A CASE STUDY ON CDIO IMPLEMENTATION IN CHINA

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ABSTRACT

The CDIO Initiative has been gradually introduced into China from 2005. With the full-scale implementation in Shantou University and the involvement of the Chinese Ministry of Education (MOE), it had soon become a national-wide initiative. A group of institutions were gathered to implement CDIO. The pilot group has been very active in practicing, sharing and disseminating the CDIO initiative. It attracted 39 member institutions and influenced over 200. Shantou University and many other Chinese universities have been undertaking the CDIO based engineering education reform and have achieved significant results. These institutions have been undertaking comprehensive review of all aspects of engineering education, including definition of program objectives, detailed syllabus codifying the standards of the program objectives, development of the integrated curriculum, the implementation of active learning methods such as inquiry-based and project-based learning and establishment of quality assurance and continuous improvement system of programs. CDIO is becoming one of the effective ways in China to promote the reform of national engineering education.

KEYWORDS

Engineering education reform; CDIO pilot group; Program syllabus; Integrated curriculum.

INTRODUCTION

CDIO represents Conceive, Design, Implement and Operate. It sets operating life cycle of products, processes and systems as engineering educational context and builds an integrated system of training standards and curriculum for active and practical engineering learning. CDIO composes and the knowledge, skills and qualities that a qualified engineer needs, then organizes them, and refines them to be observable and measurable in learning outcome, and ultimately constitutes the CDIO Syllabus and 12 Standards. CDIO Syllabus and Standards are two key guidance documents of CDIO.

From 2005, CDIO Initiative was introduced into China. In 2008, the Chinese Ministry of Education (MOE) supported Shantou University to establish a working group, named CDIO Working Group including 39 members. The pilot group has taken a lot of very active working to promote the reform of national engineering education with CDIO mode.

CDIO DEVELOPMENT IN CHINA

CDIO pilot group of institutions in China

The CDIO initiative was introduced in China soon after the start of worldwide CDIO Initiative. Shantou University started implementing CDIO as the first Chinese institution in 2005. Many other universities joined in CDIO organization and started systematic implementation work with

CDIO-based education reform, such as Tsinghua University, Beijing Jiaotong University, Chengdu university of Information and Technology and so on. CDIO Initiative has become a planning supported by Chinese Ministry of Education (MOE) initiative in China.

It was later realized that practical implementation of the method is more important than investigations. Thus, a group of 18 institutions named "CDIO Engineering Education Study and Practices Group" was formed to implement CDIO. This group was led by Shantou University and supported by MOE. All the participating programs among the 18 institutions are at bachelor level. The programs were divided into four fields, including civil engineering, mechanical engineering, electric & electronic engineering and chemical engineering.

Since 2009, the pilot group of institutions meted twice every year to exchange working experiences and provide training workshops. The meetings are open to everyone. Hence, CDIO had been disseminated rapidly. People from over 200 institutions have participated in workshops or have visited the pilot institutions. By 2012, the number of the pilot institutions had been expanded into 39. It was then decided that the pilot group should not be increased. The higher order experiences should be drawn from the implementation.

In June 2010, MOE started a national engineering educational initiative named "Excellent Engineering Education Plan". This plan has adopted the outcome-based approach in learning objective setting and required integrated approach in curriculum design. Apparently, the CDIO methodology and the implementation experiences summarized by the CDIO pilot group have played very important roles bringing in impacts into the national plan. Shantou University has thus in many cases required to undertake the workshops and to present the integrated approaches used in the CDIO initiative to other institutions.

There were more than 300 people attended the CDIO meeting held in December 2011 at Nanjing Institute of Technology. After 2012, the Pilot Group planned to organize CDIO annual conference at the end of each year.

