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Reforming the teaching of a single chip microprocessor course based on CDIO engineering education

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ABSTRACT: Conceive - Design - Implement - Operate or CDIO in short, is an international and innovative engineering education model. This model was applied to the course, Principles and Applications of the Single Chip Microprocessor, to create a new teaching system. The teaching is based on an engineering project, and promotes teaching, inspires students, and enhances the knowledge and practical abilities of students. The teaching of the Principles and Applications of the Single Chip Microprocessor course shows the new teaching system to be highly effective.

INTRODUCTION

Conceive - Design - Implement - Operate, or CDIO, is the latest development in engineering education reform in recent years [1]. China's colleges and universities inherited the Soviet-style training model many years ago. Although higher education reform has been implemented, the curriculum reform did not reflect market and societal requirements. Nowadays, over 80 per cent of graduates cannot adapt to the competitive environment of the modern enterprise when starting their first job and require vocational training by their companies. The current teaching pays more attention to the interpretation of principles than to practical training. Students' system engineering knowledge is weak and they lack practical education. At most, they only have addressed the first half of CDIO (Conceive, Design), and not the second half, Implement, Operate. This will cause students not to complete their training in school, but leave the training of the second half (IO) for enterprises, which will increase the burden of training on enterprises, and possibly lead to enterprises hiring lower-level students who are easier to train. Modern undergraduate education should cultivate practical engineering skills capable of supporting the whole process of the student's post-project period independently. This is the reason for research and exploration of teaching using a CDIO engineering education model applied to the course, Principles and Applications of the Single Chip Microprocessor.

Since 2000, transnational research by four universities, including the Massachusetts Institute of Technology and the Swedish Royal Institute of Technology, has obtained nearly $US20 million from the Knut and Alice Wallenberg Foundation in Sweden. Through four years of research, the CDIO engineering education concept of *learning by doing* was developed, as well as the organisation, named CDIO. The CDIO model is a generalisation and expression of *learning by doing* and *project based learning* (PBL) [2]. The CDIO model simulates the real work environment of the modern engineer. It uses the concept of an *industry cycle* and puts forward guidelines and requirements for training programmes, teaching methods, student assessment, and learning framework, which focus on both engineers' knowledge and their capabilities. So far, dozens of world-famous universities have joined the CDIO organisation, and a number of universities work together to explore reforms.

During the period of improvement in the quality of undergraduate courses in China, CDIO aroused strong interest in higher education, and it is one of the foreign education models widely accepted by Chinese education authorities and colleges in recent years [3-5]. Many colleges and universities have started using CDIO, and have established CDIO communication and co-operative organisations.

The CDIO engineering education model advocates a problem-driven approach, and focuses on practical teaching and practical ability. It proposes that theoretical teaching should be driven by specific, practical requirements in creating products. The aim of this article is to outline the application of the CDIO education model to the course, Principles and Applications of the Single Chip Microprocessor, and to present a specific implementation plan, based on CDIO. The plan is oriented to engineering design, and aims to develop personal abilities including self-learning, innovation and teamwork. A project is used to promote training. The application of the CDIO model will have a profound impact on the reform of undergraduate education in China.

THE CURRICULUM

Curriculum Concept

The Principles and Applications of the Single Chip Microprocessor course is a specialised basic course that is very practical and mainly taken by students majoring in electronic and information engineering, computer science and information technology, software engineering, electrical engineering and automation at the Mudanjiang Normal University, Mudanjiang. It involves four majors and six classes and is offered in the school as an optional course. The course has become one of the most popular among electrical majors.

The course is based on the premise of developing a single-chip system that meets the demands of enterprises, while increasing students' employability. It aims for projects relevant to enterprises that develop students' professional and practical abilities. The teaching model is student-centred and teacher-guided with integrated learning [6].

Course Content is Determined by Projects

Course content is determined by the needs of enterprise product research while developing students' abilities. The teaching is driven by the requirement to produce single chip microprocessors involved in projects that produce relatively complete products defined by a requirements specification of system functions. Hence, the teaching produces products of use to enterprises. The schematic diagram of the teaching projects is shown in Figure 1.

