UNFOLDING CERTAIN ENGINEERING PROCESSES IN A LECTURE-BASED ENGINEERING COURSE

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ABSTRACT

This paper presents the experiences of the introduction of some steps of “Conceive” and “Implementation” stage of the real-world engineering processes in a traditional lecture-based course, called Electromechanical Transmission Control, to develop the student competencies, such as system thinking, engineering reasoning and knowledge discovery. To intensify the understanding and perception of the technical fundamentals, a series of experiments are also scheduled in this course. In the lecture session, inquiring-based learning and design-directed learning are adopted to stress the design directive or requirement specification defining of “Conceive” stage. Meanwhile, in the series of laboratory work, the validation against the requirement of “Implementation” stage is unfolded in some sense with the different instruction in the before, during and after phase of the whole experiment process. Based on a set of validation experiments, a small-scale design-build-test project is arranged by the end of the course to enhance the students’ engineering experience and skill. The enthusiasm shown by most of the students and well presented reports are very positive to our reform attempt.

KEYWORDS

Design-directed learning, Inquiring-based learning, Experimental learning, Engineering processes

1. INTRODUTCTION

Nearly by the end of 2005, the CDIO initiative of engineering education [1] was introduced to the College of Engineering of Shantou University as the first one in China. Based on the CDIO concept, Shantou University developed the engineering education into a design-directed EIP-CDIO program with the competencies fostering as the main aim [2]. In response to the problem of the lack of the understanding and appreciation of the historical, social and environmental responsibilities in the conventional engineering education in China, EIP-CDIO program stresses Ethics, Integrity and Professionalism; furthermore these qualities should be reasonably integrated into the context of Conceiving – Designing – Implementing - Operating systems and products. The vision is to make graduates become qualified engineering talent not only with CDIO skills but also with high social responsibility, good professionalism and healthy personality.

With CDIO Syllabus 2004 and CDIO Standards 2004 as a reference, we preceded curriculum reform for all five majors of College of Engineering since the spring term of 2006. Before we formally started the four-year EIP - CDIO engineering program for 2006 freshman, several mandatory courses for year two and year three of every major are chosen as the CDIO pilot course. Among them, Electromechanical Transmission Control has been tested in fall term of 2006 and 2007 respectively. In some sense, it is interesting to share some experience of this reform test with the readers in the following sections. In section 2, we firstly introduce the main task of this course. Then, the teaching and learning characteristics during the lecture is presented in section 3, and followed by the corresponding experiment process description in section 4. After the introduction of the lecture teaching and experimental learning, how effectively assess the outcomes, e.g. student CDIO skill, is discussed in section 5. The feedback of the students is shown in section 6. Finally, section 7 contains the conclusions.

2. ELECTROMECHANICAL TRANSMISSION CONTROL PILOT COURSE

As a core mandatory course of the major of Mechanical design, manufacturing and its automation, Electromechanical Transmission Control provide students the basic electrical fundamental knowledge of mechatronic engineers. It is characteristic of the integration of mechanics and electrics while electrics serving for mechanics. Adapted to the technical development trend, kinds of power electronics technical knowledge relating to transmission is included spanning from the basic low-voltage electrical appliance, relay logic circuit to the most advanced variant frequency regulation system. On the other hand, this course stresses the value of the practice with 27% credit hours allocated to experiments, which can really strengthen the understanding of the corresponding knowledge [3].

For the student showing the low-level self-study ability and no interest to any courses duing to the high-school study mode mainly driven by the testing marks, the great challenge is how to stimulate their intrinsic curiosity, and how to provide the hands-on experience to foster lifelong self-learning habit.

Among the 12 CDIO Standards [4], the first one tells us the context of engineering education should be the product and system life-cycle development and deployment – Conceiving, Designing, Implementing and Operating. Thus in this CDIO pilot course, some steps of the Conceiving and Implementing stage are introduced into the lecture and experiment process, which is appropriate for the course's feature and student status. Compared with the CDIO Syllabus [5], the education goals of this pilot course are revised as shown in Table 1 [3].

