CURRICULAR REFORM BASED ON THE CDIO INITIATIVE IN SHANTOU UNIVERSITY

Peihua Gu
College of Engineering,
Shantou University, Shantou,
Guangdong, China

Minfen Shen
College of Engineering,
Shantou University, Shantou,
Guangdong, China

Xiaohua Lu
College of Engineering,
Shantou University, Shantou,
Guangdong, China

Abstract
This paper reports an overview of engineering curricular reform based on the integrated and holistic approach of the CDIO education frame work at Shantou University. A design-directed structure was devised to re-plan curriculum of all the five programs of the College of Engineering. To address the special need for ethics, integrity and professionalism associated with engineering education, EIP are prefixed to the initiative to the get EIP-CDIO. Initial piloting and applications show potential for success.

Keywords: specialty education, EIP-CDIO, curricula reform

Introduction

In the 1950s, the Chinese higher educational system had undergone a large scale reform, which had profoundly changed the educational paradigm in China. Following the educational experience in the former Soviet Union two major actions were taken in that reform. The first was a complete reshuffle of the departments among all universities and colleges of the whole country. The other was the introduction of the “specialty” education [1]. Rational of the reform included, besides others, to optimize the educational resources to educate large numbers of specialists at that time eagerly needed for the economical development and construction of the country. “Specialties” were identified and designed by the government according to the economical needs. “Specialty” as a commonly accepted term, is similar to, but significantly different from the term “major” of study or “program” of a degree. A “specialty” means more a specific area of working associated with positions such as casting than a profession such as mechanical engineering. That is, the program of a specialty was designed to educate the students to fit for designated positions. Such a practice served the planned economy because, upon graduation, students were assigned jobs and dispatched to their designated positions where they can work for most of their career time.

Accompanying with the specialty education was the wide acceptance of the pedagogical theory of I. A. Kairov. With respect to knowledge transmission, Kairov’s theory may be summarized as discipline-centered, classroom-centered and teacher-centered education approach. Believing that knowledge can be transmitted via indirect experiences, meaning classroom teachings, the theory requires that rigorous curriculum-syllabus-textbook system be set up to ensure the quality of teaching. Though experiments and internships may also be required, they were implemented mainly for proving the theories and gaining experiences of applying the theories, instead of letting the students construct their own knowledge bases. In short, the specialty education emphasized on theoretic transmission of static disciplinary knowledge structures to students. Not enough considerations were given to self and active learning ability of a student, dynamic development of science and technology, and the resulted changes in social and industrial practices.

With the rapid development of the market economy in China in recent years, the specialty education has been facing unprecedented challenges. Widely discussed shortcomings of the current specialty education include narrowly defined scope of specialty and less emphasis on the student's ability to creatively apply theories in practices. According to research by the McKinsey Global Institute[2], every year over 600,000 engineering graduates leave schools in China, and the graduating number will be increased as the expansion of university intake occurred in the last few years. However, McKinsey reported an estimate of less than 10% of them were suitable for working in multinational companies. One of reasons the report identified is that the Chinese educational system is "biased toward theory" where "Chinese engineering students received relatively little practical experience in projects or teamwork compared with engineering graduates in Europe and North America". Although accuracy of these findings and conclusions may be debatable, it did point out the underlying issues that universities should carefully examine.

In spite of continued efforts were made to reform the educational system in China, gaps between the graduate profiles and the societal requirements are becoming larger. A common practice of broadening the curricula is to add new courses to existing curricula. As a result the students become over burdened by a larger number of courses and have less time to participate in co-curricula activities. Practical competencies are frequently interpreted as abilities to be skillful in lab operations. Therefore, in many cases, people from regulators to curricular planners specify the numbers of specific labs or internships required. Such an input-oriented educational paradigm would result in unlimited expansion of the course list in the curricula. In fact, nobody would know what she or he would be doing in her/his life time. Prescribed specialty structures would always be insufficient to satisfy the expanding engineering and industrial demands. Apparently, we need new paradigms for better education.

