

# **An analysis of the curriculum for water supply and drainage, science and engineering, based on CCDIO**

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**ABSTRACT:** Improving education for water supply and drainage, science and engineering will provide a crucial human resource base for solving China's water crisis. In this article is an analysis of the career competitiveness model and a further study of the application of CCDIO (career, conceive, design, implement, operate). Career competitiveness depends on knowledge, skills and attitude. The CCDIO is an integrated student-centred system of the NPIA (need, plan, implement, adjust) career cycle and the CDIO cycle of professional competence. In accordance with the need for applied talent and based on CCDIO, the curriculum for water supply and drainage, science and engineering was optimised and the correlation among courses analysed. The curriculum system based on CCDIO has four parts: career attitudes and soft ability; engineering foundation; engineering fundamental competence; and engineering integrated systems competence. The integrated curriculum mode was deemed suitable for water supply and drainage, science and engineering, based on CCDIO. This will be beneficial to developing graduates in solving water pollution problems.

## **INTRODUCTION**

According to the 2004 Report on Chinese Green National Economic Accounting, the environmental cost of water pollution accounted for 1.71 per cent of GDP. The main phenomena of the water crisis are serious water resource shortages, serious water pollution and serious water resource waste [1].

As industry shifts gradually from urban to rural areas, the countryside is faced with a serious water pollution problem; harnessing rural wastewater is a great urgency. Water supply and drainage, science and engineering has an important part to play in solving the water crisis. This requires a large number of higher engineering technology engineers. Therefore, there is an urgent need to reform the undergraduate teaching of water supply and drainage, science and engineering, especially the curriculum content.

The world's largest higher education system has been built in China, but the output and quality cannot meet the economic restructuring and industrial upgrading requirements. In 2011, the Ministry of Education in China began to implement a plan for educating and training outstanding engineers.

The CDIO (conceive, design, implement, operate) mode is a classic system of engineering education used at MIT (Massachusetts Institute of Technology), who were part of its development [2].

The CDIO model has been adopted for the teaching of software testing [3].

A team at Shantou University has put forward a conception of engineering education as EIP-CDIO (ethics, integrity, professionalism - conceive, design, implement, operate) [4].

The CDIO system in China has achieved a number of positive results, but there are some problems that cannot be neglected. This includes the lack of career development for students. Hence, there is a need to explore new training modes. In the current practice of engineering education, students seldom or even never, have been involved in innovative project and design training. They do not know how to develop self-learning goals and plans; neither do they have any idea of the purpose and significance of specialities in the curriculum [5].

At present, there are no clear career goals or orientation for students, and the teaching outcome of CDIO is poor. Career education has been integrated into CDIO to put forward the new CCDIO (career, conceive, design, implement, operate) model [6]. This work is a further study of the application of CCDIO to the water supply and drainage, science and engineering curriculum.

## CCDIO

### Career Competitiveness Model

Student learning outcomes eventually will need to be validated in his/her career. There are several factors affecting career competitiveness, such as knowledge, skills, attitude, education background, personal characteristics and ideas. The *career competitiveness model* is defined by Equation (1).

$$CC = (K_C + S_C)^{A_C} \quad (1)$$

$CC$  - career competitiveness;

$C$  - career;

$K_C$  - knowledge, effective knowledge *based on career*;

$S_C$  - skill, effective hard-soft skills *based on career*;

$A_C$  - attitude, positive attitude with good morality *based on career*.

The model shows that career competitiveness is directly related to three factors: knowledge, skills and attitudes. From the model it is seen that attitude plays an exponential role and is the key factor in career competitiveness. Particularly, the impact on personal career competitiveness of a positive attitude is vastly different from a negative attitude.

A positive attitude with good morals toward personal career competitiveness or society will play an important, positive role in promoting personal and social development, as well as progress. However, the impact of positive attitude with bad morals on society can cause serious damage to it.

It is most important that the reform of teaching should be beneficial to a positive attitude of students with good morality. Therefore, in the process of educating students, career education is integrated into professional education in order to cultivate knowledge, skills and attitudes.

### The Construction of CCDIO

The CDIO initiative is a collaborative framework that initially begun as a joint endeavour involving four engineering schools in Sweden and the USA, viz. Chalmers University of Technology, Linköping University, Royal Institute of Technology (Sweden) and the Massachusetts Institute of Technology (USA) [7].

Conceive, design, implement, operate focuses on four activities, viz. curriculum development, teaching and learning, workshops and assessment [8]. The multi-assessment evaluation method for CDIO draws upon project-based teaching [9]. The CDIO model is a complete system that is implemented as a whole [10].

