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Teaching Reform and Practice of Embedded System Design Based on Outcome-Based Education

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Abstract: Embedded system design is the core course of the telecommunication major in engineering universities, which combines software and hardware through embedded development boards. Aiming at the problems existing in traditional teaching, this paper proposes curriculum teaching reform based on the outcome-based education (OBE) concept, including determining course objectives, reforming teaching modes and methods, and improving the curriculum assessment and evaluation system. After two semesters of practice, this method not only enhances students' learning initiative but also improves teaching quality.

Keywords: Embedded system design; Outcome-based education (OBE); Teaching reform

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1. Introduction

Outcome-based education (OBE) is also known as competency-based education, goal-oriented education, or needs-based education. OBE concept is a result-based, student-oriented, and reverse-thinking teaching concept of the curriculum system, which has become the mainstream concept of education reform in many countries [1]. OBE emphasizes the realization of teaching objectives, the quantitative assessment of the implementation process, and the continuous improvement of the curriculum. As a local undergraduate college focusing on cultivating application-oriented talents, our university has adopted OBE teaching mode reform for telecommunication major students in the past two semesters to strengthen curriculum construction and improve teaching quality.

2. Curriculum characteristics and existing problems

2.1. Curriculum characteristics

The content of the course is based on ARM Cortex-M series microcontrollers, teaching the basic principles and

design methods of embedded systems and laying the foundation for solving complex engineering problems of electronic systems. This course has the characteristics of being applied and practical. In the learning process of this course, the embedded development board is used as the application platform of course design, and the combination of hardware and software is used to complete the control or display of various hardware devices. In this process, students' abilities in software programming, code debugging, hardware circuit construction, selection and debugging, English literature review, project development, and team cooperation are cultivated. This is a highly practical course that comprehensively examines and cultivates students' hands-on ability [2].

2.2. Existing problems

The course adopted traditional teaching methods, in which the teacher first gave detailed lectures on the basic knowledge points involved in each project in the classroom and then analyzed the source code provided by the project sentence by sentence, and students were required to reproduce the experimental results of the project given by the course routine. Lastly, the teacher proposed to expand the function of single-piece realization in this project, requiring students to group and complete. The whole process is dominated by teachers and lacks the active participation of students. Due to the use of project-driven teaching, students encounter a variety of software programming problems during the process, which cannot be solved by a single teacher, resulting in insufficient teaching time. The inability to solve the problems encountered reduces students' interest in the course and they refuse to carry out in-depth practice on the knowledge points related to the project or the extension project, resulting in poor teaching effect. Moreover, they gradually lose interest in the tasks assigned by the teacher in class, and it is difficult to further improve their practical skills. Plus, they complete the book project step by step, lacking creative ideas [2]. In general, the traditional teaching mode of lecturing is no longer suitable for today's modern teaching tasks and the thinking mode of contemporary college students. Therefore, the curriculum teaching reform based on the OBE concept is born. The purpose is to mobilize students' subjective initiative and self-learning consciousness, encourage students to actively participate in all aspects of classroom teaching, and then improve the teaching quality and students' individual comprehensive ability.

3. Curriculum teaching design

OBE curriculum teaching design should be based on students' knowledge, ability, and quality to meet the established requirements and strive to achieve the consistency of teaching objectives and results, which belongs to the design logic of the reverse design and forward implementation. The OBE concept mainly solves key problems such as goal, demand, process, evaluation, and improvement in the process of talent training. Aiming at the course, the teaching design is carried out according to the orientation of undergraduates in our school, professional training objectives, and market demands. It is set for practical engineering applications to solve the problem of consumer electronics design products [3].