In Chinese higher education, there have always been special emphases on social morality and ideological education. However, less attention has been paid to issues like the social, historical and ecological impacts of engineering practices, professional codes of practice, etc. The advancement of science and technology has greatly increased capacity and capability of humans to interference the natural environment. Therefore, it is critically important that we understand the consequences of our activities in altering the natural system. The rapid expansion of the Chinese economy has supported tremendous numbers of engineering activities. In the meantime, a great number of problems occur. Official statistics shows that in year 2006 alone, 1,523 people died in coal mining accidents [3]. Just in October 2006 alone, 16 major (meaning more than 3 casualties) accidents happened, taking 59 lives [4]. These are just a tip of an ice burger of much broad social, societal and environmental challenges. Each year engineering accidents, environmental pollutions, natural resource depletions, corruptions, intellectual property infringements, etc. emerge in huge numbers. Reasons behind these are complex. However, engineering professionals have the social and historical responsibilities to prevent these problems. Although current engineering curricula are addressing these issues through moral and ideology classes, professional ethics, integrity and responsibility should be emphasized through learning and practicing engineering professionalism.

Adoption of the CDIO Initiative

The CDIO initiative was first made known to the College of Engineering, Shantou University in the end of 2005. It was soon discovered that this initiative would provide a good solution to our challenges. The best of it is that it provides an integrated, holistic approach to addressing the changing and expanding industrial demands. In the old discipline-centered system, a student was required to take in whatever courses were prescribed in the curriculum. Focus was placed on knowledge transmission. It is hence a close system. The CDIO approach is student-centered. A student uses the curriculum as an applying example to build up her or his own knowledge bases. Education process focuses on competency development. It is hence an open system. In concept, traditionally the faculty is acting as a giver and the students as receivers. The CDIO approach would transform the faculty as a facilitator and the students as explorers. The process of the present explorations through the CDIO curricular reform combines personal, inter-personal and system competencies as well as the technological knowledge and reasoning into integrated practices.

The professional registration bodies in China are emerging quickly. However, they have not yet matured as independent professional entities as those in developed countries like US and Canada. Professional codes of practice have not yet been emphasized fully in the current professional practice. When a major incident happens, professional investigations may be carried out for the purpose of administrative and legal actions. But the findings of these investigations have not been properly included in regular university engineering curricula to ensure that the future engineering students in universities are properly prepared for professional conduct. Therefore, we took ethics, integrity and professionalism (EIP) as a special issue and incorporate them into our CDIO reform, turning it into EIP-CDIO. A new course, "Ethics and Professionalism of Engineers" is introduced in every degree program of the College. In addition, we believe in the integrated approach of the CDIO initiative and introduce a full course of the Students' Studies to help the students to develop their professionalism through both curricular and co-curricular activities. The "operation" concept and the open feature of the CDIO initiative allow the integration of the professionalism into the curricula.

Implementation of the CDIO Initiative

Dr. W. A. Wulf, President of National Academy of Engineering, USA, has his own definition of engineering as "design under constraint" [5]. We also believe that design is the essence of engineering. Hence, the design-directed approach has been adopted in implementing the CDIO initiative [6, 7]. Through a series of iterative design projects the students perceive the "constraints" in much broader contexts than the narrowly pre-designed curricula. The students learn the disciplinary knowledge and at the same time apply them under application constraints. This would help students to develop their expandable knowledge bases and competencies instead of passively receiving limited discrete number of subjects. Design projects incorporate the personal, interpersonal and system competencies and establish professionalism in context education.

As illustrated in Figure 1, projects are categorized into three levels. Level 1 projects, which are open-ended projects, if designed well, could cover most of the essential competencies of a degree program. Each level 2 project integrates a cluster of inter-related core courses. At least two Level 1 projects are required for each program. Usually the first Level 1 project is the introductory project and the second one is the final year project. Level 2 projects link individual courses and echo to the issues arising from earlier Level 1 project(s). Level 3 projects may be used for the teaching and learning of single courses, helping the active learning and knowledge constructiveness of the students.

