DESIGN AND INNOVATION OF PHYSICS EXPERIMENT BASED ON CDIO MODEL

Jijun Zhou, Xiaolin Zheng, Lei He, Jianan Sheng, Xiuying Gao, Min Chen

College of Optoelectronic Technology, Chengdu University of Information Technology, Chengdu, Sichuan, 610225, P.R. China

ABSTRACT

For undergraduate students, the course of Physics Experiment (PE) introduces the general knowledge of laboratory research and experimental skills about science and engineering. Through the course, students can learn the principles about college physics and practice their scientific thinking and skills. By implementing CDIO engineering education model, PE teaching model is innovated in aspects of curriculum design, teaching method and outcome assessment. The 7th and 8th CDIO standards are enhanced in this CDIO practical course [1].

We proposed an ability-oriented teaching pattern for PE. We construct four-level experimental projects, including elementary physics experiment, knowledge application experiment, system design experiment and innovation experiment, which are responsible for the training of students' experimental skills, laboratory research methods, scientific thinking and creative abilities respectively. We adopted CDIO engineering education innovation during the teaching process of PE to achieve these goals. In the course, students carry an active learning by following Concept, Design, Implement and Operate for every experimental project. The process evaluations are used to assess the outcomes of knowledge and abilities of students. The assessments from students and teachers of following professional courses are used to investigate the teaching results of PE.

In this paper, we present the objectives, contents, innovative design, implementation process, as well as the results achieved after reform in PE course teaching. The learning outcomes are verified from student's surveys.

KEYWORDS

Physics experiment, Curriculum innovation, CDIO engineering education, Ability cultivation, Standards: 7, 8.

INTRODUCTION

Since 2009, CDIO engineering education mode has been introduced into our university. A series of reform in engineering education have been carried on, which emphasizes the cultivation of students' practical ability. As an elementary engineering course, PE course provides a platform that can effectively exercise the students' practical ability. Therefore, how to well combine PE teaching with engineering education, and give full play to the role of PE course in the cultivation of students' practical ability, is an urgent problem to be solved in our university.

Motivated by the concept of CDIO engineering education and the teaching method of Concept-Design-Implement-Operate(C-D-I-O)[2], a comprehensive construction and teaching reform of PE is being implemented in our university. We have innovated PE teaching model on curriculum design, teaching method and outcome assessment. We have proposed an ability-oriented teaching pattern for PE, and teaching practice is carried in the PE course.

In this paper, we present PE teaching system of students' ability-oriented cultivation and the innovate teaching pattern with doing C-D-I-O by students in details. We also present the objectives, contents, innovative design, implementation process, and the outcomes of students' and teachers' surveys achieved after reform.

ABILITY-ORIENTED TEACHING SYSTEM OF PE CURRICULUM

The curriculum of PE is the elementary class for introduction of laboratory research method and experimental skills for undergraduate students in the major of science and engineering. Through the course, students can learn the principles about college physics and practice their scientific thinking and skills. At the beginning of the PE reform, we firstly constructed a specific teaching goal about ability-cultivation for the course, which refer to experimental method and skill, scientific thinking and innovation consciousness and ability.

