Innovative Education Model Based on CDIO and Innovation Practice Base

Shi Dong-yan[a], Teng Xiao-yan[a] and Chen Yan[b]
College of Mechanical and Electrical Engineering, Harbin Engineering University, Harbin 150001[a], College of Aerospace and Civil Engineering, Harbin Engineering University, Harbin 150001[b]
Corresponding Author Email: shidongyan@hrbeu.edu.cn

CONTEXT
The CDIO (Conceive, Design, Implement, Operate) as a new engineering education mode does follow the concept of modern engineering education. Innovation education is the theme of education reform in the world in 21 Century, and also the goal and the trend of educational development. In order to meet the needs to the development of international higher engineering education, a series of innovative entrepreneurship courses are opened by Harbin Engineering University recent years and the practice base about university students' scientific and technological innovation activities is established. The construction and development of the base provides a strong support to integrate CDIO and innovative education. Therefore, the application and innovation abilities of students are effectively promoted to become innovative engineering and technical personnel.

PURPOSE
This paper aims at cultivating innovative talents for the purpose of future development needs by innovative education model based on CDIO and innovation practice base.

APPROACH
CDIO and innovation education is integrated relying on innovation practice base. In the project, the group as a team (5-6 persons) hold an interaction, discussion and practice. Innovation platform is provided to students by opening experimental environment. To stimulate interest in learning, students are encouraged to participate in science and technology innovation contest and carry out scientific research projects, which strengthens the foreign exchange and develops the innovation practice base extension.

RESULTS
5 innovation practice courses, totally 420 hours, are offered in the past three years and 1255 students enrol in courses. The number of course-selecting students on average increases by about 10% year by year, and the attendance rate is more than 98%. Before the deadline for submission, 22 awards in innovation and technology competition have been obtained, and 28 new utility model patents and invention patents have been authorized in total, which shows the remarkable teaching achievement.

CONCLUSIONS
By the teaching practice in recent years, it has been proved that the teaching model which combines CDIO with innovative education is applied in the course teaching, so that students can participate in scientific research and innovation practice as soon as possible. A series of remarkable achievements prove that it is feasible to integrate CDIO into innovative education, and it can be popularized in other universities and colleges.

KEYWORDS
CDIO; Innovative practice; Innovation practice base.

1. Background

From the trend of world education reform, it is the tide of the world education reform to pay attention to the cultivation of talents, especially creative talents. Since the cultivation of innovative talents must rely on innovative education, innovative education is the theme of education reform in the world in 21 Century, and also the goal and trend of educational development (Liu Yan et al., 2014). The basic purpose of promoting innovative education is to culture high-quality personnel of innovative spirit and practical ability to improve the quality of education.

It has become a consensus in the field of higher engineering education that a large number of innovative engineering and technical personnel are trained to construct a country rich in human resource. In fact, culturing innovative engineering and technical personnel need higher engineering education reform. CDIO reform is a representative of engineering education reform, and can promote the development of engineering and educational. CDIO represents Conceive, Design, Implementation and Operation, which is the representative of "Learning in practice "and "Education and learning based on the project". CDIO mode which achieves the innovation of engineering education model is the latest achievement in international engineering education reform in recent years. It has inherited and developed the theory of engineering education reform in Europe and America over the past 20 years (Bankel et al., 2003). The cultivation of innovative engineering and technical personnel based on CDIO is not only one of the goals of innovation education, but also a reflection of the achievements of educational innovation.

Since engineering innovation has the characteristics of complex, comprehensive and interaction, it means that engineering education basing culturing innovative talents is compound. The goal of university engineering education aims culturing engineering talents with composite knowledge background who can lead the development of the industry in the practice of engineering innovation. Engineering innovation and entrepreneurial talents who are cultured under this goal should have engineering practice ability, multi-disciplinary background and holistic thinking mode. Also skills of coordination, communication, teamwork and leadership skills are needed. They should have the comprehensive quality of dealing with the relationship between engineering and ecological environment, economic development and social progress.

2. Objective

This paper aims at cultivating innovative talents for the purpose of future development needs by using CDIO based inquiry teaching method of innovation practice. Consequently, this paper employs project design oriented CDIO teaching mode, takes the innovation and entrepreneurship courses as the carrier. A new teaching method whose basic features are "project as the main line, practice as the platform, teachers as the guide, students as the main body, CDIO ability training" is formed.