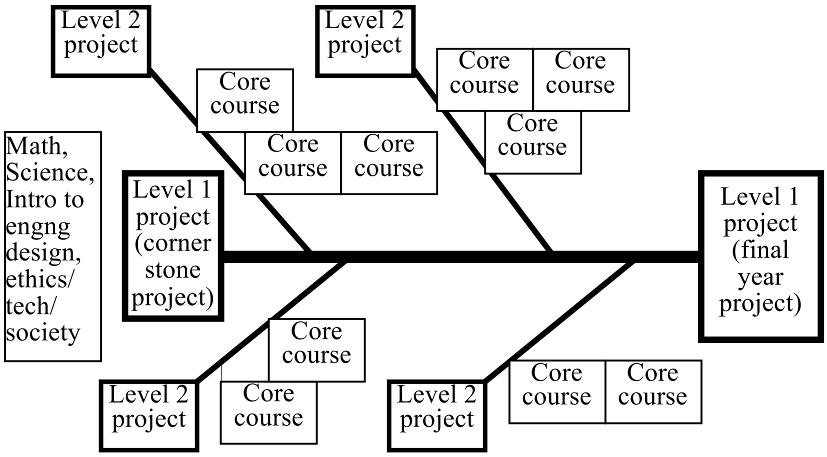

Figure 1 Curricular structure of a degree program

To specially address the EIP issues, EIP requirements are also incorporated in the objectives of individual courses and projects as well as the newly introduced independent course. Taking the curriculum of civil engineering as an example [8], in all level 1 and level 2 projects the students need to address sustainable development problems during their planning and reporting. In particular, the first level 2 project contains “sustainable construction materials” and “human habitat and green buildings”. The third level 2 project considers “construction life cycle” and “project evaluation”. These have not been in a traditional civil engineering curriculum. They are introduced into the new curriculum as a part of the integrated approach. In addition, EIP issues are further elaborated during various forums, seminars and other co-curricular activities.

Actions and Results

Following the design-directed approach described above, each of the five degree programs has completely re-planned its curriculum. To remain consistency of education, the core disciplinary content of each program has been kept largely unchanged. The most critical change is to cultivate knowledge and competencies through an integrated approach. This allows the most wanted competency trainings being seamlessly incorporated in a curriculum without expanding the course list in the curriculum. Every course syllabus lays out objectives relating to the personal, inter-personal and system competencies as well as the disciplinary objectives. These objectives would not be achieved through simple classroom teachings.

To accumulate experiences, 8 courses were selected as pilot courses in 2006/2007 semester II. These courses were still under old curricula and the integrated CDIO approach was not applied to them. However, each course could try to add some CDIO elements within the scope of the course deliveries. In the end of the semester, survey forms were distributed and 85 feedbacks were received. 48 (56%) chose discussions as "the most impressive change". In response to "the best you have gained from the course", 59 (69%) chose analytical capacities, 51 (60%) chose team spirit. With respect to the most liked changes, 32 (38%) chose the integrated experiments, 11 (13%) for discussions and 9 (11%) for the opportunities of applying learned theories. It should be pointed out that the features of the pilot courses were very different. Some did not have experiments at all. In response to "the least liked" part, 11 (13%) chose assessment method, 5 (6%) chose the way of delivering the course and 4 (5%) complained too many exercises. The student's most wanted changes in implementing CDIO initiative include facilities 15 (18%) and the faculty competencies 9 (11%). Most people, 64 (75%) supported the immediate implementing of CDIO reform. The rest felt more preparations were needed. Many people 52 (61%) were eager to know how CDIO reforms were implemented in overseas universities. In summary, most people felt positively about the reform. The student's most concerns coincide with what we are striving to change in the reform.

In 2007/2008 Semester I, 16 more courses were piloted for students in second, third and fourth year of their program (before the 2006 cohort). Again, the courses were still under the old curricula. Significant efforts had been made to shift the focus from knowledge-centered teaching to competency-centered education. An example of the change may be seen from the axle structure experiments given to Mechatronics students. The course contains six types of axle systems. Traditionally, the faculty would first explain the theories and the procedures of doing the experiments. Then the students would conduct the experiments according to a given set of instructions and then submit written experimental reports. This is a typical old process of knowledge transmission. The instructions and the procedures are proven sets of knowledge. The students are supposed to understand them and take them in as a part of their disciplinary knowledge. In the whole process the students are passive receivers.

