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Application and Development of CDIO Engineering Education Mode in Undergraduate Science Program

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Enlightened by successful implementation CDIO (Conceive, Design, Implement, and Operate) in Engineering Program, CDIO is applied to undergraduate science program in Chengdu University of Information Technology. In this work, CDIO is adapted into science program as a systematic framework including setting explicit professional training standards, reconstructing curriculum system, optimizing theoretical and experimental teaching mode, and intensifying process assessment. The results show that the adaptation of CDIO can inspire the interests of study as well as the practical ability of students in undergraduate science program.

Key words: CDIO, Undergraduate science program, Training standard, Curriculum system, Course designation, Process assessment.

1. Introduction

Established in 2004, engineering education mode of CDIO (Conceive, Design, Implement, and Operate) was based on the philosophy of product life cycle. In CDIO mode, the students learn engineering and obtain engineering ability in the way of initiative, practice, and courses with effective connection [1, pp. 1-4]. Thus make CDIO mode suitable for cultivating engineering talents of engineering majors.

Since 2008, Chengdu University of Information Technology (CUIT) has taken the lead in implementing the CDIO engineering education mode in China, which was involved in all engineering majors in the aspects of teaching theory, teaching plan, curriculum system, teaching method and assessment method. The reform process and results have gained the recognition of domestic and international peer.

Besides the undergraduate engineering program such as Electronic Engineering, Computer Science and Optical Engineering, multi science programs are taught in CUIT such as meteorological science, applied physics and applied mathematics. The education mode carried on in the past is focusing on the theoretical knowledge which ignores the knowledge application. The modification and development of this old education model is crucial for better ability of scientific thinking, knowledge application, problem solving as well as creation.

In 2011, enlightened by CDIO engineering education reform, CUIT introduced the educational theory focusing on the raise of comprehensive ability of students combined with knowledge, ability and quality together in the science major cultivation program, learned from the ability cultivation standard out of the engineering education standard to creatively apply CDIO teaching method into science major education and implement assessment module of equal stress on both taught knowledge and practical ability. Based on those reforms, CUIT proposed and propelled the integrated education and teaching reform in science majors [2].

ENGINEERING EDUCATION 16'2014

2. Curriculum for undergraduate science program in CDIO

2.1 Setting explicit professional training standards

According to the professional knowledge and ability requirements of the Ministry of Education and the ability and quality demand of science talent from society, industry and enterprise, we set the training standards for knowledge, ability and quality of science talent. The standards are the basic training goals. The standard syllabus is divided into three professional levels and four ability levels of professional knowledge, personal and team skills, science and humanities. Table I demonstrates the training standards of Applied Physics.

(1) Professional training indicators

As shown in table 1, there are three levels of ability indicators from left to right. Four first level indicators represent four kinds of general capability of science talents, and every ability field is divided into many second level indicators which represent ability categories with professional characteristics. And then

Table 1. Training Standards of Applied Physics

First level	Second level	Third level
1. Professional knowledge and the humanities	1.1 Mathematical and physical fundamental knowledge	1.1.1 Higher mathematics, linear algebra and probability theory
		1.1.2 Basic theory and experimental method of college physics
	1.2 Engineering fundamental knowledge	1.2.1 Engineering introduction and basic theory of engineering drawing
		1.2.2 Basic knowledge of computer
		1.2.3 Circuit and electronic application technology
	1.3 Professional fundamental knowledge	1.3.1 Basic theory and method of theoretical physics
		1.3.2 Structure, composition, preparation and properties of solid materials
		1.3.3 Semiconductor optoelectronic materials and the properties
		1.3.4 Physical basis, design and manufacture of photoelectric device
	1.4 Humanistic literacy ability	1.4.1 Basic knowledge and ability of the humanities
		1.4.2 Humanistic spirit and character
		1.4.3 Historical and cultural environment
		1.4.4 Contemporary issues and values

2. Technical ability, professional skills and attitude	2.1 Experimentation and knowledge discovery	2.1.1 Ability to access to scientific literature and information
		2.1.2 Preparation of optoelectronic materials and optoelectronic devices according to the experimental scheme
		2.1.3 Testing and evaluation of experimental results
	2.2 Design and implementation of the comprehensive experiments	2.2.1 Put forward and express the problems of optoelectronic materials and devices
		2.2.2 Design and preparation of photoelectric material
		2.2.3 Design, simulation and making of photoelectric devices
		2.2.4 Testing, analysis optimization of material device performance
	2.3 Design, implementation and innovation of systems	2.3.1 Conceive, design and preparation of new photoelectric functional materials
		2.3.2 Design and implementation of optoelectronic devices and systems
		2.3.3 Judging the constraints of material devices and systems
		2.3.4 Pursuit of innovative attitude and awareness
	2.4 Professional skills and attitude	2.4.1 Keep pace with the development of world engineering technology
		2.4.2 Occupation morality and sense of responsibility
		2.4.3 Active planning of personal occupation development goals
		2.4.4 Keep the lifelong learning with physical and mental health
3. Interpersonal skills: teamwork and communication	3.1 Teamwork	3.1.1 Building effective team
		3.1.2 Keep team operation
		3.1.3 Team work
	3.2 Communications	3.2.1 Basic communication ability and skills
		3.2.2 Written communication
		3.2.3 Multimedia (data, chart) communication
		3.2.4 Oral expression skills
	3.3 Communications in foreign languages	3.3.1 Certain English ability in listening, speaking, reading and writing

4. Conceiving, designing, implementing and operating systems in the enterprise and societal context	4.1 Society and industry	4.1.1 Know the culture industry, objectives and planning
		4.1.2 Social entrepreneurship
	4.2 Design and production ability	4.2.1 Set the performance goals of photoelectric devices and the system's
		4.2.2 Decomposition of design of photoelectric device system
		4.2.3 Production of materials, components, modules and systems
		4.2.4 Testing, verification and certification

the third level indicators are the specific abilities which are developed in the courses. The decomposition of indicators realizes the transformation of the training standards from macro to micro.

