Training Students' Practical and Innovation Ability in Hardware Experiment

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***Abstract*—How to effectively cultivate students' practical ability and innovative spirit is the subject of Computer Science in Colleges and Universities, especially for the first-year or second-year undergraduate students. This paper introduces the experimental teaching reform trial of the Digital Logic courses, and sums up the experience of how to stimulate students' awareness of innovation in the hardware experiment teaching and how to improve the students' practical ability. This paper proposes that we should start the student independent innovation experiment as soon as possible at the university stage. We design the independent innovation experiment in digital logic courses that experiment is an open-minded experiment. After years of experiments carried out, the students deepened understanding of the knowledge of theory course, improve the interest in the design of hardware, understand the basic processes of the design of electronic products, improve the ability of practical, and establish the consciousness of innovation and practice. Our trial has proved that it is very meaningful and feasible to enhance the ability of innovation practice in the low grade students of computer major.**

Keywords—Experimental Teaching; Computer Hardware; Innovation Ability; Practice Training

I. INTRODUCTION

Currently all aspects of society need a large number of high quality talents who have the practical ability and the innovation spirit. However, for the colleges and universities, how to effectively train the students' practical skill and creative spirit is still a challenge, especially for those first two year undergraduate students.

Many colleges and universities made a lot of exploration to find a good method for improving the innovation and practice abilities [1]. They set up a series of specialized courses for students to help the students improve their creative skills and innovative thinking, such as through interdisciplinary or innovative training. For example, in Tsinghua university X-lab or I-center provide a platform for the students who have new ideas and want to make some new things, and these platforms will provide the technical or financial support. But these trainings or platform are generally for the higher grade undergraduates. They have the technology basis or some skills, so they can independently accomplish some innovation projects with little help. But for the lower grade undergraduates, they are under the stage for learning the basic course, so they perhaps have not much time or willing to join such projects for improving their creative ability. So how to do some creative training for the lower grade undergraduates in these basic courses, and how to stimulate their innovative consciousness are the key problems. We made some exploration on our courses in computer professional students these years and got some benefit progress.

The computer professional requires many practices, so the experimental teaching is very important in computer professional students training process [2]. In the process of experiment teaching, we tried to stimulate students' innovation consciousness and trained the hand-on skills for the first-year or second-year undergraduate students. Through such training, we hope these students will join more innovation activities in the following two years' study. The hardware experiment is a good choice, because it is good for show that can attract the students, and it needs a lot of hands-on practice, and easy to make some creative trail. So we selected the Digital Logic course as a starting point [3]. This course is a compulsory fundamental hardware course for computer professional sophomore in Tsinghua University.

For these motivation, we made some trail on course and experiments, set up the new experiment, used some new experimental methods, to consolidate the students' theoretical knowledge, and cultivate their ability of innovation and practice.

II. EXPERIMENT ARRANGEMENT

Digital Logic course in sophomore is one of the earliest hardware courses for computer professional students [4]. In the curriculum system of the computer professional, the Digital Logic course is the forerunner course for Principle of Computer Organization, Computer Architecture, Embedded System and other hardware related courses. It is the important foundation for the following courses, providing the fundamental knowledge and skill.

First in the curriculum system, according to the students' interests and knowledge level, we set up different experimental and theoretical courses, as shown in Fig. 1.

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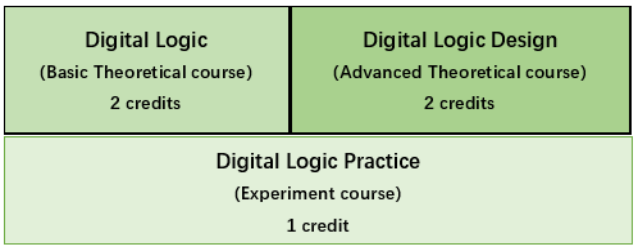

