

A CDIO curriculum development in a civil engineering programme

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ABSTRACT: A design-directed curriculum based on the CDIO (Conceive - Design - Implement - Operate) principles was proposed for the civil engineering programme in the College of Engineering at Shantou University in Shantou, China (for the class of 2006 and later). The proposed curriculum utilises design projects as vehicles to integrate all the courses. The main differences of the new curriculum from the original one are reported in the article. A fishbone diagram was developed to present the features of the new curriculum better with an emphasis on the design projects. The design projects specifications are introduced as well. It is indicated that the designed-directed CDIO curriculum puts students in a broad and active design environment where they learn and use engineering science, technology and non-engineering knowledge, and exercise their communication, project management, leadership and other skills. All projects are designs that are based on group projects in order to cultivate team spirit.

INTRODUCTION

The CDIO (Conceive - Design - Implement - Operate) education curriculum has been widely used in mechanical, aeronautical and electrical engineering programmes [1]. In order to realise the CDIO initiative better, a design-directed curriculum had been proposed and used in the College of Engineering at Shantou University in Shantou, China [2][3]. The design-directed curriculum puts students in a design environment where they learn engineering science, technology and non-engineering knowledge, and when they need to use them. They are also required to work as a design team and exercise their communication, project management, leadership and other skills.

However, little material on using the CDIO Initiative is available for civil engineering programmes. The challenge for a civil engineering programme is to develop a design-directed curriculum based on the CDIO Syllabus and Standards [1][4]. For example, CDIO Standard 5 requires that a curriculum includes two or more design-build experiences, including one at a basic level and another at an advanced level. However, civil engineering products, like buildings, bridges, etc, require long periods, large spaces, huge amounts of money and special working skills to build them. Hence, it is difficult to plan operating products to fulfil the design-build requirements (ie close to impossible to assume the same way as the other programmes do in designing their CDIO curricula and design-build projects).

Referring to the rationale of the Standard, obtaining and iterating the design-build experiences has the following purposes:

- Promote early success in engineering practice;
- Reinforce students' understanding of the product and system development process;

- Provide a solid foundation upon which to build deeper conceptual understanding of disciplinary skills;
- [Give] students opportunities to make connections between the technical content they are learning and their professional and career interests [4].

Great effort has then been paid by the authors to fulfil these objectives by overcoming the above difficulties for the civil engineering programme since 2005.

THE MAIN FEATURES OF THE DESIGN-DIRECTED CURRICULUM

Realising the importance of real-world experiences and the difficulties in implementing students' designs, an integrated approach, termed as design-directed curriculum for civil engineering programme (for the class of 2006 and later), was designed by the authors in order to achieve the overall objectives of the CDIO initiative. The main differences of the new curriculum from the original one are as follows:

- The new curriculum is *design-directed*, whereas the original one was *course-directed*;
- The number of major design projects has increased from three for the original curriculum to six for the new one (as shown in Table 1, the projects *Introduction to Civil Engineering Design*, *Engineering System Design* and *Integrated Design-Build Project* were not included in the original curriculum);
- Factors considered in the projects of the new curriculum are more than those of the original one. The environment, natural resources and professional ethics are included in the projects of the new curriculum.

In accordance with the requirement set out by CDIO Standard 5, in addition to the fundamental courses, a new course,

Table 1: The main projects in the new curriculum of the civil engineering programme.

Project	Stage	Project specifications
<i>Introduction to Civil Engineering Design</i>	Year 2, Semester 1	Students make civil plans for a new town. They pick one item in the plan, such as a building or bridge, and give more specifications on the description/design
<i>Architectural Design</i>	Year 2, Semester 2	Students refer back to their conceptual designs in the first cornerstone project and modify original preliminary designs (such as buildings or bridges) with the new knowledge learnt in this cluster of courses
<i>Structural and Geotechnic Engineering Design</i>	Year 3, Semester 2	Students refer back to their conceptual designs in the cornerstone project and their architectural design, and modify their designs according to the new knowledge learnt in the cluster of courses with special attention paid to structural safety
<i>Engineering System Design</i>	Year 3, Semester 2	Students refer back to their conceptual designs in the cornerstone project, their architectural design, and structural and geotechnic engineering design. Students evaluate and modify their designs according to the new knowledge learnt in the cluster of courses concerning the specifications and considerations of lifecycle design
<i>Integrated Design-Build Project</i>	Year 4, Semester 1	Students form multidisciplinary groups with students from other departments to search for possibilities of innovation, either in the civil engineering field or other professional fields
<i>Advanced Civil Engineering Design</i>	Year 4, Semesters 1 & 2	Students work on a major construction development project, such as the Shantou Metro system

Introduction to Engineering Design (riding on a project), was designed for the common first year for engineering students. This course provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills.