(2) Ability level

As shown in the table, there are four ability levels from top to bottom. The first level is professional knowledge and the humanities, the second is technical ability, professional skills, the third is the ability of communication and cooperation, and the fourth is the ability to adapt to industry. The four levels reflect the comprehensive training of students' knowledge, ability and quality.

2.2. Reconstruction of curriculum system

Based on the professional training standards, the courses are divided into four categories which include public basic courses, basic disciplinary courses, professional courses and practice. We reconstruct the curriculum system according to the process of decomposing the standards, optimizing the basics, integrating courses content, and penetrating projects. The implementation of training standards are decomposed to every course, meanwhile, practice projects in three levels which include course, course group, and profession penetrate the entire training process. The knowledge modules are organically linked, and the curriculum system with knowledge, ability, and quality is formed.

Students' key abilities are gradually cultivated in the practical projects and related courses. Innovative experiments and cross, comprehensive design innovation experiments combined with professional basic theories broaden students' horizons and innovative thinking, and the individual needs of students are met in diversified innovation practice and entrepreneurship training projects.

3. Course designation based on CDIO in undergraduate science program

CDIO emphasizes on the ideas of Conceive, Design, Implement, and Operate to cultivate comprehensive ability of students in order to effectively promote the student learning ability as well as personal skills. In order to make student fully command the knowledge and promote their personal skills, we adopted CDIO active learning method on the science major education to enforce students to learn knowledge actively and forge them to put the knowledge into practice actively.

3.1. Active theory of teaching

We succeed in realizing the transformation of the single teaching way that focus on teacher's explanation of knowledge together with student's listening to the class into the active and multiple-interaction teaching way. We adopted diverse teaching methods to use applied exemplification to guide teachers and supervise students to take part in the theory

METHODOLOGICAL SUPPORT OF CDIO IMPLEMENTATION

ENGINEERING EDUCATION 16'2014

teaching as well as extracurricular special training, the purpose of this is to cultivate student's skills into implement.

3.2. Independent experimental teaching method

In experimental teaching, we take the single experimental project as the basic teaching unit to set up the index of project capacity as well as student's independent experimental project. During teaching process, teachers will change the role of speaker into guide; students will change the role of involver into active experimental actor in the experimental project in order to enforce their experimental skills and comprehensive ability.

The student's independent experimental process implements the idea of CDIO including the design of independent experiment, completion of independent experiment process, analysis of experimental results, access personalized experimental results and promotion of personal skills. That process will fully manifest the open experiment contents, process and results. Under the supervision of teachers on the experimental design and process, students will experience the whole view of CDIO training process, which will further enhance the cultivation of student's experimental skill as well as comprehensive ability.

3.3. PBL training

Project Based Learning (PBL) is one of the key approaches to carry out comprehensive engineering training. The students take the initiative to be involved in the whole process of PBL and experience the gradually changing problems in the process. The students are divided into several teams and carry out the project simultaneously [3, pp.17]. How to manage the teams effectively at the same time? Self-management is the answer. This is our idea of integrating teamwork into PBL in order to foster the skills of inner-team. Furthermore, the competition is introduced into PBL. The student's teams can compete with each other in learning process. This is helpful to the active implement of the project.

4. The assessment of knowledge and ability in the frame of CDIO ability standard

4.1. Processed assessment

We adopted multiple assessment method to supervise real time knowledge and skill cultivation process, increase usual process assessment and improve score of ratio in the usual assessment. It includes three categories:

(1) Conventional investigation: it focuses on the assessment of student's class discipline, learning attitude, regular homework completion. This assessment will occur in different teaching process in order to ensure the normal teaching order and emphasize on the assessment of student's knowledge learning.

(2) Special assessment: it focuses on the assessment of student's completion of specific task during learning process, mainly occurs in the second or third levels of teaching process. According to requirements of different teaching methods, the assessment will be based on the specific task or the learning results to examine the student's understanding of knowledge as well as the application of knowledge into practice in different teaching process.

(3) Ability assessment: it focuses on the assessment of student's personal skills manifested in the completion of specific task and the assessment of expected teaching goals by using different teaching methods.

4.2. Diversification of final exam

We made reform on the proposition exam paper, trying to reduce the assessment only on the memory of knowledge from books and increase the exam types of knowledge understanding and application. It requires students not only command correct concepts, principles,rules and methods but also requiring students to solve practical problems by using qualitative analysis and quantitative estimation. We used double assessments on student's knowledge and ability through exam of applied case analysis and applied design.

5. Conclusion

Based on the comprehensive promotion and sufficient practice of CDIO education model in our engineering majors, we reformed cultivating mode of science majors from the education idea, training standards, curriculum, teaching methods, and assessment methods. The application and development of CDIO model make educational goals of knowledge, ability, and qualities more specific for educational subjects, and then the educational process is more effective. Teaching practice has achieved initial results which demonstrates positive results of implementing CDIO education model in undergraduate science programs.

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