At present, more than 100 institutions worldwide are involved in CDIO. Thus, it can be seen that CDIO has been applied widely around the world, as well as in China.

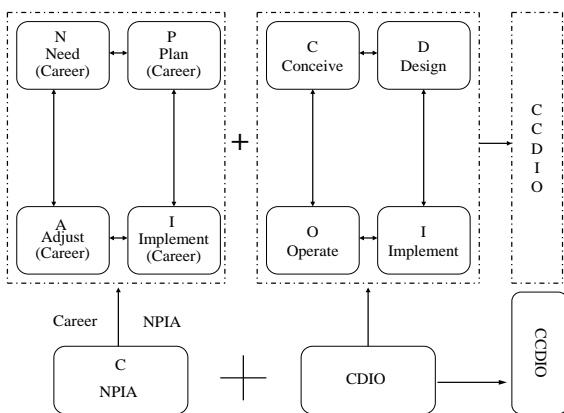


Figure 1: The formative process of CCDIO.

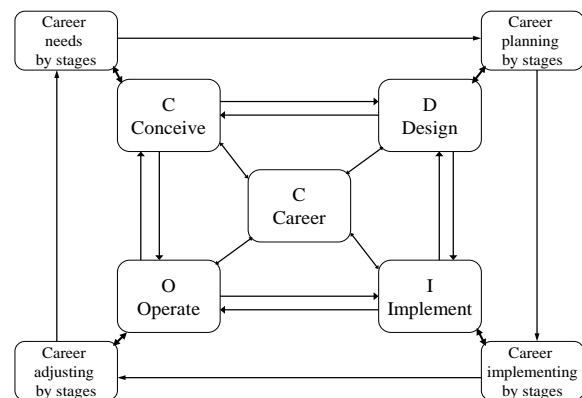


Figure 2: The system construction of CCDIO.

According to the career competitiveness model, it is most important for university students to have effective knowledge, hard-soft skills and a positive attitude with good morality. These factors may vary by career. However, on the whole, there is an examination-oriented education system in China, from primary school to university. This results in a lack of career education, so students do not have the incentive of a career objective.

*Career* can be viewed as a staged cyclic process of *needing-planning-implementing-adjusting* or *need a career, plan a career, implement a career, adjust a career*, which is hereinafter referred to as the NPJA model or the NPJA career cycle. Therefore, with CDIO as the basis, career education can be introduced into the education process.

The CCDIO model was defined as career, conceive, design, implement, operate [6]. The further study of CCDIO will be considered from a formative process and system construction aspect. The formative process of CCDIO is shown in Figure 1, and the system construction of CCDIO engineering education is shown in Figure 2.

Figure 1 shows that CCDIO is the product of an interaction between CDIO and the NPJA cycle. Figure 2 shows that CCDIO is the talent cultivation system for the student's career, including a career system and professional skills system.

The career system consists of *need a career, plan a career, implement a career* and *adjust a career*. The professional skills system consists of engineering *conceive, design, implement* and *operate*. Therefore, in view of outdated, but still current, Chinese career education, CCDIO engineering education is deemed suitable for Chinese engineering education reform.

## DEVELOPMENT AND CONTENT OF WATER SUPPLY AND DRAINAGE, SCIENCE AND ENGINEERING

### Development of Water Supply and Drainage, Science and Engineering

The development of water supply and drainage, science and engineering in China can be divided into five stages:

- Before 1952:

As part of civil engineering, there were several undergraduate civil engineering courses on water supply and drainage, such as that at Harbin Institute of Technology, Tsinghua University and Tongji University.

- Growth stage, from 1952 to 1965:

Transformation occurred from being a part of civil engineering to engineering for urban and industrial water supply and drainage.

- Standstill, from 1966 to 1976:

During the Great Cultural Revolution, colleges and universities abolished college entrance examinations. Specialty development was at a standstill.

- Restoration and development, from 1977 to 1996:

Water quality issues became increasingly prominent. There was a rapid development of the related science and technology. It became most urgent to reform the teaching of water supply and drainage engineering.

- Comprehensive development as a specialty since 1996:

In 2003, China established a professional education system for water supply and drainage engineering. In 2011, the Ministry of Education launched a plan for *educating and training outstanding engineers*. A corresponding pilot programme was launched for water supply and drainage engineering.