Table 1
CDIO skills developed in Electromechanical Transmission Control*

		Contact	Train	Application
2. Personal and Professional Skills and Attributes	2.1 Engineering Reasoning and Problem Solving	A	B	C
	2.2 Experimentation and Knowledge Discovery	A	B	C
	2.3 System Thinking	A	B	B
	2.4 Personal Skills and Attitudes	A	B	B
	2.5 Professional Skills and Attitudes	B		
3. Interpersonal Skills: Teamwork and Communication	3.1 Teamwork	A	A	A
	3.2 Communications	A	B	B

4. CDIO process in the Enterprise and Societal Context	4.1 External and Societal Context	D		
	4.2 Enterprise and Business Context			
	4.3 Conceiving and Engineering Systems	A	C	D
	4.4 Designing	B	C	C
	4.5 Implementing	A	B	C
	4.6 Operating	D		

* Note: A, B, C, D are used in the goal column to show the different level, where A is the highest, and when there is no requirement, it is kept vacant.

By the close integration of the context of the lecture and experiments, students are expected to become more willing to participate the total experiment process, which will help them intensify the understanding of the fundamentals, enhance the skills of observation, analysis and expression, and moreover master the method of exploring the knowledge and develop lifelong learning ability.

3. CLASSROOM TEACHING PROCESS

During the classroom teaching, the Inquiring-based learning is adopted to experience the requirement analysis and specification definition of Conceiving stage. The key aim is to help students realize the relative position of the learned content in the subject discipline hierarchy system, and their connection with the relevant knowledge they have studied, then find out the orientation and the feasible way to enrich their own knowledge framework.

For inquiring-based learning, how to set the context to induce the various inquiries is the main point to guarantee the effect. Here, the clue is the core, which is used for steering students towards the main content that should be learned and facilitating the control of the inquiring process. Moreover, teacher should be aware of which kind of presentation of the clue is the fittest to inspire the student.

For example, when learning the Relay Logic Circuit and Programmable Logic Controller, based on the understanding of the basic principle and design procedure of the former, the students are induced to analyze with the lecturer its non-adaptivity exposed in the process of the production procedure change and the new one trial, and the cause of this situation. After being sure of the inherent defect of Relay Logic Circuit, the lecturer help students define which is the key problem needed to be solved combining the natural and regular patterns of the technology development. Furthermore, whether it is possible to find out the solution to it or not can also be analyzed with the aid of the fundamental knowledge of the related subject discipline, such as the micro-computer and micro-electronics. Finally, it is the lecturer that gives the description of the high efficiency and great economic value benefiting from the adoption of the new technology.

With the intrinsic technology development pattern as the clue of the Inquiring-based learning, student can get preliminary contact with the real-world engineering problem and actively experience the basic engineering reasoning process.

4. THREE STAGES OF EXPERIMENT PROCESS

The validation of Implementing stage is presented by the series of experiments scheduled to match with the lecture content. Taking advantage of the Experimental learning, different instruction is assigned in before, during and after phases respectively for every experiment. In the before phase, students are asked to do preparation according to the manual, to think over why the operation is instructed as this step by step, and to anticipate what will happen in the key step. In this way, not only will the experiment process become more effective, it will also become very helpful to enhance the logical thinking skill of the student.

In the during phase, students are promoted to more actively engage in the trial and error. Through this process, students are expected to experience the value of the teamwork cooperation and the trust and support among members. On the other hand, for unforeseen problems will almost certainly arise, when they failed to observe the expected phenomena and data, they are encouraged to survey carefully the operation steps and the surrounding circumstance, and find the main factor of the failure for themselves with the guidance of the teacher, then try to handle and observe again. This cycle will greatly intensify the understanding and flexible application of the related knowledge, which is the very knowledge acquired by the hands-on practice. Meanwhile, it is hoped to be positive to the knowledge exploring ability and decision making skill.

