	--	B
13	4.4.1, 4.4.3: The design process; Utilization of knowledge in design.	Multidisciplinary application of Architecture, Structure, Economics, Management & others.	--	--	C
14	4.5.1; Designing the implementation process.	**Simulating** ESD processing in the "real" enterprise & societal context.	--	--	D

***:** A, B, C, D shows the required degrees to each specified abilities, "A" represents the highest and blanket means not required. There are no training and assessment required in the column of "Touch". Under the "Train", the training and assessment should be given to the students. "Apply" is the applications whether the relevant training and assessment are given or not.

3. TEACHING CONTENT OF "ENGINEERING SYSTEM DESIGN"

ESD was a teamwork project with 3~4 persons in a team. It required taking previous finished result of Project Planning, Architectural Design, Structural And Geotechnical design, and to continue implement Building Construction (BC), Project Evaluation (PE) and Final Report [see fig.2] for the project of "My Dream-town Wuqiao Island". With teacher's instruction, all the works had to be carried out by students themselves. There were only 6 hours classroom activates of presentations, comment, defences and discussions for three stages of BC, PE and Final Report work, in which each stage took 2 hours individually.

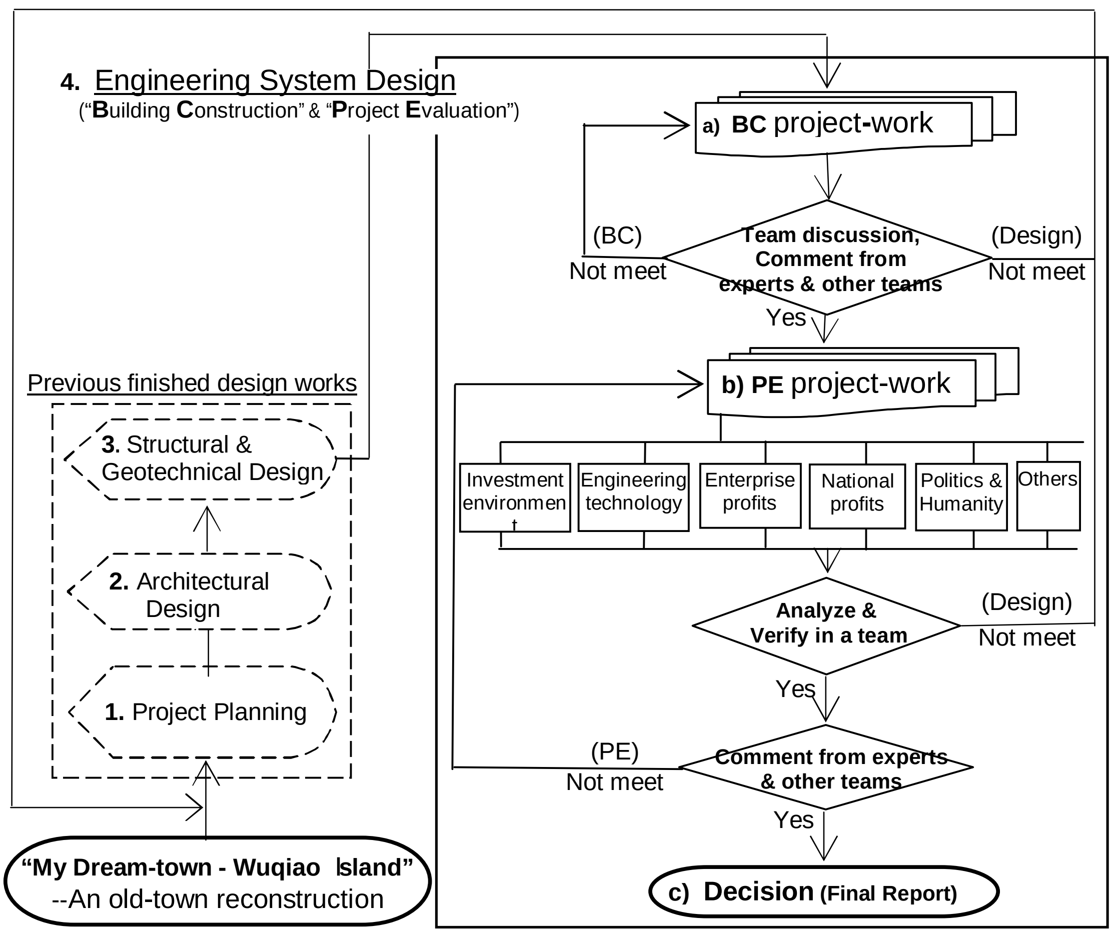

Figure 2, Flowchart of PBL "Abilities-Attitudes-Knowledge" integration teaching system Of "Engineering System Design" course

Detailed ESD project processing was divided into three stages as following:

The first stage [see figure 2, ⑴] was to do "Building Construction (BC)". Within a team students had to finish construction plane design, constructive section planning and construction schedule. Classroom comment was to evaluate the learning effect at the end of this stage. Through the whole implement training, students learned the abilities of "communication and teamwork" and "technical knowledge and reasoning" as listed in CDIO grogram.