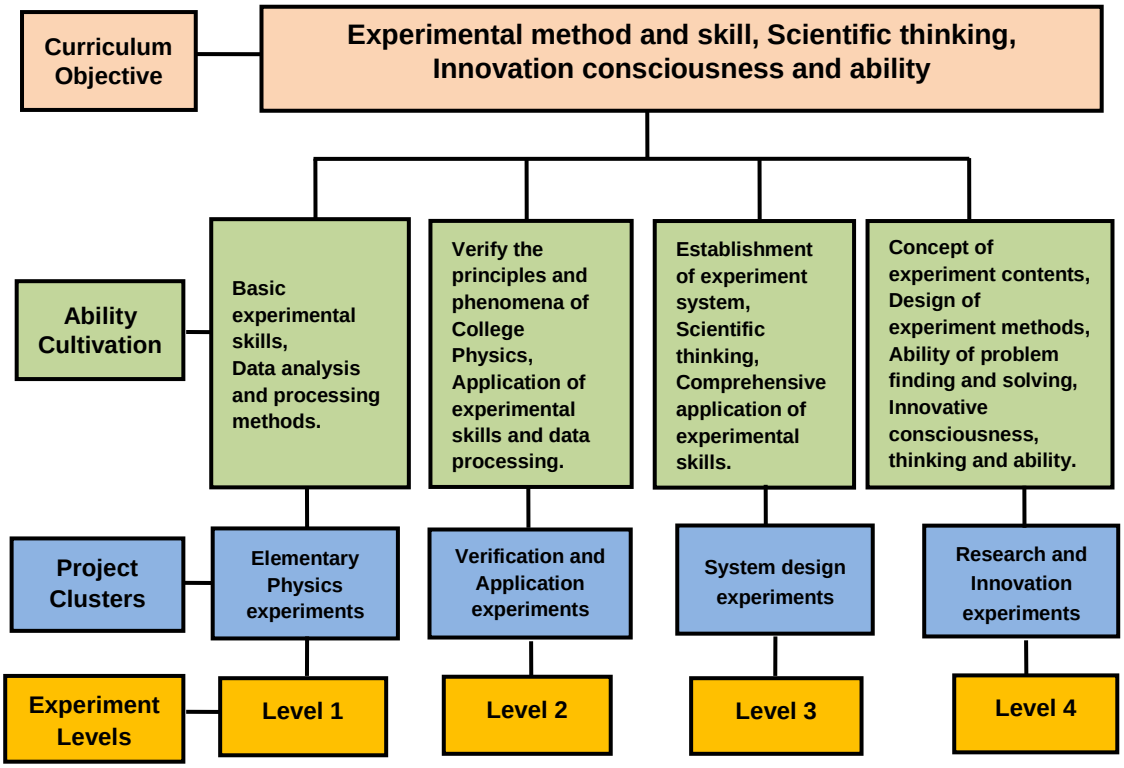

Figure 1. The framework of PE teaching system

Guided by the goal, we rebuilt the PE teaching system as shown as Figure 1. In the teaching system, there are more than forty experiments engaged into the contents of Mechanics, Thermotics, Electromagnetics, Optics and Modern physics. Some related technology and its

application are added into the experiments too. The PE experiments are divided into 4 levels in the system and every level includes several projects called project cluster. The first level of project cluster is consisting of elementary experiments, in which students can practice their ability of basic experimental skills and data analysis and processing methods. The second level is the knowledge verification and application experiments, in which students can verify the principles of College Physics and apply the theories into explaining the experiments and builting the experimental methods. The third level is the system design experiments, in which students promote their ability of experiment system establishment, scientific thinking and comprehensive application of experimental skills. The fourth level is the research and innovation experiments, in which students can learn the skill of experiment contents, experiment design methods, problem finding and solving, innovative consciousness, thinking and ability. When students completed the four-level project clusters, curriculum objects of PE are achieved.

In order to achieve the goals of PE, we built the course standards according to the CDIO syllabus by designing three-level abilities, as shown in Table 1.

Table 1.The standards of PE course

First-level Standards	Second- level Standards	Third- level Standards
1 Technical knowledge and reasoning	1.1 Basic knowledge of Physics	1.1.1 Basic theoretical of physics
		1.1.2 Basic experimental research methods and skills
	1.2 Physical application of core engineering knowledge	1.2.1 Physics basis of application
		1.2.2 Conception and method of engineering application
2 Personal ability, professional ability and attitude	2.1 Ability of logical reasoning and problem solving	2.1.1 Discover and express physical or scientific problems
		2.1.2 Define concept, discover law and establish physical model
		2.1.3 Qualitative analysis and quantitative calculation
	2.2 Experiment and knowledge discovery	2.2.1 Problems discovery in experimental research
		2.2.2 Establish experimental exploration methods and skills
		2.2.3 Analysis and comparison of experimental results
	2.3 Personal ability and attitude	2.3.1 Logical thinking, innovative consciousness, thinking and ability
		2.3.2 Active learning
		2.3.3 Self-taught and lifelong learning
3 Interpersonal skills: team work and communication	3.1 Ability of Communication	3.1.1 Ability of expressing engineering and scientific problems
		3.1.2 Ability of teamwork cooperation