CDIO development in Shantou University

In October 2005, the College of Engineering, Shantou University, started CDIO engineering education reform and become a member of worldwide CDIO Initiative Group in 2006. On the basis of CDIO, as well as the advanced undergraduate education philosophy, and special requirements for current socio-economic engineers at Ethics, Integrity, and Professionalism, the college integrated Ethics-Integrity-Professionalism into CDIO with the essence of innovation. It started implementing design-oriented EIP-CDIO engineering education from Grade 2006 students. The University conducted a series of explorations and practices including the construction of CDIO framework of programs, CDIO training standard system, integrated curriculum system design, project-based learning and teaching system, and quality assurance-assessment-improvement system.

Design is the core in the product life cycle, which means through the design-oriented learning students acquire the technology and practice skills and find the engineering directions. It's different from the traditional ways of teaching to more variety through the changes of teaching facilities and resources planning. Questions are designed to present general learning goals and contents while all the answers can be found in the process of C-D-I-O. Meanwhile, students can acquire the teamwork and communication skills as well as overall planning ability. In the continuing design and practice process, they gradually "feel" what engineering is.

However, the work is still facing many challenges. The greatest challenge is the sustainability of the initiative. Many people simply take CDIO as equal to project-based learning. They claim that they have been practicing CDIO long before they understand the connotation of CDIO. Therefore, in many cases, not enough attention has been paid to context changes and the corresponding changes in curriculum design, teaching, learning and assessment. In addition, short of evaluation mechanisms make it hard to improve the reform continuously and hence sustainably.

Realizing the challenge, Shantou University has been making significant efforts to consolidate internal achievements. By increasing faculty buy-in, the group expects to collect some high quality practical examples. We will compile these examples into a guide for practice and carry out workshops using these examples. It is hoped that by doing so we would change the perception and practice of the faculty and make the sustainable changes. Further, the theme of pilot group annual conference is sustainability in 2012. We will discuss this issue and display selected examples national-wide to promote sustainable CDIO implementations.

CDIO IMPLEMENTATION IN CHINA

Core work of CDIO education reform in Shantou University

According to the characteristics of the EIP-CDIO, Shantou University made a general idea of integration reform (shown in fig.1) Based on this top-level design, the university has been undertaking/promoting the integration reform in all aspects including defining unambiguous program objectives, making detailed syllabus (knowledge, ability and quality), developing integrated curriculum, implementing active learning methods and establishing assurance and formulating continuous improvement system, which constitute the core of the integration reform process and keep improving in a four-years cycle from the entrance to the graduation.