Fig. 1. Digital Logic courses

Digital Logic Practice course, which separates the experiment from the theory course, to form a specialized independent experiment course. All the students are required to select this course. Through the experimental teaching in this course the students will receive the hands-on practice training, that can help them setup the solid fundamentals of digital logic knowledge in practice. For the theory course, this course teaching is divided into two different levels of courses. One is Digital Logic course, which is the traditional teaching content, to meet the basic major teaching requirement; another is a course is face to the students who are interested in the design of hardware, called Digital Logic Design, which contains the contents of Digital Logic and additional project design content. The students need to spend more effort and time to complete some complex experimental content. The two courses are parallel in the curriculum plan, and the students only need to select one of them. In these courses, we use different experiment equipment, experiment methods and the contents of experiment.

Digital Logic Practice course includes the equipment using, combinational logic circuits, sequential logic circuits, such basic experiment content, as shown in Table I. The students who select this course perhaps first touch the real hardware experiment. In the experimental teaching process, the course mainly emphasizes the basic experiment content and practical operation ability. So in the experiment arrangement we set a lot of experiments using the wire to connect the chips, and required the students to use the equipment to do the hardware debugging, master the general digital circuit design and debug skills. In the meanwhile, we also arranged a part of programmable device experiments. We designed the Experimental equipment according to our requirement, as shown in Fig. 2. It uses the simple and convenient connection wire, and it has simple and clear structure. This equipment is convenient to operate, and has high reliability, so it is very suitable for fundamental hardware experiments.

TABLE I. EXPERIMENTS

Experiment	*Description*	*Type*
Instrument Operation	Learn how to the use of experimental instruments, including the oscilloscope, logic analyzer, etc.	Basic
Chip Measurement	Measurement of the delay and transmission characteristics for 74 series chip.	Basic
Adder	Assemble the adder circuit using 74 series chip.	Basic
Timing Control	Using 74 series chip to assemble a circuit, which can control an device with three period of timing.	Advanced
Adder/ Counter	Use hardware description language to design and implement an adder and a counter.	Basic
Traffic Lights	Use hardware description language to design and implement a controller of the traffic lights.	Advanced
Electronic Cipher Lock	Use hardware description language to design and implement an electronic cipher lock.	Advanced
Colored LED Show Originality	Use the light emitting diode or light array to complete a creative idea experiment.	Innovation

For Digital Logic Design course, besides the more difficult theoretical content, the students are required to complete a complex digital circuit design project in the later half course. The hardware equipment has a large-scale programmable logic device on it and has more hardware resources and interfaces, as shown in Fig.3. In the experiment, we first arranged some interface experiment content, such as VGA display, keyboard input, and other input/output experiment content. And then the students were required to design a complex experiment project. The project content was not assigned by the teacher but raised by students themselves. In this course experiment, the students mainly used the HDL to implement their design.

For the student who only select Digital Logic course, they only need to complete the experiments in Digital Logic Practice.