3.1. Determining the course objectives

The main task of the "Embedded System Design" course is to let students learn the architecture, development environment, various peripheral hardware applications, and system design methods of STM32F103 series controllers, and to cultivate students' ability of hardware design and software programming of embedded systems. In view of the shortcomings of traditional teaching methods, the curriculum objectives are determined as follows according to the graduation requirements supported by the curriculum. Firstly, the objective is to explain the basic concept and application scope of embedded systems, and correctly use hardware and software to build the system, laying a professional foundation for solving complex engineering problems of electronic

systems. The second objective is to be able to face complex engineering problems, flexibly apply the knowledge learned in this course, and consult other literature to determine the design objectives, conduct systematic functional analysis, and propose feasible system solutions. The third objective is to be able to correctly use common development tools in the industry to complete comprehensive simulation, analysis, debugging, and design of the system [4]. In the teaching process, all the teaching links should be guided by the curriculum objectives, and students can complete the overall improvement of the three dimensions of knowledge, ability, and quality through the implementation of each link in the teaching process.

3.2. Establishing the curriculum knowledge module

Centering on the teaching objectives of the course, knowledge content is divided into nine units according to students' actual cognitive ability and market demand, namely software application, LED (light-emitting diode) flow light, matrix key, serial communication, external interrupt, timer, LCD (liquid-crystal display) display, ADC (analog-to-digital converters), and DAC (digital-to-analog converters). Students from each project complete the implementation process and consolidate the hardware knowledge and related software programming, and even function expansion application, which is the only way to cultivate innovative talents. Through each knowledge module, various knowledge points in this course are integrated, so that students can learn to analyze and solve problems, and achieve a close combination of theory and practice [2].

4. Teaching methods and means

In terms of teaching methods and means, the teaching effect and teaching quality are constantly improved by adopting various methods such as problem-based learning, project-based teaching, and discussion.

4.1. Problem-based learning method

The PBL (problem-based learning) method is an emerging problem-oriented teaching concept that integrates problems into embedded system courses to improve students' problem-solving skills, communication, and teamwork [3]. According to the principle of step-by-step and easy-to-difficult, the teaching content is divided into three types of questions: basic questions, improvement questions, and application questions. In the teaching process, the mode of teaching while practicing is adopted. The basic questions are mainly completed and the students read books by themselves, which makes it easy to obtain knowledge points. Improvement questions are completed after a certain amount of thinking. Application questions are technical problems related to market demand or practical applications, which require students to complete them in groups after class and are slightly more difficult. The difficulty of each type of question ranges from low to high, purposefully guiding students and cultivating their various abilities.

4.2. Project-based teaching method

The project-based teaching method is used to establish the corresponding relationship between the course content and some engineering problems and organically integrate the teaching content into the engineering project. The subject of project-driven teaching is students, who grasp relevant professional theoretical knowledge by solving engineering problems under the guidance of teachers, which has certain practical significance and application value for improving the comprehensive quality of applied talents [4]. In order to facilitate the implementation of project-based teaching, the embedded development board is issued in a group of two people. Students can make full use of resources such as videos and project programming cases on the supporting development board to realize that they can carry out practical projects online and offline anytime

and anywhere.

Embedded development board: The system uses the STM32F103VCT6 microcontroller of STMicroelectronics as the main control chip, which can be powered by a USB port, and uses a DAP (distributed algorithms platform) simulator for program debugging and download. The development board comes with buttons, three-color lights, an OLED display, and various sensor interfaces, which are convenient for students to use for expansion projects. The experiment board is shown in **Figure 1**.

Figure 1. Experiment board

Project implementation: According to the course content and requirements of each chapter, teachers have designed practical training projects for students that can be carried out immediately after class. For example, in the chapter about GPIO (general-purpose input/output), a practical training project for water lamps is designed. Firstly, the types and applications of street neon lights in daily life will be introduced into the classroom teaching content to attract students' interest; at the same time, the display reason and software programming method are explained from the principle of microcontroller pin function and visual retention. This teaching method, which is closely related to practical application, stimulates students' learning motivation and improves the teaching effect. In this teaching method, students act as the main body to complete the project, and teachers primarily provide guidance, answer questions, and solve doubts, which integrates teaching, learning, and research, strengthens the interaction between teachers and students, and improves students' practical skills.