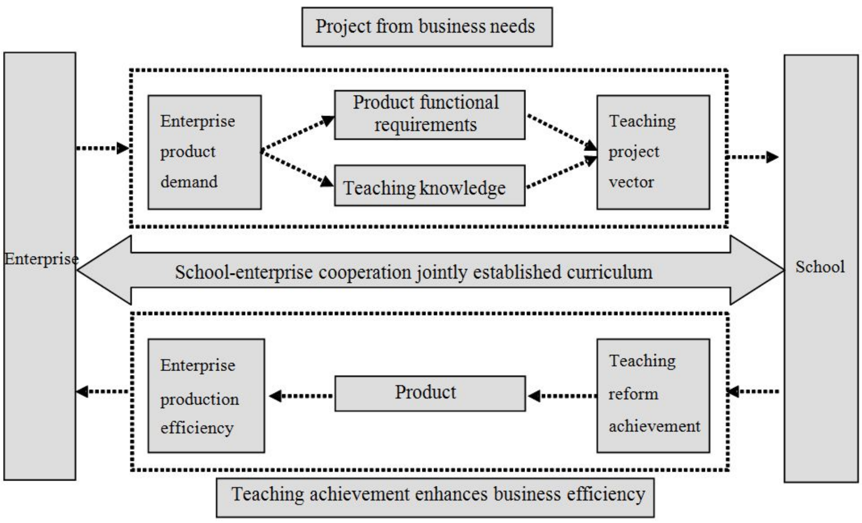

Figure 1: Teaching projects.

Enterprise Experts' Involvement in the Curriculum

After a teaching project is defined according to enterprise requirements, enterprise experts analyse and approve the project considering the following:

- Whether the implementation scheme is reasonable and well-planned;
- Whether the teaching project meets the technical demands for enterprise products;
- Whether the teaching project is versatile, and whether it can cultivate students' CDIO ability in designing and researching single chip microprocessors.

The teaching project can be improved and modified based on the experts' analysis.

MAIN CONTENT OF THE COURSE

Teaching Content

The teaching content of the Principles and Applications of the Single Chip Microprocessor course include two aspects: one is the application of hardware resources, including internal resources (timing, counting, interrupts, storage, communications, etc) and external resources for the single chip microprocessor. The other aspect is the microprocessor as a development platform, including the development software Keil (uVision3) and simulation software Proteus.

Selection of Teaching Projects

An example of a teaching project was to produce a product needed by the Mudanjiang Daming Machinery and Equipment Company. The product was an intelligent pressure controller for a press-fitted welding machine [7]. This pressure controller is composed of five modules: the single chip microprocessor, keying and digitron display circuit, A/D conversion circuit, relay-driving circuit and serial communications circuit.

Each module of the hydraulic pressure controller was mapped to the teaching of the single chip microprocessor. This led to five CDIO teaching projects, which form the basis of the project teaching on the course (see Figure 2). These projects enable students to master the basic principles and applications of single chip microprocessors, with a focus on training students to design and develop single-chip systems.

CDIO teaching projects
Item 1: Pressure controller relay drive circuit design
Item 2: Pressure controller digital display circuit design
Item 3: Pressure controller A/D conversion circuit design
Item 4: Pressure controller serial communication circuit design
Item 5: Pressure controller software and hardware joint commissioning

Figure 2: Teaching projects.

Teaching Content

Each teaching project is a complete CDIO implementation. The implementation process of each teaching project is shown in Figure 3. Each teaching project is implemented through four typical sections, i.e. Conceive (C) - Design (D) - Implement (I) - Operate (O).

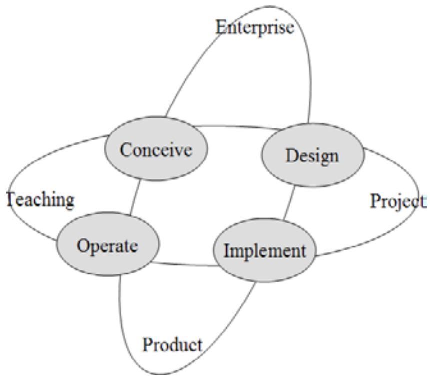

Figure 3: Implementation process.

Teaching Content and Timetable

Project-based teaching was adopted for this course, which consists of five teaching projects. A teaching project is implemented through two teaching modules, as shown in Table 1 and Table 2. Module 1 focuses on conception (C) of a circuit, simulation and the schematic circuit diagram and program design (D). Module 2 focuses on implementation (I) and operation (O), mainly involving the soldering and debugging of a circuit board.