### Content of Water Supply and Drainage, Science and Engineering

Good use of water in society is the historic mission of the water supply and drainage engineering discipline, in order to support social production and people's lives. In light of the social impact of water, the professional content of the subjects water supply and drainage, science and engineering is divided into four parts:

- Municipal water supply and drainage:

This includes municipal water supply and drainage pipework, water quality engineering, municipal water supply and drainage construction and operation.

- Building water supply and drainage:

This includes building water supply engineering, building drainage engineering, building fire engineering, as well as the construction and operation of building water supply and drainage.

- Industrial water supply and drainage:

This includes industrial water supply engineering and industrial drainage engineering, as well as the construction and operation of industrial water supply and drainage.

- Water resources and water environment:

These include the planning and management of water resources, water pollution control and water environment protection.

At present, China's worsening water crisis is caused by water pollution and a shortage of water resources. There is no time to delay in harnessing rural wastewater. Therefore, the protection and use of water is the core of the specialty, water supply and drainage, science and engineering. It is involved in all water-related activities, such as agriculture, industry and services.

### CURRICULUM FOR WATER SUPPLY AND DRAINAGE, SCIENCE AND ENGINEERING

The curriculum system for water supply and drainage, science and engineering, is closely related to the desired quality of the training. Previous curriculum systems based on CDIO included engineering foundations and introduction and, then, from CDIO, engineering conceive, design, implement and operate [6].

Now, the curriculum has been further optimised. Table 1 shows the curriculum system for water supply and drainage, science and engineering, based on CCDIO. The curriculum is divided into four parts, viz. career attitudes and soft ability, engineering foundation, engineering fundamental competence and engineering integrated systems ability.

Career attitudes and soft ability are fully integrated into all parts of the curriculum. A student's internalisation of career is embedded into the whole process of teaching and learning, to enhance the students' ability to learn, conscious of the career objective. The development of soft ability and professional ability are guided by the student's career. This is an important characteristic of the integrated curriculum, based on CCDIO.

Table 1: Curriculum for water supply and drainage, science and engineering, based on CCDIO.

Curriculum based on CCDIO			
Career attitude and soft ability	Engineering foundation	Engineering - fundamental competence	Engineering - integrated systems ability
Chinese and foreign cultures, history, philosophy, business etiquette, teamwork, professional communication, self-management, employability, entrepreneurial ability, management psychology, engineering ethics, engineering leadership	Advanced mathematics, linear algebra, physics, foreign language, law, computers and programming, electrics and electronics, chemistry, engineering hydraulics, water microbiology, introduction to engineering, management of the economy	Information literacy, engineering drawing, engineering survey, water analytical chemistry, pumps and pumping stations, building water supply and drainage, water supply and drainage networks, water quality engineering, water engineering construction	Water engineering operation and management, project management, water construction costs, water engineering economy, water saving and water resources, water environmental assessment and protection
Career is embedded in the teaching and learning			

### Correlation among Courses for Water Supply and Drainage, Science and Engineering

For a curriculum, core courses should have a certain degree of internal correlation. The degree of correlation among core courses for water supply and drainage, science and engineering is shown in Table 2.

This is a measure of the connections between a course and the courses that preceded it in the programme. Each connection was rated on a five-level scale, ranging from *no correlation*, scale value 1; *weak correlation*, scale value 2; *medium correlation*, scale value 3; *good correlation*, scale value 4; and *strong correlation*, scale value 5.

A row in the matrix indicates how the content of a course is used in subsequent courses. A column in the matrix shows the extent to which a course uses knowledge from previous courses. Table 2 shows that humanities and social science courses have little correlation with foundation courses and have a greater degree of correlation with professional courses, particularly the development of soft ability and professional competency.

It is important to understand the connections among the disciplinary topics, that is, where there are interactions or isolation of the topics within the courses. Establishing a curriculum system based on CCDIO required an analysis of the correlation among courses. This was very beneficial in clarifying the logical relationship among courses and optimising the course structure.

Table 2: Correlation among core courses for water supply and drainage, science and engineering.