The build-in design project of this course stimulates the fresh interest and creativity of students, exposes students to the process of knowledge creation and development, and gives students a sense of responsibility in social and historical contexts. This introductory course and its build-in project finished in semester 1 of year 1 are thought to provide a good starting point for students to perform their following design projects.

For year two to year four studies, the new civil engineering curriculum can be illustrated by the fishbone diagram shown in Figure 1. It can be seen that the proposed curriculum utilises design projects as vehicles to integrate all courses. The trunk of the fishbone consists of a cornerstone project and a capstone

project, both termed level 1 projects. The branches of the fishbone include four level 2 projects with each leading a cluster of core courses. Individual courses may also contain mini design-based projects, termed level 3 projects. Hence, all projects are design-based group projects. The approach is termed as design-directed. The specifications of all level 1 and 2 projects are indicated in Table 1.

MAIN TASK OF THE FIRST PROJECT IN LEVEL 1

As presented in Figure 1 and Table 1, the cornerstone project (*Introduction to Civil Engineering Design*) is to be carried out in the autumn term of year two. Students are given a stretch of land to plan a new town. With little knowledge of civil engineering, students need to make civil plans for the new town. They have to plan the residential, commercial, political, social, educational and recreational districts, and plan traffic facilities like roads and bridges. The purpose is to force students to conceive civil problems within social, environmental and historical contexts.

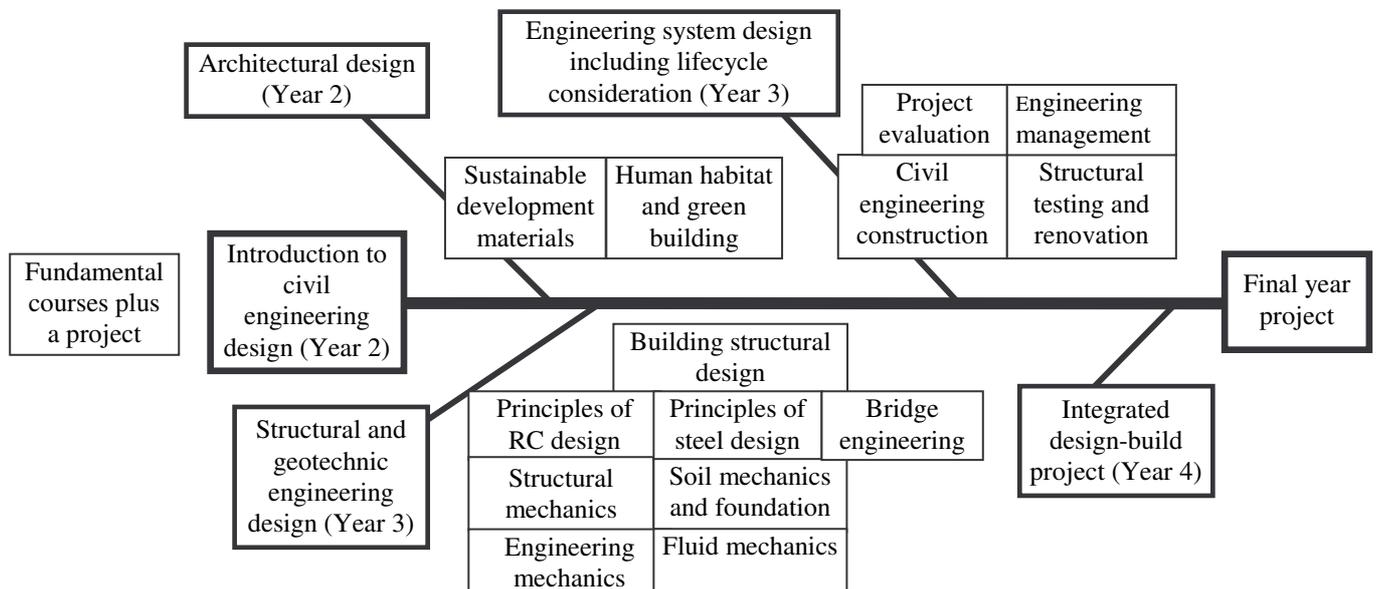


Figure 1: The main framework of the design-directed curriculum for the civil engineering programme.

The key requirement for students is *reasonability*. In order to prove the reasonability of their designs, students have to turn to various resources, which work as a good introduction course and stimulate students' interests. As the plans need only to be *reasonable* instead of being *correct or perfect*, it has the effect to encourage creativity. In this project, each group also needs to pick up one item in the plan, such as a building or bridge, to give more specifications on description/design. Students need to indicate the functions, format, styles, dimensions and materials to be used for the selected design.