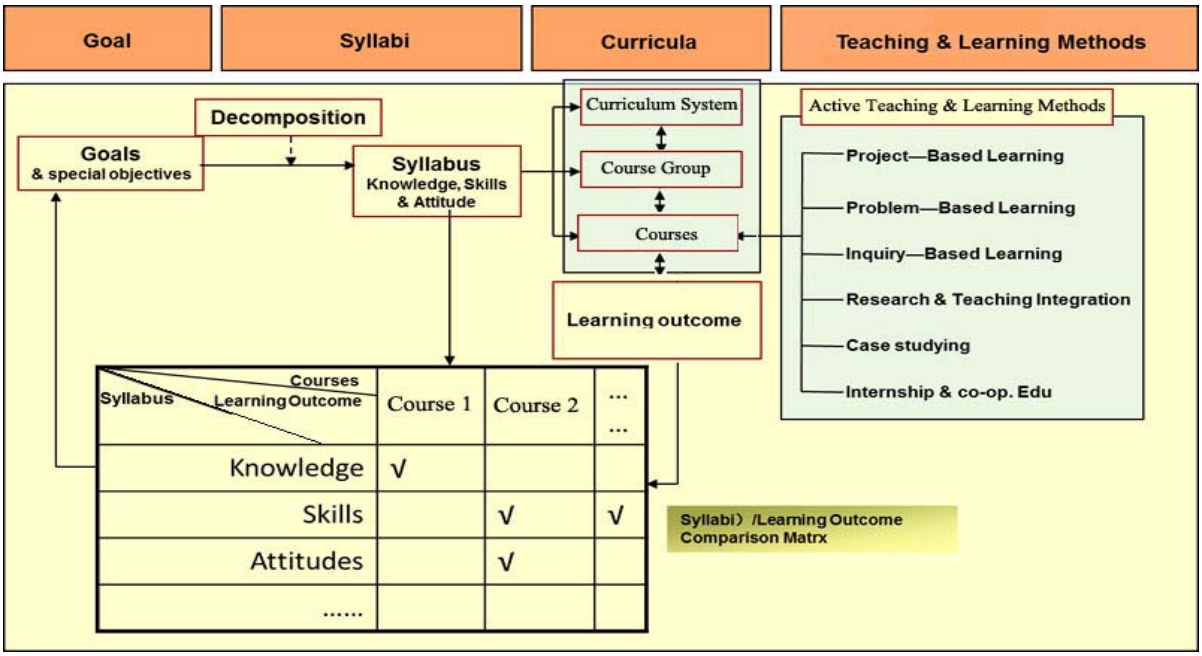

Figure 1. General idea of EIP-CDIO engineering education in STU

The seven core work in STU will be as follows:

Work 1: Top-level design with specific missions and program objectives

With the vision and position of a program as well as talent training requirements of the university, we designed the macro objective of talent training as the mission of a program. According to the future development and positioning of the program, the requirements of society, and the role and duties of future employees, we set the training objectives and requirements which include these questions: what knowledge, skills and quality should be mastered by the graduates? Are they ready for their future work? The top-level design displays the vision, the objectives, the strategy of the program and requiring knowledge, skills, quality and so on by a simple way. So the stakeholders can quickly understand the program's mission and objectives.

Work 2: Detail design with the program syllabus

In order to achieve the training goals of CDIO, we need to decompose and refine the learning outcome of engineering graduates. Therefore, we made the syllabus, which is a set of objectives with integrated, detailed, and observable learning outcome.

In order to achieve the above objectives, for example, Civil Engineering Program made the syllabus including four aspects: (1). technical knowledge and reasoning ability. (2). personal quality, professionalism and attitude (integrity). (3). Interpersonal abilities: teamwork and communication ability. (4). C-D-I-O in enterprise and social environment. All of these belong to the first level of EIP-CDIO Syllabus. And then the first level is refined and decomposed. For example, technical knowledge can be decomposed into three parts: 1.1 Knowledge of underlying mathematics and science; 1.2 fundamental knowledge of engineering; 1.3 advanced engineering knowledge that constitutes the second level of EIP-CDIO syllabus. And so on, all points continue to be refined and decomposed until that the teachers consider EIP-CDIO syllabus requirements can be assessed in specific courses and teaching processes.

Work 3: Detail design with integrated curriculum

On the basis of CDIO and combined with Shantou University's philosophy and the program feature, the college of engineering established an integrated curriculum with three-level of design-oriented projects as the main support.

Inside the three-level project skeleton, the knowledge and comprehensive ability training, course learning and interest, and knowledge learning, personal competency development, teamwork and communication, as well as macro-controlling ability are organically integrated.

For example, Mechanical design manufacturing and automation program in STU, its integrated project-design-oriented curriculum is based on the EIP-CDIO syllabus and the survey of stakeholders. It designed the curriculum including three level-1 projects for several simple mechanical and electrical products, four level-2 projects for group course, and several level-3 projects for each course, which was shown in figure 2.