3. Analysis of domestic and foreign research status

The so-called innovative education, is an education form to cultivate innovative spirit, innovative consciousness, innovative thinking, innovative ability and innovative habits. It takes the depth development of human innovation activities as teaching materials, through innovative mechanism study, innovative case analysis, innovative design and other aspects of teaching. Innovative talents are not born with innovate abilities, on the contrary, most of them are gradually acquired through learning and practice. Therefore, carrying out the innovation education is the most direct and effective way to cultivate the innovation ability. How to cultivate innovative engineering and technical talents is one of the focal problems in the reform of higher engineering education at home and abroad. In recent years, with the idea of CDIO, the new concept of "teaching and learning" in CDIO is put forward. Aiming at the main problems existing in China's current higher engineering education, a new mode of

innovative education with effectiveness is constructed in universities of science and technology. Combined with the actual situation, culturing system of innovative engineering science and technology personnel is established (Zhang Ying, 2014).

CDIO engineering education mode is a new achievement of international engineering education reform in recent years. It is a kind of advanced teaching mode based on engineering education, which is established by the Universities of ABC lasting for four years. It takes the whole life cycle of product including development, operation, maintenance and disposal as carrier, to establish an integrated mutual support and linked curriculum system, so that students learn engineering in an active and practical way. CDIO capacity syllabus and the 12 standards are the two most important guidance documents of implementing CDIO engineering education model, which answers the fundamental problems of engineering education that what kinds of people are going to be prepared and how to train people (Tomas, 2009). Compared with a lot of engineering education reforms, CDIO is an international, comprehensive, more comprehensive and systematic engineering education reform model. From 2000 to 2004 years, under the foundation of ABC, the Universities of ABC founded the CDIO engineering education model and established international cooperation organization named CDIO through collaboration.。Since 2004, the international CDIO engineering education organization has been developed to more than 81 countries and 25 universities in five countries. In 2011, the member of ABC, XX, won the American Academy of engineering, the highest education award, "Gordon Award" for the creation of CDIO engineering education model (Zhang Ying, 2014)&(Tomas, 2009).

CDIO model, as a typical representative of the engineering paradigm, reflects the essence of engineering practice, displays extension of contemporary engineering and complexity of engineering activities. It has been proved that it represents the development trend of engineering education through practice. It has important value of the times and theoretical innovation which has an important reference to the reform of China's engineering education. In 2005, University of ABC carried out CDIO reform in China firstly, which served as a mark that CDIO engineering education model was officially introduced in China. Subsequently, this engineering talent culturing model in China has been rapidly spread and the promoted in many colleges and universities. In 2008, the Ministry of Education Department of higher education of science and technology with domestic 18 colleges and universities, established the CDIO pilot working group, which was responsible for the promotion and implementation of mechanical, electrical, chemical and civil engineering (Jiang Da-zhi et al., 2012). Till 2014, totally 39 universities and colleges have carried out the pilot work of CDIO in China. University of ABC has made some progress in the reform of CDIO based curriculum teaching. Zhong Yu-guang (2016), aiming at the characteristics and problems of mechanical system design course, sets up the system architecture of mechanical system design curriculum reform thought idea of engineering education based on CDIO. Based on this, the specific implementation strategies of curriculum contents, such as modularization, hierarchical teaching process, comprehensive evaluation and so on has been put forward. Through the practice of curriculum reform, students can master the basic theory and methodology of mechanical system design, and improve the teaching quality of the courses.

In summary, in view of the main problems in higher engineering education, innovative engineering science and technology personnel culturing strategy is put forward and an education model of integration of CDIO and innovation is constructed. It has an important significance for cultivation of innovative talents. Relying on science and technology innovation practice base of Harbin Engineering University, driven by innovation, innovative practice platform of interdisciplinary fusion is constructed. Taking the science and technology competition and the student scientific research project as the basic way, innovation education mode based on CDIO and innovation practice base is established.

4. Innovation education mode based on CDIO and innovation practice base

(1) Syllabus of CDIO. The syllabus of CDIO is based on the comprehensive analysis of the talent culturing goal, which is divided into 4 categories, 17 articles and 70 points according to the contemporary engineering practice of the reasoning principle. It mainly includes following aspects: technical knowledge and reasoning, personal ability, professional ability and attitude, interpersonal skills and the ability to conceive, design, implement, and operating system in the enterprise and social environment(Ron et.al,2016). In order to improve the operability, the CDIO syllabus refines the above goals, and level 2 and Level 3 indicators are established. Syllabus of the content becomes more comprehensive and abundant and modern engineering knowledge, ability and attitude of higher engineering education reform is constructed. The teachers regard it as a comprehensive description of the teaching effect and students regard it as a way to realize the engineer's ideal.