INNOVATIONOFPE TEACHINGPATTERN

Based on the ability-oriented system of PE, we carried on a reform of teaching mode in PE course. We renewed the teaching concepts, methods and assessments by using the concept of CDIO engineering education and the teaching method of Concept-Design-Implement-Operate(C-D-I-O).

In the teaching pattern, teacher is responsible for the planning and supervising for PE project, while the students are asked to dominant the whole project. Before PE class, the teachers need to plan the objects and standards of experiment project, and design the main stages of experiment. The students should make the preparation for the experiment, understand the experiment plan and write a preparation report. During the PE class, the teacher explains the plan with students and helps them to do experiment. The students set up the experiment system and complete the experiment independently according to their own plan, then show experiment results to teacher. After PE class, the students would write the report of the project according to their own experiment process, and do the data processing and result analysis. The teaching make the assess for the report and the student's skill and ability. Thus, Project based learning are used in the teaching process of PE[4-5]. In each project, students can experience the whole process of C-D-I-O, and their skills and abilities can be trained continuously during the active learning.

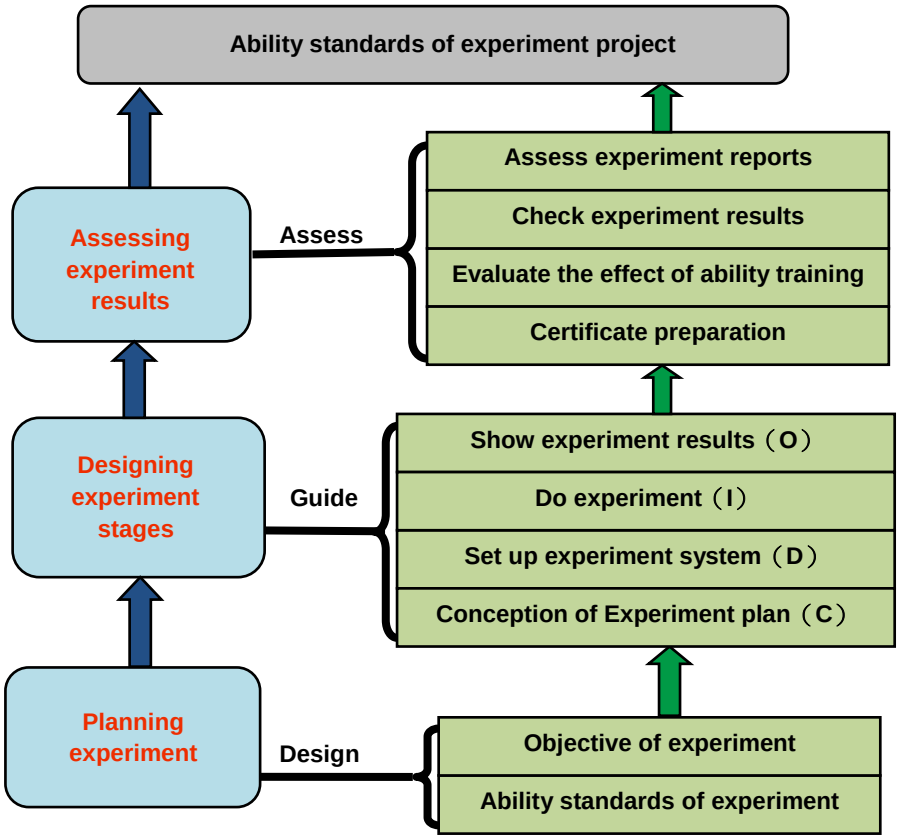

Figure 2. Teaching pattern of PE experiment project

TEACHINGPRACTICE OF PE COURSE

In order to achieve the goals of PE and work on the new teaching pattern, the ability cultivation is set for every experiment, which is called the project syllabus. CDIO stages are designed for every experiment. In every stage, several main tasks are designed, and the weighting of stage in the assessment and the related assessing standards are set according to the needs of experiment. All PE teachers are asked to implement the teaching program of project strictly during the classes. All PE students must do all the jobs designed in the program.