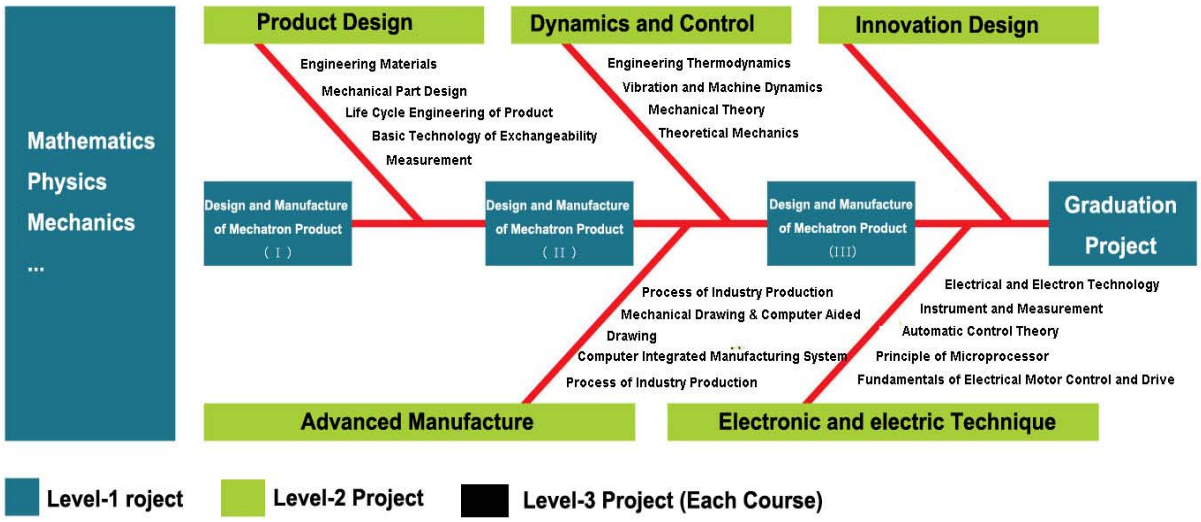

Figure 2. Project-design-oriented curriculum of Mechanical design manufacturing and automation program in STU

Work 4: Detail curriculum documents design with course portfolios

In each course file, its function in the training plan is refined. Moreover, it is explicit in the course properties, goals, schedules, teaching methods, prerequisite courses, follow-up professional courses, assessment methods, teaching materials, and other important content in the curriculum. More importantly, the required knowledge, the capacities, and the corresponding teaching contents are clearly defined in the course outline.

What's more, the effect of these contents can be assessed. Level-3 project is the most important part to consolidate the knowledge and capacity. Therefore, level-3 projects are designed in each course, which reflects the core knowledge and training objectives, and be small-scale, low-cost, and short-time. A detailed project instruction is required in the files too.

Work 5: Feature personal lesson plans for instructing class

The setting of each course file means that the course instructor has established his/her lesson plans for instructing the class, rather than just PPTs or other materials. Each lesson plan is generally for a two-hour lesson. It gives in detail the objectives, contents, knowledge, the CDIO capacities (use the level-4 indicators) and so on. Then for each section, it gives the auxiliary materials, teaching methods and strategies (questions, examples, quizzes, etc.). The lesson plan is very detailed. It requires the accumulation and improvement of years on work on the basis of a serious attitude and practice. It embodies the teacher's featured or charming teaching methods which does not seek stereotyped but encourage the innovation of their own characteristics.

Work 6: Teaching and learning methods with project/question-based inquiry learning

Project-based learning organically integrates course through project design. All the training contents are trained around the team projects and make a whole. The CDIO requiring abilities are trained during the project.

In a single course teaching, EIP-CDIO first called for reform in the course syllabus which traditionally contains only the knowledge requirements, into an integrated one with a set of knowledge, ability and quality requirements

Under the new syllabus, It requires the reform of teaching content and activities, to broaden their knowledge (strengthen relationship with other courses), to reduce teaching hours and increase discussion and project hours. Finally, it requires changing the learning outcomes assessment by reducing the proportion of written test results, and increasing that of the team design project results.

Work 7: Continuous improvement system with the quality assurance

The College of Engineering quality assurance system in the engineering education is mainly composed of four parts: survey and feedback of stakeholders, teaching process management & quality assurance system based on ISO certification, professional certification and engineers certification.

The survey of stakeholders is mainly used to assess if the EIP-CDIO syllabus, which is developed by institutions meets the requirements of stakeholders. Timely adjustments will be made according to the feedbacks. For example, the civil engineering teachers conducted a survey of professional engineers who has been engaged in civil engineering industry for nearly ten years.