In piloting this course in the CDIO context, the students were required to design their own assembly schemes according to theoretic principles and the objectives of the experiments. They needed to make proper choices of gear systems, axles, cog wheels, bearings, fittings and plays as well as the sequences of assemblies. Then they had to sketch assembly drawings and assemble them according to the drawings. In the following steps, testing, and modifying the design and testing were carried out until the system ran satisfactorily. The report included a written report and an oral presentation, during which, the students needed to defend their designs and answer any queries arose during the oral presentation. In such a way, the students explore the system and build up their own knowledge base. As active learners, they would learn much more than the prescribed set of knowledge/skills.

In 2007/2008 Semester I the only course taught in the College to the 2006 cohort (EIP-CDIO curricula) was "Introduction to Engineering Design". The design and conduct of this course was reported in another paper of this conference [9]. Since current Chinese university students are inexperienced in teamwork and project work, this introduction course helped the students to develop their team spirit, project management and communication skills. There was a case where a group leader complained that one of his group members was doing the minimum and this had affected the progress of the whole group. Taking this opportunity, a class discussion was conducted. Through incidents like this, we help the students to realize the importance of team spirit, ethics, integrity and professionalism. Review shows that the course was constructive in developing the student's personal and interpersonal competencies. However, measures need to be taken to confine the student's projects within realistic scopes.

Faculty competency in the new context is a critical issue in implementing the initiative. Various kinds of seminars and discussions have been held in forms of College assemblies, departmental meetings, committee meetings and working group meetings, etc. For example, because the 2006 cohort of student will soon start intensive studying with the new CDIO curricula, recently a seminar was held by the College's Teaching Committee members and faculties of all pilot courses to exchange ideas and experiences of teaching in the new context. Broad topics were discussed in the over 3 hour seminar. These included course syllabi, textbooks and teaching notes, the process of course delivery, project management, methods and requirements of exercises, experiments, reports, presentations, assessments and professionalism, experiences of handling discussions in large (>100 students) classes, encouraging students to express their of ideas, lab developments and, very importantly, how to evaluate the implementation of the initiative. Such seminars are very helpful in changing mindset of the faculties and to ensure the smooth implementation of the reform.

Figure 2 An Illustration of the Designed Hybrid Renewable Energy Generation Display

To facilitate the student's cross-disciplinary product development activities, apart from student's project centers in individual departments, a 600m^2 CDIO Innovation Center has been setup as a common platform for all students of the College. Currently 11 financially supported projects are being carried out in the Center. Among the 11 projects, "Hybrid Renewable Energy Generation Display" is a project participated by students from

Mechatronics, Electronics and Civil Engineering. They will erect a solar/wind electric generator with a digital display panel on the campus. It would become a landmark of symbolizing the cross-disciplinary, team spirit and caring for the nature and environment features of the CDIO reform.

Figure 3 Visit to the CDIO Innovation Center during 2006 National Higher Education Accreditation

The second example is the stair-climbing carrier. The device can climb stairs while keep the platform level so that goods on the platform could not fall. The main developer of this device shown in Figure 4 is currently a final year student, who spent two years on this project. He will graduate in July this year. But he already secured a job with Honda Motor (China) as early as the end of last year. This case clearly demonstrates that graduates with solid product development experiences would be more competitive in the job market.

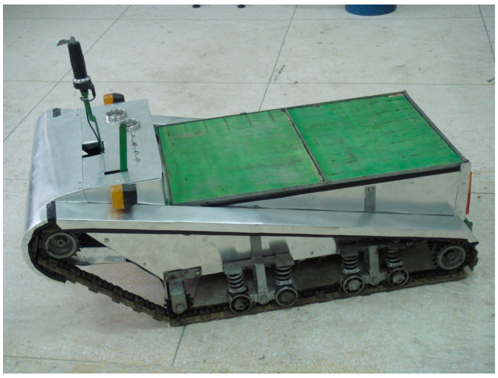

Figure 4 A Stair-climbing Carrier Developed by a Group of Final Year Students

As a part of the integrated approach, a series of co-curricular activities have been organized. There are freshmen orientation activities, Growth Salon and various club organized activities where the faculty and the students share their stories of learning and growths. In a recently completed forum, students and invited professors held a roundtable talk on sustainable development and professionalism. They shared their views on the industrial development and its impacts on the society and history. They also discussed sustainable development problems and the paradox between professional integrity and personal interests.