Water supply and drainage, science and engineering	Core curriculum based on CCDIO																																	
	Freshman					Sophomore							Junior					Seniors																
	Philosophy	Advanced mathematics	Chemistry	Foreign language	Introduction to engineering	Critical thinking	Positive psychology	Teamwork and entrepreneurial ability	Professional communication	Career and counselling	Engineering hydraulics	Water microbiology	Management of the economy	Information literacy	Engineering drawing	Engineering survey	Water analytical chemistry	Pumps and pumping stations	Etiquette and self-management	Engineering ethics	Building water supply and drainage	Water supply and drainage networks	Water quality engineering	Water engineering economy	Water saving and water resources	Management psychology	Engineering leadership	Water engineering construction	Project management	Engineering integrated training				
Philosophy	5	1	1	3	5	5	5	4	4	1	1	3	1	1	1	1	3	5	5	2	2	2	3	4	5	5	4	4	5					
Advanced mathematics		5	3	1	3	2	1	1	1	1	3	3	4	4	1	3	3	3	2	2	3	3	3	4	3	1	1	3	3	4				
Chemistry			5	1	3	1	1	1	1	1	3	1	1	1	1	5	2	1	1	1	1	1	4	1	3	2	2	1	1	3				
Foreign language				5	5	3	4	4	4	4	3	3	4	4	2	2	3	2	3	3	3	3	3	2	4	1	2	3	3	3				
Introduction to engineering					5	5	5	5	5	5	2	2	1	5	3	2	2	2	1	2	4	4	4	4	4	3	4	4	4	4				
Critical thinking						5	5	5	5	5	2	2	3	5	2	2	2	2	3	4	3	3	3	3	3	4	5	4	5	5				
Positive psychology							5	5	5	5	3	3	4	5	2	2	2	2	5	5	3	3	3	3	3	5	5	3	5	5				
Teamwork and entrepreneurial ability								5	5	5	3	3	4	5	3	3	3	3	5	5	3	3	3	3	3	5	5	5	5	5				
Professional communication									5	5	3	3	5	5	3	3	3	3	5	5	3	3	3	3	3	5	5	5	5	5				
Career and counselling										5	2	2	3	3	2	1	2	2	5	5	4	4	4	4	3	5	5	3	5	5				
Engineering hydraulics											5	1	1	1	1	1	1	5	1	1	5	5	5	5	5	1	1	1	1	2				
Water microbiology												5	1	1	1	1	2	1	1	1	1	1	5	1	2	1	1	1	1	3				
Management of the economy													5	4	1	1	1	4	5	4	2	3	3	3	3	5	5	4	5	5				
Information literacy														5	2	2	3	3	4	4	5	5	5	4	4	5	5	3	5	5				
Engineering drawing															5	2	1	5	1	3	5	5	5	5	3	2	1	1	3	4	5			
Engineering survey																5	1	3	1	1	5	5	3	1	1	1	1	1	1	3				
Water analytical chemistry																	5	1	1	1	2	2	5	1	1	1	1	1	2	3				
Pumps and pumping stations																		5	1	1	5	5	5	1	2	1	1	3	1	4				
Etiquette and self-management																			5	5	3	3	3	3	3	5	5	3	5	5				
Engineering ethics																				5	5	5	5	4	3	5	4	5	5	5				
Building water supply and drainage																										5	4	3	3	4	4			
Water supply and drainage networks																										5	4	5	4	2	2	3	5	5
Water quality engineering																											5	5	3	3	3	5	5	5
Water engineering economy																											5	4	1	2	4	2	5	
Water saving and water resources																											5	1	1	3	4	5		
Management psychology																												5	5	4	5	5	5	
Engineering leadership																												5	5	5	5	5	5	
Water engineering construction																													5	2	5	5	5	
Project management																														5	5	5	5	5
Engineering integrated training																																		5

1 - no correlation; 2 - weak correlate; 3 - medium correlation; 4 - good correlation; 5 - strong correlation

## TEACHING MODES FOR WATER SUPPLY AND DRAINAGE, SCIENCE AND ENGINEERING

There are four modes for teaching engineering education, viz. disciplinary, integrated, problem/project and apprenticeship. The apprenticeship mode is used mainly to train skilled personnel, whereas the disciplinary, integrated, and problem/project modes are used mainly in higher engineering education. China still mainly uses the disciplinary mode for engineering education. But, the drawbacks of this mode have become increasingly apparent. Since many universities have a pre-existing disciplinary organisation, it may be difficult to transform an existing programme to one with a comprehensive problem-based organisation.

The problem/project mode is used widely in developed countries and, especially, the project mode. Comparison between the disciplinary mode and the integrated mode is shown in Figure 3. In this figure, disciplines run vertically, and projects and skills, including soft skills and professional skills, run horizontally. Figure 3 shows that a disciplinary curriculum system emphasises disciplinary knowledge, whereas the integrated curriculum emphasises professional skills. The disciplinary curriculum is organised around general education courses, foundation courses and professional courses.