AIMS OF THE FOUR PROJECTS IN LEVEL 2

As shown in Table 1 and Figure 1, four level 2 projects were arranged and each integrates a number of core courses. The project *Architectural Design* comprises human habitat and green buildings, as well as sustainable civil engineering materials. The project *Structural and Geotechnic Engineering Design* incorporates courses in mechanics, structures and geotechnics. The project *Engineering System Design* integrates courses in construction, structural assessment and maintenance, as well as renovation, engineering management and project evaluations.

In the first level 2 project, *Architectural Design*, students need to refer back to their conceptual designs in the cornerstone project and modify their preliminary designs (such as buildings or bridges) according to new knowledge learnt in this cluster of courses with an emphasis on environment protection and resource saving. This project is different from the original one in the old curriculum, which does not consider resource and environment. The modified designs should be correct and good.

In the project of *Structural and Geotechnic Engineering Design*, students also need to refer back to their conceptual designs in the cornerstone project and their work in the *Architectural Design* project. They need to modify their designs according to the new knowledge learnt in the cluster of courses with a special attention on structural safety. Students are also required to make a balance between safety, aesthetics, feasibility, environmental impact and energy consumption in their design. This balance was not included in the original project of the old curriculum. It is highly encouraged that each group of students modifies the designs finished by another group of students in a cornerstone project and architectural project. Discussions, debates, understanding and compromises are expected in the communication process.

In the totally new project called *Engineering System Design*, students need to refer back to their conceptual designs in the cornerstone project, as well as their work in the *Architectural Design* and *Structural and Geotechnic Engineering Design* projects, and also evaluate and modify their designs according to the new knowledge learnt in the cluster of courses concerning the specifications and considerations of lifecycle design and the macro-costing (including initial investment and anticipated maintenance fees) of engineering projects. Because this project provides students with the opportunity to relate their design activities and decisions to social and professional responsibilities, this approach is quite different from the original one, which introduces students to all the engineering science and technology materials, but where most students have little or no engineering appreciation.

The last level 2 project, entitled *Integrated Design-Build Project*, requires students to form multidisciplinary groups with students from other departments to search for possible innovations either in the civil engineering field or other professional fields. It is expected that this project will lead to an intensive communication practice in students of the whole university.

After these projects, students should have gained good experiences with *conceiving*, *designing* and partially *operating*. The *implementing* part will be made up by onsite internships. While on construction sites, students participate in the implementation process of real-world designs. However, whatever differences exist between the student's design and the design of the real world construction, there must, nevertheless, be some similar components/parts. Students are then required to pay special attention to those parts of implementation and hand in special reports on them.

AIMS OF THE SECOND PROJECT IN LEVEL 1

The second level 1 project called *Advanced Civil Engineering Design* (final year project) works as the capstone to integrate what students have learnt in their four years of study. These projects are large and complex, such as the Shantou Metro system.

The aim of this project is to reach the standards of CDIO in an engineering and society system. The key requirement for each student of a group is, as one member of a team, to provide a correct and feasible individual detailed design using technical and non-technical skills, as well as global insights such as social, environmental and historical contexts.

CONTENT OF THE LEVEL 3 PROJECTS

Design-build projects, termed level 3 projects, are placed in individual courses. Although the major purposes of these projects are to enhance the learning of the core courses, they also compensate the *implementing* deficits of the level 1 and level 2 projects. Examples of level 3 projects include the *Construction Material Design Competition* and *Structural Competition*.

The former is actually an R&D project that may yield practical solutions. Students need to learn the fundamentals of construction materials. They work in groups to make mix designs of Portland cement concrete for specific purposes, such as pavement or marine concrete. They then make the specimens according to the mix and test the specimens to validate the design.

After that, they have to present their work to the class, and discuss and defend their ideas. The properties, environmental impacts and energy consumption of the material's design and production by students are all the evaluation indexes of the competition.

The *Structural Competition* links the theoretical analyses learnt from the course of *Structural Mechanics* to the physical world. Students from the 2003 and 2004 classes have shown great enthusiasm for these projects.

SUMMARY

A design-directed curriculum based on the CDIO Initiative was proposed for the civil engineering programme in the College of Engineering at Shantou University in Shantou, China. The design-directed CDIO curriculum puts students in a broad and active design environment where they learn and use technical and non-technical skills, exercise and design. It is believed that this new curriculum complies with the CDIO Initiative and Standards. Evaluations and modifications will be continuously performed based on the practice of the new curriculum for students of the 2006 class and beyond.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the funding provided by the National Education Science Plan Office of China (DIA060144).

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