Table1: Teaching plan (Module 1: focus on conception and design).

No.	Class period	Teaching project	Teaching contents
1	2	Project 1: Design and production of relay-driving circuit for the pressure controller Unit 1: Design and simulation of input interface circuit	Development tools and development process for single-chip microprocessor control system; structure of optocoupler, working principle and design of driving circuit; compiling method for input interface control program; simulation and debugging methods of output interface control circuit.
2-3	4	Unit 2: Design and simulation of input interface circuit	Structure and working principle of the relay; design of relay-driving circuit; compiling method for output interface control program; simulation and debugging method for output interface control circuit.

4	2	Unit 3: Drawing and PCB design of schematic diagram of relay-driving circuit for the pressure controller	Use PROTEL99 to draw schematic and PCB diagram of relay-driving circuit.
5-6	4	Project 2: Design and production of digitron display circuit for the pressure controller Unit 1: Design and simulation of working status indicator circuit	Working principle and parameters of light emitting diode; interface implementation method for light emitting diode and single chip microprocessor; compiling method for control program for status indicator circuit; simulation and debugging method of status indicator circuit.
7-8	4	Unit 2: Design and simulation of pressure display circuit	Structure and working principle of digitron-driving circuit and interface implementation method; compiling method of control program for digitron dynamic display; simulation and debugging methods for digitally dynamically display circuit.
9-10	4	Unit 3: Design and simulation of keying circuit	Structure and connection characteristics of keying circuit; interface design method for keying circuit and single chip microprocessor; structure and working principle of timer; the concept of interrupt and programming of timer interrupt.
11-12	4	Unit 4: Schematic diagram and PCB design of digitron display circuit for the pressure controller	Use PROTEL 99 to draw schematic and PCB diagram of digitron display circuit.
13	2	Project 3: Design and production of analog-digital conversion circuit for the pressure controller Unit 1: Design and simulation of signal acquisition circuit	Structural design and parameter calculation of the analog signal amplification circuit; Simulation and debugging method for data acquisition circuit.
14-15	4	Unit 2: Design and simulation of data conversion circuit	Type and working principle of A/D conversion; interface design of A/D conversion and single chip microprocessor; program design of numerical conversion, programming of external interrupt; simulation and debugging method for data conversion and processing circuit.
16	2	Unit 3: Schematic diagram and PCB design of analog-digital conversion circuit for the pressure controller	Use PROTEL 99 to draw schematic and PCB diagram of analog-digital conversion circuit.
17	2	Project 4: Design and production of serial communication circuit for the pressure controller Unit 1: Design and simulation of state storage circuit	Structure, type and working principle of state storage circuit; interface circuit design of state storage circuit and single chip microprocessor; simulation and debugging method of state storage circuit.
18-19	4	Unit 2: Design and simulation of serial communication circuit	Basic concept and implementation principle of serial communication; design method of serial communication circuit; compiling method of serial transmitter and receiving interrupt program; simulation of virtual serial port and joint debugging method of upper and lower computers.
20	2	Unit 3: Schematic diagram and PCB design of serial communication circuit for pressure controller	Use PROTEL 99 to draw schematic and PCB diagram of serial communication circuit.
21-22	4	Project 5: Complete design for the software and hardware of the pressure controller Unit 1: Simulation debugging of automatic operation of the pressure controller	Division of system functions; allocation of single-chip microprocessor's I/O resources; compiling method for complex control programs; simulation and debugging method for automatic operation.

Table 2: Teaching implementation plan (Module 2: focus on implementation and operation).

No.	Class period	Teaching project	Teaching content
1	2	Project 1: Design and production of relay-driving circuit for the pressure controller Unit 1: Soldering of relay-driving circuit	Usage of program download software; soldering of relay and with Darlington transistor.
2	2	Unit 2: Debugging of relay- driving circuit	Driving and debugging relay.