The second stage [see figure 2, ⑵] was the "Project Evaluation (PE)". The market analysis, financing and expenditure plan, benefit-cost analysis, national benefit analysis and uncertainty analysis were required to carry out. The comprehensive verification had to be made by concluding above individual evaluation result. And the final decision for the project had to be given accordingly after team-discussion and classroom comment at the end. Under the teamwork implementing, refer to CDIO program level 4, students could be capable to implement a project in engineering and society context with industrial based needs.

The last stage [see figure 2, ⑶] was to compile a "Final Report". Each team has to review, amend and summarize the whole project work, including CEDI, AD, SGD and ESD. The oral presentation for the report had to be given, as well as the comment and defence. Thus, by repeat doing each teaching procedure (fixed actions) given in CDIO program based syllabus (such as in table 1), students got the more comprehensively and systematically understanding of a real engineering project

4. LEARNING EVALUATION

Table 2

Learning Evaluation & Standard For “Engineering System Design”

Learning Goals	**1st** Technical knowledge & reasoning	**2nd** Personal & professional skills & attributes	**3rd** Interpersonal Skills (teamwork & communication)	**4th** Conceiving, Designing, Implementing, and operation systems in the enterprise & societal context.
Learning Content	1. Correct engineering idea; 2. Mechanics, Architecture & Structural design. 3. Engineering Economics, Project Management, Construction Cost Estimation & etc.	1. Sustainable development design. 2. Harmony of company profits & social interests. 3. Scientificity, correctness & creativity.	1. Accomplish project work according to scheduled. 2. Cooperation, coordination & oral expression. 3. Minutes, written formation & technology language. 4. Enthusiasm & discipline.	1. Discover & solving problem. 2. The implementation in the enterprise & societal context.
Activities	Implementing Construction Design & Project Evaluation, compiling Final Report for “My Dream town-Wuqiao Island” teamwork project.			
Assess	“Construction Design”	“Project Evaluation”	“Final Report”	Total
Rating	40%	40%	20%	100%

Teamwork project training is emphasizing the CDIO abilities’ learning process. Learning evaluation is focused on the qualified completion of every teaching procedure (“fixed actions”), rather than the perfect result on knowledge. Such as, the project plan and result have to be made after team discussion. A good score could be given to a team, when students made proper scientific verification and have a right analytical concept. The full assess score is divided into three parts, one part is for building construction work at 40%, one part is for project evaluation work at another 40%, and the last 20% given to final report. Table2 gives a standard of score to evaluate learning effect for ESD course.

5. CDIO PROGRAM BASED LEARNING PERFORMANCE

The 1st Level Of “Technical Knowledge And Reasoning”:

As an example refer to the table 1 at item 1.3.5.3, to improve students’ multidisciplinary knowledge, teaching syllabus required that students had to implement the evaluations on the technology, enterprise and national benefits, uncertainty and risk, politics and laws for the project. One of students from team 2 exclaimed: “after this project’s implementation, we learned how to synthetically apply multidisciplinary knowledge on a project and also get clear of some key-knowledge in which we did not fully understand during the theory study in the classroom.”

The 2nd Level Of “Personal And Professional Skills And Attributes”:

To improve students’ practical capability, such as: Perseverance and Flexibility, Creative Thinking and Critical Thinking, Awareness of One’s Personal Knowledge, Skills, and Attitudes as listed in table 1 (item 2.41~2.47). It required that all the implementing plans, schedules, result have to be decided after team discussion. At the end of one report, there were some thoughts from team 10, as: “at the beginning of doing this project, we had no idea how to continue our work when we encountered numerous problems of that related to many subjects other than scientific technology. Such as: historical culture, economics and politics.

But after literature study, team discussion and consulting, within teamwork we finished our project work."

The 3rd Level Of "Interpersonal, Teamwork And Communication":

Cultivate leadership, set up highly effective team, learning communication and corporation is a light of this course study. At this aspect, the teaching syllabus required that project work had to be carried out under team-leader's coordinating. The all plans and result had to be made after team-discussion. There were classroom comment required for each team's report. Defence and amending based from the comment was required for each team.

The 4th Level Of "Conceiving, Designing, Implementing, And Operating System In The Enterprise And Societal Context":

To implement ESD project, it was not only revolving technology, but also related to market, cost, construction time, financial and politics. It might get totally different result when any of above mentioned facts had been changed. Through this kind of training, students' abilities have been promoted from single technology to the multidisciplinary knowledge application. By doing the evaluations on the aspects of national economy and societal benefits, the engineering recognition for students have been promoted from microcosmic single enterprise to macrocosmic society. It gives students the more understanding of engineer's role and responsibility in engineering and society context.

6. IMPROVEMENTS NEEDED

This course has been taken for 3 years by the 3 grades' students in Civil Engineering Department at STU. Reviewing the learning result, the needs for the improvements are clear, in which summarized as following two main aspects:

①. To give students the more practical training environment in real engineering society.

②. By using the theory of project management to build a teaching management system to monitor and control the progress and learning quality through the whole learning process.

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