Work features in other Chinese CDIO pilot institutions

In recent years, the first and second batches of CDIO pilot institutions and characteristic programs in dozens of universities have achieved significant results in promoting CDIO engineering education reform. In the implementation of CDIO, the schools have reconsidered the approaches of engineering education reform, reconstructed the syllabus, curriculum, training implementation, practice environment, and assessment mechanism, and explored the localization and characterization of CDIO in many aspects.

Work 1: Improve program training plans

CUIT (Chengdu University of Information Technology) has designed training plans for each program and reconstructed the curriculum. The curriculum emphasizes the organic combination of professional knowledge learning and quality development, theory and practice, learning inside and outside class, imparting knowledge and educating people, learning skills and creative thinking training. Besides, it redistributes the available time and teaching resources, compresses total class hours, balances ability training and disciplinary knowledge, sets the courses modularly, and provides options for students in broadening knowledge and improving the engineering quality.

The Engineering design and analysis program in Yanshan University have used CDIO concept as a guide, and integrated traditional mechanical design concept with the courses like CAD/CAE Technology to set the project-based curriculum suitable for metallurgy heavy machinery and equipment. This curriculum system focuses on the training of the engineering application as well as design ability, and has achieved good results.

Work 2: Implement project-based learning methods

Yanshan University has a lot of successful experiences in implementation of project-based learning and other active learning methods.

Mechanical design and analysis program in YSU, for example, has taken the CDIO engineering education concept as a guide, and designed an integrated project-based curriculum system, which includes 7 level-3 course projects, 1 level-3 practical project, l level-2 project, and 1 level-1 project, and is called "metallurgical machinery equipment structure and CAD/CAE technology, experiment/practice" (as shown in figure 3). The system attaches much importance to fundamental professional knowledge and engineering ability development.