3	2	Project 2: Design and production of digitron display circuit for the pressure controller Unit 1: Soldering and debugging of digitron display circuit; debugging of status indicating circuit	Digitron soldering; debugging of light emitting diode; debugging of segment control and position control.
4	2	Unit 2: Debugging of keying circuit; design and simulation of scanning button control program	Simulation of keying circuit; program debugging of button scanning.
5	2	Unit 3: Design and simulation of key control program for interruption; programming and debugging of keying circuit	Key circuit simulation; key interrupt debugging; button control procedures, burning.
6-7	4	Project 3: Design and production of analog-digital conversion circuit for pressure controller Unit 1: soldering and debugging of signal amplification and analog-digital conversion circuit	Soldering single chip microprocessor and opto-isolator circuit; soldering of signal amplification circuit; debugging of A/D converter ADC0809.
8-9	4	Project 4: Design and production of serial communication circuit for the pressure controller Unit 1: Soldering and debugging of state storage circuit; soldering and debugging of serial communication circuit	Soldering of storage circuit and serial communication circuit; debugging of storage circuit; debugging of Com Wizard and serial circuit.
10-11	4	Project 5: Joint debugging of software and hardware of the pressure controller Unit 1: Joint debugging of the pressure controller	Steps, methods and problems of joint debugging of software and hardware; detection and elimination method of common system fault.

CDIO Teaching Model

In order to realise the integration of teaching, learning and *doing*, the CDIO teaching model has been adopted for the course, Principles and Applications of the Single Chip Microprocessor, as shown in Figure 4.

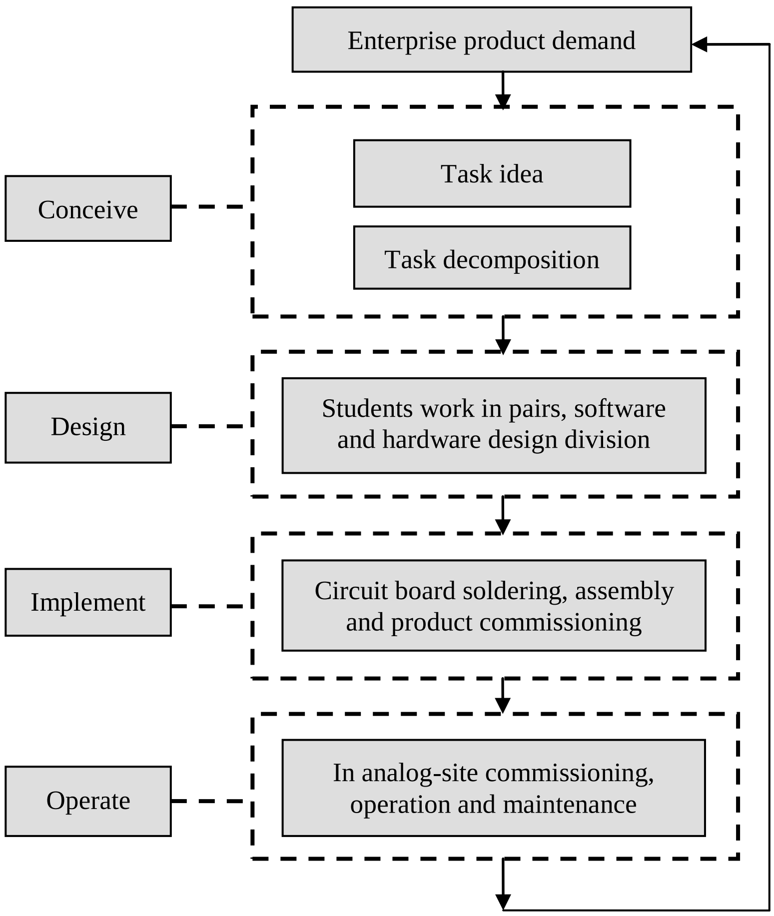

Figure 4: CDIO teaching model.

In the CDIO teaching model, which is project based, under the guidance of teachers, students complete task conception, task decomposition for a product required by an enterprise; they work in pairs to design and simulate the software and hardware, solder and debug the circuit and, finally, debug, operate and maintain the debugged product on a simulated site.

CONCLUSIONS

Through project-oriented CDIO teaching, the educative and teaching aims to reproduce real enterprise projects have been achieved. The key point was to build a *learning by doing* curriculum and to produce highly skilled individuals through training. The approach adopted here was to use shared resources of the school and enterprises, and to combine projects with learning to develop students' knowledge and skills in developing a single-chip microprocessor system. The course was also designed to enhance students' interest in innovation [8], improve students' ability to analyse and solve problems, to expose students to a rigorous working style, and so produce highly skilled graduates for automation engineering design.

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