(2) Consistency of CDIO syllabus and innovation ability. CDIO syllabus taking conceive, design, implementation, operation as the main line, considerate comprehensively the professional basic knowledge, personal and professional skills as well as teamwork and communication skills (Johan, 2010) & (Soh, 2011). CDIO also takes the process of CDIO in the whole enterprise and social environment as consideration and is applicable to a variety of different engineering majors. The program is expected that graduates of engineering education can carry out engineering practice in a modern, team-based environment according to syllabus makers. There is a very high consistency between the CDIO syllabus ability and innovation ability. The first part of syllabus is that the technical knowledge and reasoning is the basic goal of engineering education, and also the knowledge base and precondition of innovation. The second part of syllabus is that engineering thinking, scientific thinking and systematic thinking can help to find the problem, put forward the hypothesis, verify the problem and solve the problem. It is the mental process of creativity.

The third part of syllabus is that team spirit and communication skills are a personal character to enhance cooperation and create innovative team. And also are necessary condition to innovate in modern organizations and enterprises. The fourth part of syllabus presents the requirements for creating and running a new product or system execution process. Most scholars generally agree with the definition of creativity: “Creativity is a kind of process, which is a kind of novel and practical product that can be satisfied and accepted by groups.” Generally speaking, "novelty" and "practical" are the basic connotation and basic attributes of creative products. In the survey of innovation, the British Industrial Association defines innovation as: “The successful development of new thinking” (CBI, 2005). Development of new thinking requires a spark of new ideas in practice through teamwork and communication with others. This is consistent with requirements of the CDIO program in the 4.3(conceive), the 4.4(design), the 4.5 (implementation), the 4.6(operate), the 3.1(team work), and the 3.2 (communication). People who like to innovate have personality characteristics including creative thinking (CDIO syllabus 2.4.3). In addition, successful innovators need understand the enterprise to have a reasonable position, then carry out the work in the enterprise. This requires them to clear business strategy, objectives and planning (syllabus 4.2.2) and be responsibility of the Engineer (syllabus 4.1.1) and then successfully work in an organization (syllabus 4.2.4).

CDIO syllabus is derived from the modern engineering practice, which applies to different engineering majors. It serves as a model for all engineering majors in order to obtain a specific learning effect. The syllabus summarizes the knowledge, skills, and development prospects of the current engineering that engineers can successfully lead the team to carry out the conceive, design, implementation and operation of the engineering system, aiming at creating a new integrated education mode. The goal is to provide students with more work knowledge on the basis of technology, to teach engineer to be a leader in the process of

creating and implementing new products or systems, and to understand the importance of their work and the value of their strategies.

5. Research approach of the inquiry innovation practice teaching method based on CDIO

Integrated progressive innovation education model is put forward with design as a carrier, relying on innovation practice base. The mode based on CDIO (first part, second part 2.1-2.4, third part, and fourth part 4.1, 4.3-4.5 of syllabus) takes the practice of engineering foundation course, innovative practice of professional courses, innovation practice of special innovation courses and innovation practice of science and technology competition / scientific projects as the basic way. The students of different majors in the same grade take part in the project and learn the knowledge about the project to achieve target to master theoretical knowledge in practice and active learning.

The thought mode of education is: Constructing the knowledge base and courses guiding practice. The thing that students involved in science and technology innovation activities can not only rely on enthusiasm, but also has a solid foundation of knowledge. Only in this way can a better idea be sprouted. For example, figure 1 is the innovative education model of mechanical and electrical engineering. In recent years, the innovation and practice base of mechanical and electrical engineering apply innovative ideas techniques on professional courses such as design methodology, mechanical system design, mechanical and electrical integration test technology, principle and application of robots, innovation design and manufacture of robot and so on. For example, in the course of mechanical system design, after a careful study of a variety of institutions, the functions of each organization are analyzed. Model rooms are open all day long, so that students can understand the specific structure and function of various typical institutions at any time. Learning by analogy, intensive culturing is taken through curriculum design and homework; In the mechanical and electrical integration test technology course, students are trained how to complete the conceptual design of a mechanical system according to the requirements. Mastering the design method of the schematic diagram and PCB diagrams, that is, teaches students how to turn a concept into a real system. Through classroom teaching, students' professional basic knowledge has been greatly improved, and the students' innovation consciousness has been raised. Innovative design methods of courses specialized teaching students innovative methods and principles, especially TRIZ innovative techniques. In the classroom, teachers explained with examples to introduce innovative methods, and guide the students to use the method to solve practical problems. This kind of culturing can stimulate students' innovative thinking.