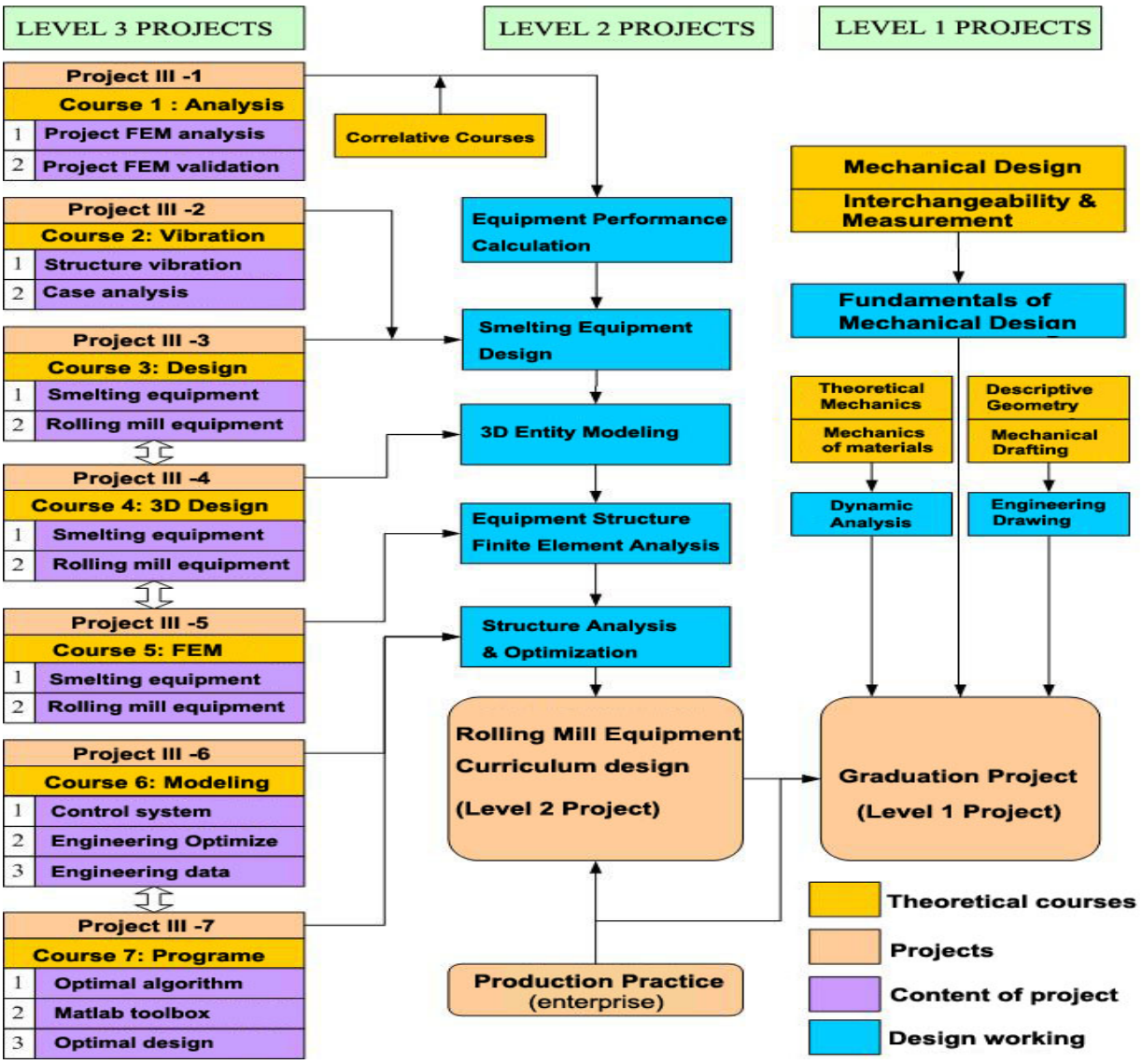

Figure 3. CDIO project structure diagram in Yanshan University

Work 3: Improve assessment mechanism

CUIT has conducted a lot of explorations on teaching quality assurance and assessment. It made the flow chart about innovation team and project management, and used computer

database management, which greatly enhanced the management convenience of project-based learning. Moreover, the strict implementation schedule was made.

The program of mechanical design, manufacturing and automation in Northeast Petroleum University has designed a multi-party assessment system, as is shown in Table 1, to make improvements on many aspects of traditional project assessment, such as an array of abilities of cooperation, innovation, organization, information acquisition, and social communication.

Table 1. Capability evaluation sheet of project design in Northeast Petroleum University

Category	Knowledge/skills	Per.
Technical knowledge	Fundamental science knowledge (1-10points)	30
	Fundamental professional knowledge of engineering (1-10 points)	
	Advanced Professional knowledge of engineering(1-10 points)	
Engineering ability	Problem solving skills (1-6 points)	30
	Application of knowledge (1-6 points)	
	Logic thinking and system thinking (1-6 points)	
	Creative thinking and lifelong learning skills (1-6 points)	
	Professional qualities and social responsibility (1-6 points)	
Teamwork spirit	Teamwork spirit (leadership, organization and execution) (1-10 points)	20
	Communication skills (including foreign language proficiency) (1-10 points)	
CDIO ability	Understanding of enterprise and society context(1-10 points)	20
	Understanding of product development process (1-10 points)	

CDIO IMPLEMENTATION EXPERIENCES IN CHINA

Any reform must have a strong driving force. For instance, Shantou University's main leader personally planned and conducted the EIP - CDIO engineering education reform. He introduced CDIO Initiative to teachers and students in college of engineering for many times and participated in the CDIO seminars and training classes in the college. Besides, he helped to gain the resources to support the EIP - CDIO reform in the college and set the stage for the reform and promoted exchange and cooperation with well-known international institutions and universities, like MIT, and so on.