The World Engineer Forum invites renowned engineers and experts to exchange their experiences and views of work and life with the students. In Session 4 of the Forum, after introduced the process of developing the open source software "SciLab", a renowned professor directly addressed software pirating and scientific integrity problems. He indicated importance of cultivating professionalism and integrity in universities.

In Session 9 of the Forum the General Manager of a publicly listed company shared with the students on enterprise elements, structures and operations, enterprise culture, and finally how one should deal with industrial requirements, personal profiles and professional objectives.

In Session 10, the Chief Engineer of a research institute displayed a large array of startling engineering failures practically occurred around us. One of the cases he showed that over 30 million Renminbi (Chinese currency) was lost due to simply a wrong sequence of construction - the consultant did not define the sequence and the contractor did what was the most convenient. He further stressed that whenever there is a failure, we should scrutinize it and learn the lesson. We should flag it up instead of covering it up. University is the best venue for learning the lessons.

These activities made significant impacts on the students. The activities also help them to develop their practical, social and cultural, economic, environmental and historical perspectives and finally grow up as qualified professionals.

Summary

In traditional Chinese higher engineering education, the emphasis was placed on the disciplinary structure of "specialties" with less emphasis on development of the students as professionals. All engineering curricula have been re-designed based on the CDIO education framework, which is called EIP-CDIO. Several pilot courses have been performed. The preparations of students and faculty have been continuing since early 2006. The student survey results were positive. In analysis of the current engineering curricula, it is our believe that the integrated approach of the CDIO initiative provides a solution for transforming the engineering education from discipline-centered to student-centered. The design-directed implementation of the CDIO initiative in Shantou University appears promising for cultivating professionals for meeting growing industrial demands.

Reference

1. Jianhua Hu, "*The Origin of Modern Chinese Higher Educational System: the Higher Educational Reform in the 1950s*", Nanjing Teachers University Press, 2001 (In Chinese) 《现代中国大学制度的原点：50年代初期的大学改革》胡建华著，南京，南京师范大学出版社，2001
2. MacKinsey Global Institute, *Addressing China's Looming Talent Shortage*, MacKinsey & Company , 2005
3. State Administration of Coal Mine Safety, http://media.chinasafety.gov.cn:8090/iSystem/shigumain.jsp
4. Ministry of Construction, P. R. China, http://www.cin.cn/quality/file/2006111002.htm
5. William A. Wulf "*The Urgency of Engineering Education Reform*" The Bridge, Spring 1998, Vol 28 No.1, The National Academy of Engineering
6. Ian Yellowley and Peihua Gu, "Design Directed Engineering Education", Journal of Engineering Design and Innovation, Issue 1, 2005.
7. Peihua Gu, Xiaohua Lu, Guangjin Xiong, Shengping Li and Minfen Shen, *Development of design directed engineering curriculum based on CDIO Framework,* World Transaction on Engineering and Technology Education，Vol 5. No. 2, 2006, pp267-270

8. Guangjing Xiong, Xiaohua Lu, *A CDIO Curriculum Development for the Program of Civil Engineering*, Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007
9. Xiaohua Lu, Zhulin Chen, *Design and Conduct an Introductory Course under Current Chinese Context*, Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007

Biographical Information

Peihua Gu is Professor and Vice President of Shantou University, China. His current scholarly interests include adaptable design, life cycle engineering, CAD/CAM, education reform. He was one of four founders of Canadian Design Engineering Network (CDEN) to enhance design engineering contents in Canadian engineering education. He initiated EIP-CDIO engineering education reform at Shantou University.

Minfen Shen is Professor and Dean of the College of Engineering, Shantou University, China. He is serving as the Chairman of the Teaching Committee of College of Engineering at Shantou University. His current scholarly interest is in engineering education reform with CDIO. He is currently leading EIP-CDIO initiative in College of Engineering.

Xiaohua Lu is an Associate Professor and Deputy Director of the Department of Teaching Affairs of Shantou University. His current scholarly interests include Steel Structures, Concrete Materials and educational reform. He is one of the key leaders in developing and implementing EIP-CDIO curricula at Shantou University.