6. The implementation of innovative education model

The innovation model based on CDIO requires students: To have a better grasp of the technology basic knowledge (1 part of syllabus); To reason and solve problems (2.1 part of syllabus); To experiment and discover knowledge (2.2 part of syllabus); To have a systematic thinking (2.3 part of syllabus); To have a creative thinking (2.4 part of syllabus)； To have team work ability and interpersonal communication skills (3 part of syllabus). To development and operate the new product, process and system in the social environment (4.1 and 4.3-4.5 part of syllabus). Advanced teaching methods are integrated into the teaching process, various innovative practice projects are developed and open innovation practice platform is provided to achieve the above training goals.

The use of various teaching methods comprehensively and flexibly .Various teaching methods such as open inquiry teaching, project-oriented teaching, problem-inquiry teaching and flipped classroom are utilized comprehensively and flexibly. Teaching process which emphasizes project-oriented is designed according to the knowledge points in the preparation stage, classroom teaching stage and summary stage after class. It trains

students to be adept at thinking, creativity, and independent innovation to explore the initiative teaching methods based on CDIO and innovation practice base. The teaching process model is shown in Figure 2. For example, in the project, the group as a team (5-6 persons) holds an interactive discussion to determine the task process, the required time and work responsibilities of each member. To a large extent, it develops the students' interest in learning, active thinking, autonomous learning ability, expression ability, and individual potential.

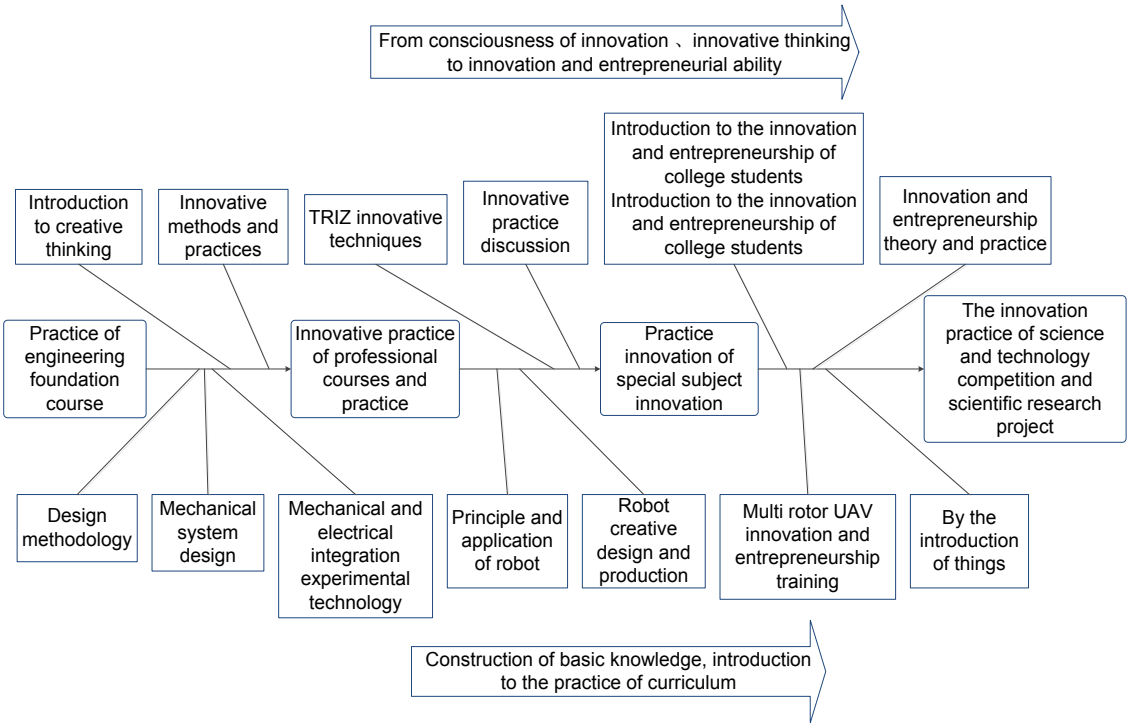

Figure 1: Innovative education model of mechanical and electrical engineering

Development practice project of innovation base. Settings of practical projects can be taken two ways: One is the extension of the teachers' scientific projects. Teachers decompose the content of scientific research projects to make projects be completed through the comprehensive work by many people. The teachers in Harbin Engineering University guide college students to participate in several competitions and achieve success through the auspices of the wind power generation, rehabilitation robots and other projects, which has a very large role in the operation of the base. The other is to build the innovative project the subject library. Students themselves put forward innovative practice projects. Collection activity of student innovation practice projects is carried out every years from teachers and teachers in innovation base are invited to evaluate the collection of projects. The worthy projects to study are selected from those. Students' science and technology innovation practice projects mainly are selected from the subject library, but also determined by the students themselves after evaluation of the teachers in innovation base.