There is no explicit career guidance, no - or poor - professional skills development, and a lack of soft skills. However, based on CCDIO, projects, and the integrated mode organised around disciplines, have explicit career guidance, soft skills, and professional skills. Therefore, choosing the integrated mode is suitable for water supply and drainage, science and engineering, based on CCDIO.

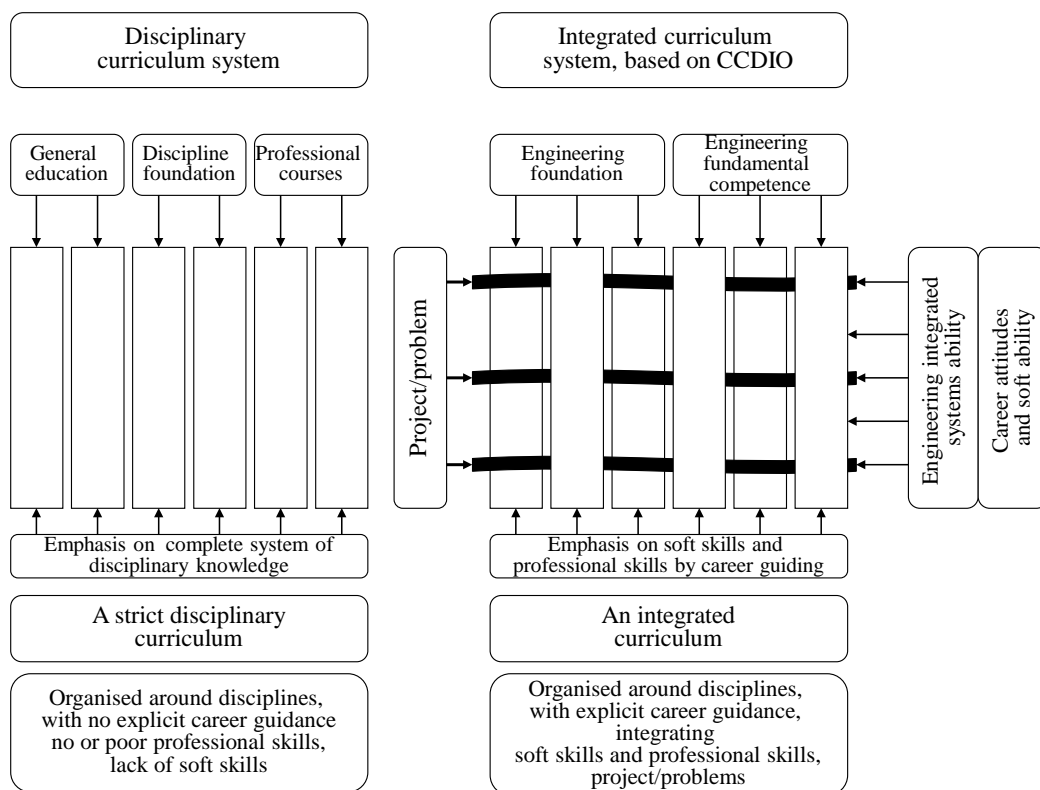


Figure 3: Comparison between the disciplinary mode and the integrated mode.

## IMPACT OF CURRICULUM CONSTRUCTION ON LEARNING INITIATIVE, BASED ON CCDIO

The CCDIO model attaches great importance to students' career development that is integrated into professional education. When students are in their freshman year, their formal career development begins, so that they think about their own career path. For example, introduction to engineering for water supply and drainage, science and engineering is a basic understanding not only of disciplines, but also career interests. At the same time, by means of calling a class meeting and interviewing students, career education is blended in teaching activities and students' daily management with the application of CCDIO, so that students can know themselves and their job requirements, have clear career goals and are able to stimulate their learning initiative. This reflects a student-centred philosophy of education and improve teaching effectiveness.

## CONCLUSIONS

Career competitiveness is directly related to knowledge, skills and particularly attitudes. The application of CCDIO was looked at in this study, which is the product of the interaction between CDIO and the NPIA career cycle. The NPIA is

based on internalisation of the career system by a student, as well as the professional skills system. The career system consists of *needing, planning, implementing* and *adjusting* a career. The professional skills system of CDIO consists of *conceive, design, implement* and *operate* in engineering education. The curriculum system based on CCDIO is divided into four parts, viz. career attitudes and soft ability, engineering foundation, engineering fundamental competence and engineering integrated systems ability. The degree of correlation among courses for water supply and drainage, science and engineering was analysed for this article. The integrated mode of teaching was chosen as being suitable for water supply and drainage, science and engineering, based on CCDIO. These will improve the quality of graduates to help solve China's water crisis.

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