

# CDIO-based Embedded Systems Training Mode in Graduate Teaching

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**Abstract.** Embedded systems now are widely used in many fields and the demand of qualified talents for embedded system professional is increasing fast. However, the teaching methods of embedded systems are lagging behind. In this paper, the characteristics of embedded systems and the existing problems in graduate teaching are analyzed. A CDIO-based Embedded Systems Training Mode is proposed. It guides the graduates grasp the basic knowledge of embedded systems and lead them how to design and develop a practical project.

**Keywords:** Embedded Systems, graduate teaching, CDIO, Training Modes, Web-based Resources.

## 1. Introduction

Nowadays Embedded systems are quietly changing our life and have been widely used in many fields such as mobile communications, intelligent appliances, automotive electronics, video monitoring, and intelligent robots, etc. With the development of wireless communication and Internet of Things technology, embedded applications are becoming increasingly popular, thus brought a lot of opportunities in embedded system fields.

Compared to the rapid development of embedded system technology, education modes and teaching methods of the embedded systems in universities, to some extent, are lagging behind. On the one hand, students do not have the actual project development experience, and it is not easy for them to find a suitable job after graduation. On the other hand, companies are complaining about being unable to recruit the right talent in embedded system fields. To solve this problem, a CDIO-based Embedded Systems Training Mode is proposed in the paper, especially in the post-graduate teaching process.

## 2. Characteristics of Embedded Systems

First of all, embedded system is highly multidisciplinary, which is based on microelectronics disciplines, electronic technology disciplines and computer disciplines. The hardware platform is based on the large scale integrated circuit technology and electronic technology [1]. Computer technology is developed for the specific application-centric in embedded system fields, which is mainly based on embedded operating system and integrated development environment for embedded systems.

Therefore, embedded system education consists of many basic or related courses. Electronics-related courses are C programming, digital electronics, EDA, SCM principles, programmable logic devices, DSP etc, which are shown in Fig.1. Computer-related courses are C programming, digital electronics, computer organization and structure, microcomputer theory, data structures, operating systems etc, which are shown in Fig.2. Embedded application software development should also master other related courses, such as computer network, network programming, database theory and software engineering and so on.

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From the above it can be seen that the requirements for talents in embedded system area are quite high. Those who devote themselves in development of embedded system, not only have basic knowledge of hardware, but also have knowledge of underlying operating system, such as task scheduling and others. In addition to the field of embedded system applications, he should have basic software development capabilities and specific expertise. Therefore, there are several kinds of people who have different professional knowledge on embedded systems. Electronic engineers focus on the design of hardware and the development of underlying device drivers. Computer engineers specialty focus on software design based on embedded development platform. Both two kinds of engineers require further training and education to be qualified for the job.

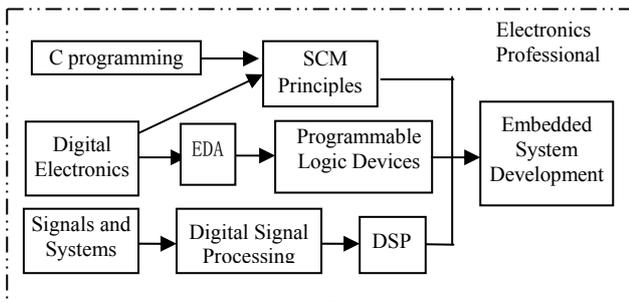


Fig. 1: Electronics -related Courses

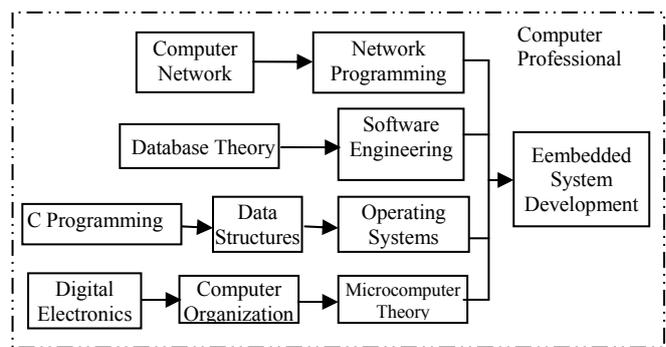


Fig. 2: Computer-related Courses

### 3. Existing Problems in Graduate Teaching

Teaching status for embedded systems in graduate school is shown as follows:

#### 3.1. Incomplete Curriculum System of Embedded System

From the view of curriculum system of embedded system, embedded system personnel training contains related courses, such as hardware design, operating system, and software development. All knowledge is not rely on one course be solved. In United States Colorado State University, embedded system certification includes three courses: guide of real-time embedded system, embedded system design, engineering training of embedded system. Through these courses, students would grasp embedded system through the whole design process, including demand analysis, system design (including hardware and software), hardware production, program development and design, unit test, system integration and testing technology and so on.