Selection of innovative practice projects for college students should consider the technical content and level of the projects, the social and economic value of innovative projects and the feasibility carried out project by students. Students can declare the project form the subject library through organizing research teams, and projects are evaluated by teachers in innovation base to determine whether or not to provide funding. Among them, the funding of the project can be divided into key funding projects and general funding projects. The setting of the base practice projects should pay attention to innovation and practicality firstly and

give priority to the choice of projects that can stimulate students' interest in innovation, innovative thinking, and practical ability. Setting of practice projects should not only pay attention to reflect their own professional background to realize the innovation understanding and application of professional knowledge , fully consider the relevant professional knowledge to realize the interdisciplinary integration.

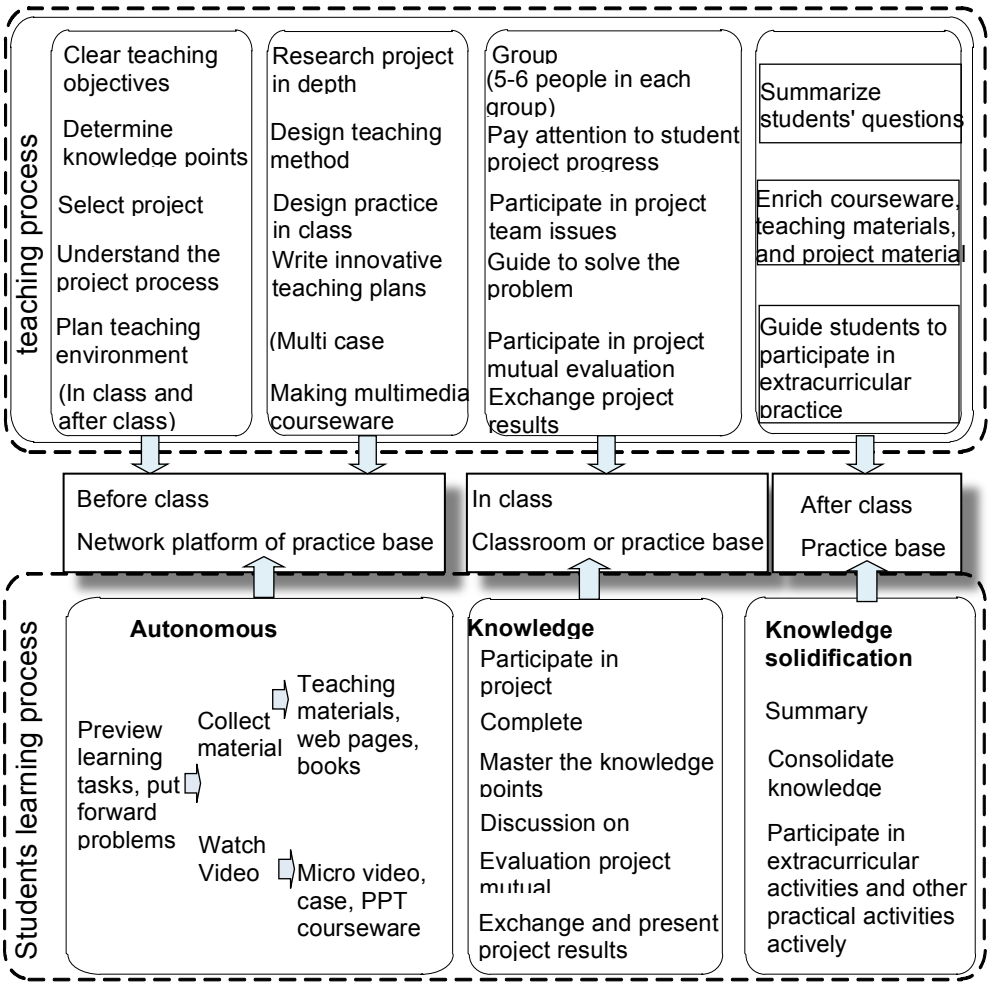

Figure 2: The teaching process model based on CDIO and innovation practice base

An open experimental environment to provide innovative platform. Practice is the most powerful support and supplement of education and teaching, and the open laboratory provides a good environment for students' innovation activities and equipment support. The space of experiments is expanded through course researches, scientific research projects, science and technology competitions and other forms, with cooperative and research based learning methods. Students can learn independently in the classroom, the laboratory, the excellent course website, the library and so on. It breaks through the restriction of the traditional laboratory space and expands the space of the experiment teaching. At present, the practice base will be open to students in the innovation laboratory for scientific research activities. Laboratories are open 8 hours a day, and the 71% of design, synthesis and innovation projects are open for the undergraduate and graduate students in related professionals. A perfect open management system is established by laboratory through management system to make the management of open laboratory be in order.

Competition to stimulate interest and result testing education model. The contests which have a positive role in expanding the students ‘vision and innovation stimulate the students

‘interests to participate in the events. Students in Harbin Engineering University win the runner up two times, two times eight and a special performance award in six national university robot TV contests, and teams can achieve remarkable results every time. Since sponsors only provide rules, planes and the productions of robots, and even the contests sites are done by the students personally. Therefore participating in a robot contest requires that 15-25 students invest nearly ten months to prepare before the games. Groups adjust the entry mode timely to combine the curriculum design, graduation design with extracurricular science and technology innovation activities after attending the first competition. In this way, the students have sufficient time in the competition, which makes a solid foundation for the success of the contests. In the three years of TRIZ contests of university students in Heilongjiang Province, students’ work based on innovative base won the first prize 3 times, the second prize 11 times, the third prize 32 times and other awards.