Only all members participate in the reform with an active attitude, the reform can achieve success. During the reform of CDIO engineering education in pilot schools, the faculty was fully aroused. They participated in various CDIO seminars and international conference actively and undertook CDIO education projects. In addition, the CDIO syllabus, curriculum, single course outline, team project design, and student assessment plans are made and implemented with all faculties involved.

It is crucial for the sustainable reform to provide the necessary resources. Education reform can’t reach the anticipating goal unless have provided long-term stable sufficient resources. Therefore, all the pilot institutions endeavored to raise resources to strengthen the support for CDIO, not only including the capital, laboratory equipment facilities and other hardware resources, but also including software resources like time, organization power, opportunities, and so on.

Shantou University and other pilot institutions have come across a lot of difficulties during implementation of CDIO, such as problems of the participants’ enthusiasm, qualified faculty, the investment, the evaluation and so on. Through explorations and attempts, we have accumulated

a lot of experiences (shown in Table 2). But we all know that even the perfect education mode, the perfect rules and regulations can't replace people's attitudes like enthusiasm and responsibility in actual operation. Therefore, teaching and research activities and quality assurance are two key points for the success of education reform.

Table 2. Experiences of CDIO implementation in China

Problems and Difficulties	Experiences
Introduction & continuous improvement	CDIO documents investigation
	Discussions between universities and institutions
	Joining in engineering education reform seminar
Teachers' participation	Discussions of teaching research
	Clear common objectives
	Faculty professionalism improvement
	corresponding reward and punishment
	Active effects of leading faculty
Course/project teaching and practice	Clear objectives/operation procedures
	Project instructions
	Teachers' consciousness
Employment conditions with teaching, scientific research and service work	Learning outcome-based teaching quality assurance
	Education reform work performance
	Define each teacher' s responsibility for education reform
	Set senior specific teaching posts

CONCLUSION

As we can see from the implementation results of pilot schools in recent years, CDIO engineering can be the supportive point to improve the quality of engineering education. It can be a model for the program structure adjustment, and featuring program construction. CDIO have provided a systematic approach to improve the talent training quality, and played a leading role in engineering education. At the same time, it will strongly promote the establishment of engineering accreditation and the university's internal quality assurance system, and accelerate internationalization of Chinese engineering education. CDIO is in good response with the challenge of Chinese engineering education. And it's believed that CDIO will be of more diversity in application in China.

Integrated with creative experiences in more and more universities, it is believed that CDIO concept will be of more diversity. CDIO is an open system, encouraging self-dependent innovation according to the actual situations of programs, institutions and countries. In the future reform, all institutions should be innovative to learn CDIO and explore new approaches of education in international education context with an open mind.

REFERENCES

[1] The Chinese academy of engineering education committee. Explore the Chinese engineering education reform road, Higher engineering education research, 2007, (6):43-47.

[2] Edward Crawley, Johan Malmqvist etc. The CDIO Syllabus v 2.0 – An Updated Statement of Goals for Engineering Education[C]. Proceedings of the 7th International CDIO Conference， Technical University of Denmark, Copenhagen, June 20 – 23, 2011.

[3] Gu Peihua. From CDIO to EIP-CDIO: explore engineering education and talents training mode in Shantou University. Higher engineering education research, 2008,(1):12-20.

[4] Edward F. Crawley et al. Rethinking engineering education: the international CDIO training mode and method. 2009.

[5] Ian Yellowley, Peihua Gu. Design Directed Engineering Education [J]. Journal of Engineering Design and Innovation，2005，1(1):1-7.

[6] Lu Xiaohua, Xiong Guangjing, Chen Zhuling. Design oriented engineering education concept. Higher engineering education research, 2007, (6):83-87.

[7] Wang Tianbao. Implement CDIO to promote our school education teaching reform (second section). Journal of Chengdu University of Information Technology, 2009 (03).

[8] Wang Tianbao, Chen Wridong. Research and Implementation on innovative engineering talent training mode with CDIO. Higher engineering education research, 2010, (01):28.

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