#### 3.2. Lack of Proper Teaching Materials for Graduate Students

Embedded system fields are relatively new. Unlike classical traditional curriculum, it has a complete curriculum system and classic teaching materials. In addition, embedded systems is comprehensive which contain electronics, computer, automatic control and any other professional knowledge, such as digital electronic technology, the principle and application of SCM, computer, microcomputer principle, operating system, programming, computer network and other curriculum content. No one material would involve so much content, especially in graduate teaching.

#### 3.3. Different Education Background

The knowledge background of undergraduate professional are quiet different. Students who major in computer would feel weak in hardware design. Whereas students who major in electronics majors would lack of knowledge of the operating system and strong software programming ability, though they have learned courses such as C language program design, microcomputer principle and so on. Even though the same electronics professional graduates, their college training programs are not the same. Some schools or professional offer embedded system course, and some does not. Therefore, different undergraduate background and uneven knowledge of the situation would bring certain difficulty and challenge in teaching of embedded system graduate.

### 4. CDIO-based Embedded Systems Training Mode

Generally, following course such as embedded system architecture, embedded operating systems, embedded application software development are offered to complete holistic instruction of embedded system. In order to connect the related knowledge points and knowledge module, we should arrange teaching contents and teaching methods reasonably.

At first we should carry out social surveys on talents demand in embedded system area. Next, we should decide what kinds of talents should be cultivated and how to cultivate talents, thus setting the training mode in embedded system.

See from the analysis of the talents demand for embedded system, talents usually need strong practical experience and innovation capacity in project development. They also need strong team cooperation experience in the team of advanced development. So it is very important for us to strengthen experimental practice and practical engineering projects so as to improve their operating practical ability. Finally curriculum system and reforming educational model are enhanced.

#### 4.1. Training Mode

With the start of globalization of engineering education, how to train engineering talents with professional knowledge, practical engineering competence and ability to solving problems has become hot spot in the reform of higher engineering education. Based on the actual teaching experience in recent years, we put forward a CDIO-based embedded systems training model shown in Fig.3. CDIO (an initialism for Conceive-Design-Implement-Operate) is an engineering education initiative that was formally founded by Massachusetts Institute of Technology in the late 1990s[3].This model is based on CDIO engineering education system, which is oriented with project design and use cultivation of engineering ability as the goal. It combines with the practical application of embedded systems, optimizing the curriculum system and teaching content from the perspective of project development. It integrates course knowledge which is closely related with embedded systems. Through a real project case, the related knowledge points were combined together, including structure design of embedded system, embedded operating system and embedded application software development. An integrated architecture of embedded system knowledge is designed to adapt to the social demands for embedded system talents. Of course, according to the graduate evaluation and the verification of social workplace, we should modify the embedded systems training mode, curriculum system and teaching methods, so as to modify and improve the syllabus and instruction design of the course.

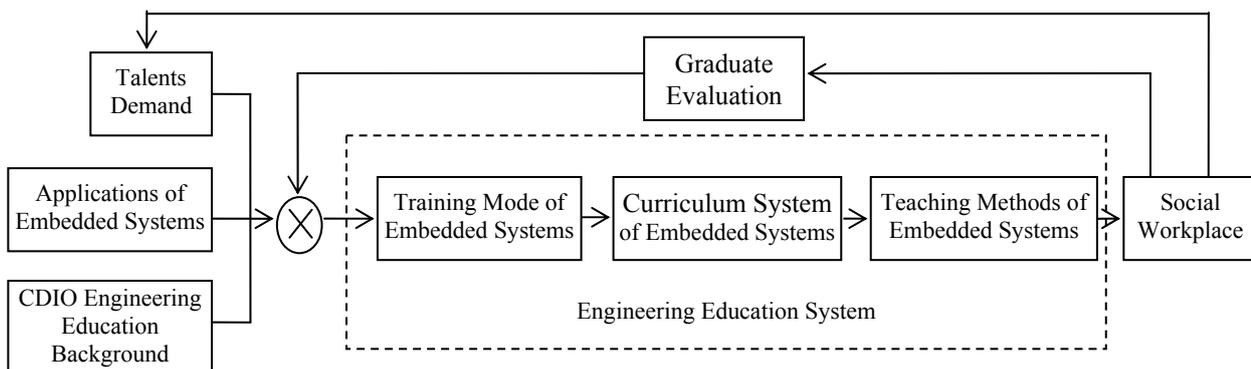


Fig. 3: A CDIO-based Embedded Systems Training Model

#### 4.2. Teaching Methods

In order to achieve CDIO-based embedded systems training mode, two methods are adopted as the following:

##### 4.2.1 Web-based course resources and problem-guided learning method

First of all, embedded system curriculum resources website[6] is designed as shown in Fig.4. Knowledge of embedded system which you should possess at the beginning of studying are listed in the curriculum resources website. There are resources about hardware design foundation, C language program design,

operating system, computer network and so on. Through the classification of learning materials provided by embedded system course resources website, different professional backgrounds students would know their knowledge scotoma or shortage at the beginning study of the embedded system course. They could learn different knowledge in extra time, discussing and exchanging with each other. These would temporarily solve the problem of different undergraduate inconsistent in knowledge defect.