4.3. PAD (Presentation-Assimilation-Discussion)

The process of PAD consists of three stages: the teacher's presentation in class, the student's assimilation, and the student's in-class discussion. PAD class [5], also known as "divided class," allows students to have prepared discussions after digitization and absorption of the content taught by the teacher and the content left blank in the knowledge points, which realizes the organic integration of the teaching method and the discussion method. Students can take the initiative to show their learning enthusiasm in all aspects, so as to improve their comprehensive innovation ability, and students' initiative learning effect is remarkable.

Course preview: Before class, the teacher will send a PowerPoint presentation of the teaching content to the online platform in advance to explain the key and difficult points in detail. At the same time, some reference videos and blog links of relevant knowledge will be added and pushed to the students, so that students can preview the knowledge points and the direction of possible function expansion of the project [2]. At the same time, students can complete some simple multiple-choice questions in advance, so that the teacher will know if there are any questions before the class.

Discussion in other classes: In order to facilitate discussion and summary, students should be grouped according to their learning ability in advance, usually in groups of four. In addition to discussing problems together, each group member serves a different function. The organizer enlivens the discussion, affirms the work of the team members, and achieves the group's overall goals. The debrief is able to clearly present the group's conclusions and answer questions from other groups. The notetaker summarizes the group's opinions or views. The timekeeper schedules time so that everyone has the chance to answer questions, and records different responses by category. In the class, first of all, a systematic summary of the completion of the previous project and a brief review of the difficult knowledge points are made. In addition, one to two groups are randomly asked to explain the knowledge acquired by the group and the knowledge points that have not been understood at present, and other groups are asked to supplement and improve the knowledge points. Lastly, the teacher summarizes the common problems and answers questions and doubts; Individual problems can be solved by group discussion or intergroup discussion.

Intensive knowledge teaching: According to the feedback of the students' exercises before class, the teacher will choose and teach the important and difficult contents for 20 minutes. At the same time, instead of teaching all the selected knowledge, certain knowledge points should be retained, so that students can learn or expand the knowledge on their own after class. This link is an important part of students' transition from passive learning to active learning. In this process, students also need to learn and discuss the improvement questions and application questions assigned by the teacher before class. Teachers do not participate in the discussion, but assess the process according to the group situation, and propose solutions to common problems at the end of the process. Students are encouraged to solve individual problems by themselves after class, so as to stimulate their learning initiative [2].

5. Curriculum assessment system

The learning of embedded system design is practice-oriented, emphasizing students' hands-on and engineering application abilities. The assessment method based on written examination for practical courses is obviously insufficient for students to master the comprehensive ability of embedded systems and affects students' innovative ability of product design. In order to better improve students' practical skills, diversified and multi-level assessment methods [3] are explored based on the characteristics of the "Embedded System Design" course, including daily tests or exercises (25%), daily experiments (25%), and practical assessment (50%). The daily tests or exercises refer to the pre-class and after-class practice and the summary of test results in class arranged on the network platform tool "classroom." The daily experiments refer to the statistical results of the completion of the practice project experiment. At the end of the course, the practice assessment is a comprehensive score based on the functional completion of each practical product and report writing.

6. Shortcomings

Although the above teaching methods have greatly improved students' ability, there are also some problems

in the teaching implementation process, which mainly include the importance of curriculum selection and projects, the role of main knowledge connecting the past and the future, and a certain degree of foresight. The phenomenon of individual members of the group loafing around causes the performances of each member cannot be correctly evaluated [3]. The practical skills of teachers should be closely combined with the actual demand of the market and directly linked with the personal ability of teachers.

7. Conclusions

Based on the teaching concept of OBE, the orientation of students, the market demand, and the practical characteristics of the course, this paper put forward a number of reform methods based on the teaching objectives of the course. The implementation results showed that students' learning enthusiasm has been improved to some extent. It exercises students' ability to comprehensively apply the knowledge to solve practical engineering problems.

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Disclosure statement

The authors declare no conflict of interest.

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