Finally, in the after phase, the standardization of the experiment report is stressed to train the written communication ability and develop the merit of honesty and integrity. Corresponding to the deviation of the observed phenomena and data from the theoretically deduced one, students are asked to give their own analysis and judgement. This training is worthwhile for the development of the documenting ability, especially of how to formulate the available materials to present a rigorous reasoning.

To highlight the design-directed engineering education mode, we extend the validation experiments to the design-build-test projects step by step to ensure it is within the most students' ability, such as Forward and Backward Turning control of AC motor with PLC in 2006, Starting, Braking and Speed regulation of AC motor with VFC and PLC in 2007, and Motor Control Design of NC Milling Machine with VFC and PLC in 2009. The moderate challenge is more interesting and engaging for students, and valuable to strengthen the CDIO skills.

5. ASSESSMENT OF THE COURSE LEARNING

Students are assessed with experiment report, subjective report and final exam. The term score is made up of these three parts with 30%, 30% and 40% weighting respectively. This weighting allocation shows the relative importance of the various kinds of skill building trial and make students pay attention to the whole process rather than just the final exam.

Subjective report depends on the student's own interest within the discipline scope of the course. The key point is it is student that finds what is the most interesting to him and experiences the regular grant proposal drafting procedure through the literature collection, reading and summarization. Students are expected to learn how to evaluate the various opinions basing on the fundamental knowledge. This kind of scientific thinking is also an important competency of a qualified engineer.

Open-book type examination is taken in the final exam. Students are asked to give a principle analysis of the key operation step or key phenomena of every experiment. Again, it is the motor's running characteristics and the transmission control method and the related circuit that should be thoroughly understood and mastered. The aim of the test is to highlight the application instead of the memorization of the knowledge. The exam result shows the reasonable Gaussian distribution. Around 70-80 percent of the students can give a fit answer and one student a perfect one in 2006 and 2007 respectively.

6. STUDENTS BEHAVIOR AND FEEDBACK

The most notable effect of this reform is that the usual passive attitude to the experiment is changed to active participation. According to the lab registration card, during the open hours, there are more than 20% teams choosing to do additional test or repeat the experiment to confirm the result on their own, while only less than 5% in the last year. Moreover, compared with their performance during the former several experiments, more and more students can raise the meaningful questions about the experiment operation and phenomena in the last two ones.

For the first small scale design-and-build project, most of the students can do well under the supervision of the lab teacher. For the second, it went not smoothly at the beginning, maybe because it is scheduled near the final exam and students wouldn't spend too much time on it. After giving the hint that to a large extent the project is the integration of the former experiments, their interest was inspired and most of them became more and more involved. Finally, almost all teams can reach the basic design requirements. Just encouraged by this result, we increase the project difficulty level further in this term to integrate the requirement of another course, Numerical Control Technique.

In the end of the term, the college ever did a survey on the CDIO pilot courses with questionnaire and face to face discussion. In general, the feedback is most positive. Over 65% percent students thought this kind of education pattern is beneficial to them, while others feel hard to adapt to the higher requirement and course assignment compared with before. Moreover, during the break talk, which is an effective way to keep close contact with students and get timely feedback of their perception, some students told me that they really engaged in the design project, and the try and test process gave them a sense of accomplishment and immense satisfaction.

7. CONCLUSION

Adopting the EIP-CDIO engineering education pattern, several kinds of CDIO skills training developed according to the pilot course feature has basically achieved the expected outcome. But it should be pointed that the study stress is beyond around 30% percent students' capacity and makes them lagged behind. It is the unavoidable intellectual challenge brought by the reformation due to the result of long time examination-oriented education. So we must be clearly aware that the main difference between the present education and the before is among the different requirement of the competency, knowledge, attitude and comprehensive quality, varieties of professional skill training method, and the different level of the lecturer's theory, engineering experience, and teaching skill. Among them, the change of the training methods and the students' performance evaluation criteria is the most urgent.

After the four-year EIP-CDIO engineering education plan was started through all the courses since 2006 freshman, the lecture time will be decreased by 30%-40% percent, then students will have more time to engage in the real-world like projects arranged on three kinds of scale. We hope it would be helpful to relieve the stress to some extent.

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