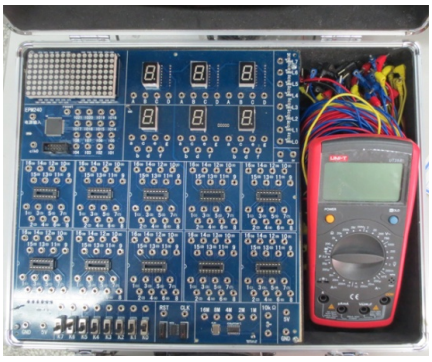

Fig. 2. The equipment of Digital Logic Practice

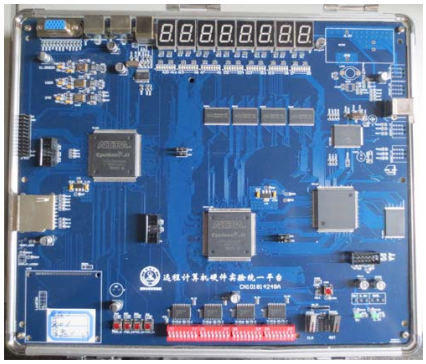

Fig. 3. The equipment of Digital Logic Design

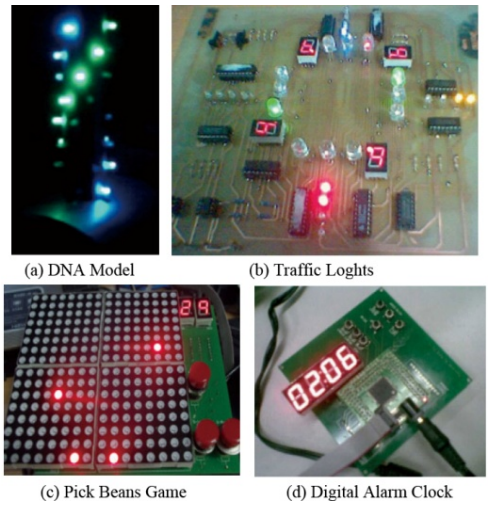

Fig. 4. Experiments demonstration

III. Experiment Result

Most of the students in Digital Logic courses are just touching the hardware experiment, so the experiment is not very difficult, and it has good visible display effect, so it can attract the students' more interest for the hardware. We designed the innovation experiment called Colored LED Show Originality in Digital Logic Practice course. This experiment is much like a small project. It requests the students to use the LEDs to make a show to display their creative ideas. In this experiment the students should think out a topic themselves, using the knowledge learned in Digital Logic courses to design and implement a circuit demonstration device to show their ideas or have some distinctive functions. The experiment requires the students to have their own ideas, but also need them to implement them in practice. This is a good exercise for training the students' ability of innovation and practice. The implementation can use ready-made circuit board, or use the circuit board designed by the students themselves. The implement does not need very complex circuit design, but there must be a sufficient display and have innovative ideas. Fig. 4 is the students' experiments, they are fun and full of innovative ideas.

In the Digital Logic Design course, the project is much more opening. The lab teachers provided much more guidance to the students according to their project design. Because the students selecting this course have interest on the circuit design, they are willing to spend much more time on the project, so they completed some significant projects, such as image recognition, audio playing, games, intelligent vehicles and etc. Fig. 5 is the students playing the game they designed.

Fig. 5. The students is playing the game they designed.

A. Experiment Evaluation

At the end of the project, all the students should give a presentation in class, and other students will give scores to the project presented. And they also need submit a project report. The report must include the design ideas, schematics, or HDL code, and the product user instructions. Meanwhile the report also includes the problems encountered in the design and the solving method. The project's final score will be:

Score = Teacher * 30% + Student Average * 30% + Presentation * 20% + Report * 20%

If the project has some innovation points, it will get 10% additional scores. The innovation includes following aspects: (1) unique or creative ideas, do the things that others have not done, (2) some interesting or meaningful things, such as the DNA double helix structure, showing its replication process, (3) technical difficulty in the design or function., such as image recognition, (4) have good display effect, such as robot control.

B. Practice Training

In order to improve the students' practical ability, it should encourage the students to practice consciously. If we only focus on learning the basics theory knowledge, overlook the cultivation of this consciousness, the students will miss the valuable opportunity to accumulate the experience for improving the practical ability. In the experiment, the teachers and laboratory only provide knowledge and technical support, the students are the dominant in experiment. Compared to the traditional validation experiments, the opening experiment project, independent ideas, efforts to complete their own creativity, the students got higher fulfillment from the project, which promoted the students to have more interest and enthusiasm into hands-on practice.