To strengthen international exchanges, expand extension of innovation practice base. Innovation practice base actively establish good relationship with domestic first-class universities, which often invites foreign experts to give lectures; And actively support the students in base to participate in an important international competitions. There are two international student innovation competitions in Harbin Engineering University: the international ice sculpture competition and international competition TRIZ. These competitions enhance the interest in innovative practice activities, stimulate innovative thinking, and promote the formation of innovation atmosphere. A variety of innovative practice competitions are planned to hold, students are encouraged to participate in innovative design competitions at home and abroad. Innovation incentive mechanism is implemented to stimulate challenge senses of students.

7. Practice achievements

Innovative practice base supports the “Sail cup”, the “54 Cup”, the National College TRIZ contest, the National Robot competition, the National Sculpture Competition, the "Challenge Cup" and other sports innovation projects in school. Taking the College of Mechanical and Electrical Engineering in Harbin Engineering University as an example, the remarkable teaching effect has been achieved in the last three years. There are 12 works totally to participate in the national college students’ innovation and entrepreneurship culturing program. There are 128 research projects of students, including a total of 421 students and 26 teachers. There are 300 people in the innovation base perennially on average. 5 innovation practice courses, totally 420 hours, are offered in the past three years and 1255 students enroll in this course. The number of course-selecting students on average increases by about 10% year by year, and the attendance rate is more than 98%. Students take an active part in innovation activities. Before the deadline for submission, 22 awards in innovation and technology competition have been obtained, and 28 new utility model patents and invention patents have been authorized in total, which shows the remarkable teaching achievement.

At the same time, 90% of the students think that the overall teaching effect of the courses is significantly higher than that of other courses through the student survey; through learning the courses, 85% of the students think that their designing capabilities, operational capabilities, theory with practical ability, team cooperation ability and so on have been greatly improved, and more than 80% of the students believe that the courses are helpful to the scientific research topics, research thinking training and innovative thinking training.

8. Conclusion

Conforming to the current development trend of international higher engineering education, the correspondence between the syllabus of CDIO and cultivation of innovative ability is analyzed. Relying on innovation practice base of Harbin Engineering University, the culturing mode of innovative engineering science and technology personnel based on CDIO is put

forward. By the teaching practice in recent years, it has been proved that the teaching model which combines CDIO with innovative education is applied in the course teaching, so that students can participate in scientific research and innovation practice as soon as possible. It stimulates students' learning initiative and enthusiasm, broadens the students' professional vision, cultivates students' innovative thinking, and greatly improves the students' ability of innovation practice and teamwork. A series of remarkable achievements prove that it is feasible to integrate CDIO into innovative education, and it can be popularized in other universities and colleges.

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