Fig. 4: Course Resources Web Site of Embedded System

Second, curriculum guidance column and cases & project column are set in the course resource web site. Fig.5 shows the required knowledge and practice ability for students to learn embedded system course and how to complete a practical project. In turn, it also shows the knowledge required to complete a project design, thus to promote better learning. All these also temporarily solve the problem of the shortage in teaching materials for graduate. The web site would expand the students' knowledge and improve their learning initiative. It also embodies the learning characteristics of self-study, self-discussion for the graduate students.

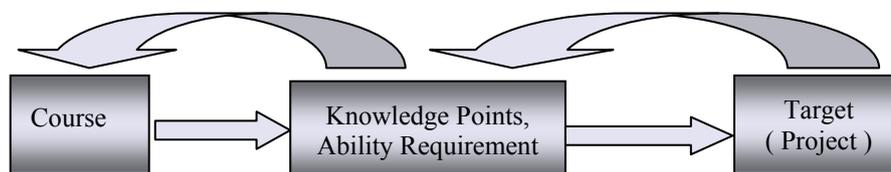


Fig. 5: The Relationship between Course and Target

#### 4.2.2 Project-based learning approach-"learning by doing"

World-famous scientist Einstein once said, interest is the best teacher. When students are interested in embedded systems, they would take the initiative to explore the whole course. They would be more active in thinking and practicing. Meanwhile, they would not give up easily when they face difficulties[2].

In order to solve this problem, we should stimulate students' interests at the beginning of the curriculum. In the classroom teaching, course would be taught around the project design, and organically concatenate the related knowledge of embedded system course. To achieve this goal, project-based teaching approach is flexible and effective[2]. This would enable the students mutual promote between learning and application, and "learn by doing".

The teaching structure of embedded system course is different from traditional courses. It would arrange a number of project topics at the beginning of the curriculum teaching. In the project, students are freedom combined into a number of study groups about 3 to 4 individual, using the form of five learning processes. Each process is based on student-centered, which are shown in Fig.6. Teachers teach the basics knowledge of embedded system course. The course will be divided into several modules according the knowledge points of the project. Smart home system is an example of our embedded Linux project which is divided into the

following thematic elements: C programming for embedded system, kernel porting and file system, inter-process communication in embedded Linux systems, design of Linux device driver, network application development, graphical develop in embedded system. Teacher mentions the main knowledge points, learning methods and key technology. Students learn through course resources website by autonomous learning form after-school. They would discuss with each other, and achieve part of the project requirements or program through experiment. They would explain related knowledge, exchanging learning experience and the method of how to solve the problems in the following class. Students' learning situation would be checked through the progress reporting of each group. At the end of the semester, each student must complete a part of the actual project development and make a final statement, including the implemented situation of the projects and the status of team cooperation. In the development of the project, they could play their expertise of different undergraduate background, learn from each other, and show the team cooperative spirit.

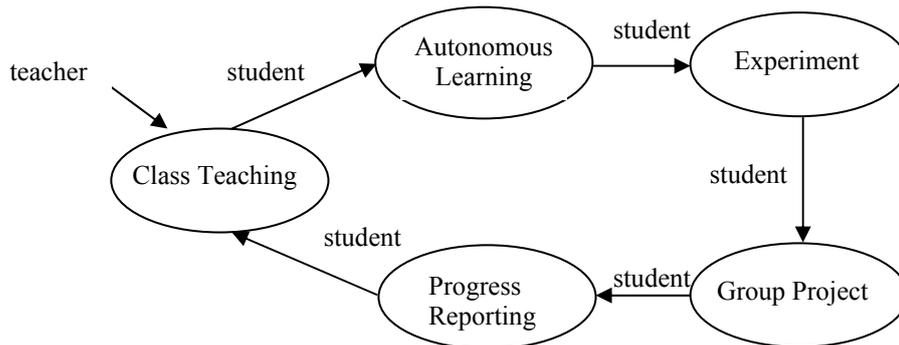


Fig. 6: Practical Teaching Design

Plenty of experiment and practical teaching greatly stimulate the students' learning interests. The teaching effect is evidently improved[1]. Finally, each student would be given a comprehensive score according to their actual project situation and learning ability.

## 5. Summary

In short, the teaching of embedded systems is not only a course, but also an integrated of series courses. In this paper, a CDIO-based embedded systems graduate training model is put forward. It guides the graduates grasp the basic knowledge of embedded systems and lead them how to design and develop a practical project. Of course, the implementation process needs further refined and improved. For examples, Web resources need to be enriched, and the examples of project development need to be increased. We also should strengthen the curriculum examine and evaluate ways to meet the social demand for embedded professionals.

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