Practical ability improving is a process of gradual accumulation of the experience. In this hardware experiment, students experienced the process from the circuit design, simulation and debugging, PCB design, to the final implement. These steps improved the students' practical ability gradually. In the experiment, the students perhaps encountered a variety of practical problems, and some problem maybe not easily to find the solution directly from the textbook, the students took many detours to solve these problems. But this process gave students hands-on practice for a personal experience, accumulated their experience, improved the ability to solve specific problems. For example, the students in the PCB board design, should take into account the location of each chip in the circuit board as well as the beauty of the circuit board, and in circuit design they should consider the driving ability of chip pins. These problems were only met in the real design. From such an experiment training, the students got much more experience on hardware design.

C. *Innovation Training*

It is a long term work to train the students' innovation spirit. This process keeps on throughout the whole the course of the university education [5]. Due to the influence of the examination education in primary and secondary schools, the students who just enter universities are often lack of interest and initiative in innovation practice. Therefore, the students should do the innovation training as soon as possible in university, in order to help them to change their inherent thinking formed by the examination education.

At the start course in hardware, the innovation practice includes two aspects, the initiative of innovative awareness and the ability to do hands-on practice. The basic experiments usually involve only one or several points of knowledge. It gives students enough practice and lets them feel confidence to do some new things. Then the innovative experiment can stimulate students' creative thinking. As long as the experiment difficult is appropriately, it will be of great advantage for cultivating the students' engineering practice ability and innovation consciousness [6].

IV. RESULT

In the past five years of experiment teaching in Digital Logic courses, we continuously improved our innovation experiment, and the students had designed and implemented a lot of very creative experiments. In the students' experiment reports, it is often mentioned that the experiment can exercise their practical ability, expand thinking. This innovation experiment is not the required experiment, students can choose by their time and interest. In order to attract students to do this experiment, we will give additional points to those who have creative ideas or completed the experiment outstandingly. So the number of students selecting the innovation experiment were continuously growing in these years, shown in Fig. 6. At the first year, only one fifth students selected the innovation experiment, but after several years of efforts, basically all of the students will choose the innovation experiment. The main reason is that the students have been aware of the innovative experiment is not complex to complete, and it has a lot of fun; and there is no denying the fact, bonus score attracts students to choose this experiment.

Digital Logic Design course is welcome by the student, as the experimental equipment is limited, we set the class size is 40, but too many students want to select, so the students need to draw lots to select this course. One student in his project report said "Through Digital Logic Design course I have a

Fig. 6. The students number select the innovation experiments

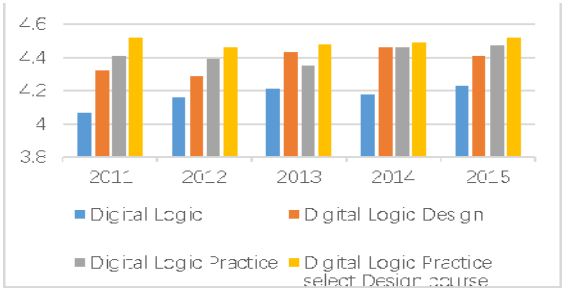

Fig. 7. Average scores of the sthudents in different courses

deeper understanding of the digital logic system. In this course, I improved the practical ability. In the process of completing the work, we encountered a lot of problems, but eventually we overcome it, that is feeling a lot."

We concluded the past five years scores of these courses, found that the student doing the innovation experiment will get higher scores. And those selecting design course will also get higher scores in Digital Logic Practice course, shown in Fig. 7. The innovation project gave positive effect on the students.

Through past several years trail in digital logic experiment, the students' ability of computer hardware design has been greatly improved, especially for the follow-up courses. In Principle of Computer Organization course, the students reflect that the digital logic course experiments are great helpful for their experiment in the Principle of Computer Organization course, especially the students selecting Digital Logic Design course, they appear to be more skillful and confidence for the experiment, and become the leader of the experiment team.

But with the experiments carried out and continuous accumulation in experiment, the students reflect that it is more and more difficult to think out a new idea that is different from the previous. So students choose gradually focus to the games, such as pinball, aircraft fighting. We are also trying to bring some new content and equipment, so that the students can have more choice in projects.

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