Table 2. Teaching plan of RLMO experiment project

CDIO Stages	Tasks	Weight-ing	Assessing Standards	Project Syllabus	Third-level Standards of PE course
Conception of experiment	Preview(Done before class): 1) Theoretical knowledge of Kinematics. 2) Measurement principle and method of velocity and acceleration.	20%	Sufficient and detailed experiment preview report	1)Survey of print and electronic literature 2)Comprehensive knowledge application	1.2.1 Physical basis of practical application
Design of experiment	Designing and Presentation: 1) How to measure velocity and acceleration according to experiment condition. 2) Experiment steps. 3) Experiment parameters.	10%	Reliability and rationality of designed process	3)Experimental inquiry 4)Oral presentation	2.1.1 Discover and express physical or scientific problems
Implement of experiment	Operating: 1) Learn operation methods of the instruments. 2) Measure velocity and acceleration according to the designed process.	30%	Operation ability of instruments and measurement results of velocity and acceleration	5)Design of experimental process 6)Experimental operation 7)Projects implement	1.2.2 Conception and method of engineering application 1.1.2 Basic experimental research methods and skills 2.2.2 Establish experimental exploration methods and skills
Operation of experiment	Demonstrating : 1) Design one experiment: project of kinematics individually 2) Finish the above experiment project process successively and independently.	20%	Quality of designed project and experiment demonstration	8) Logical thinking 9) Self learning	2.3.1 Logical thinking, innovative consciousness, thinking and ability 2.3.2 Active learning
Summary of experiment	Analyzing and Summarizing: 1) Obtain results based on the Arrangement and process of experimental data. 2) Analyze the experimental error and influence factors. 3) Improved experimental method and process. 4) Detailed experimental report.	20%	Validity of data handling and analysis, Quality of team report	10)Data handling and Analysis 11)Written Communication	2.1.3 Qualitative analysis and quantitative calculation. 2.2.3 Analysis and comparison of experimental results

For example, there is a PE project named Research on the Law of Motion of Objects (RLMO). Its teaching plan is shown in Table 2.As we can see, students can have their own ideas and experimental design in every stage so long as they are able to complete the relevant task. When they do the experiment stage by stage, they will experience an active learning process of C-D-I-O. During the experimental process, teachers will give evaluation and score for students' experiment skills and outcomes in real time. A set of pictures during the RLMO PE course are shown in Figure 3.

Figure 3. Active Learning in RLMOPE course

STUDENTS' AND TEACHERS' SURVEY AND FEEDBACK

In the past three years, we have introduced the reform and innovation PE course for all science and engineering students of grade 2012-2014 in our university. In order to investigate the effect of PE reform, a survey was used for the students involved in PE course, which included 9 questions as shown in Table 3. The other two surveys were used for the teachers involved in PE and professional experiment courses respectively, as shown in Table 4. The survey was conducted in the college of optoelectronic technology, and the resulting distribution chart is shown in Figure 4 and 5.

Table 3. Questionnaire survey for students

Numbers	Questions
1	Do you like the current PE teaching method?
2	Do you think the PE course can help you to understand the theories of Physics?
3	Do you think the "Conceive - design - implement - operation" process is helpful to carry the active learning in experiment projects?
4	Do you preview the Physics principles and conceive the experiment contents before PE class?

5	Do you design the experiment method and scheme according to the experiment content at the beginning of the PE course?
6	Do you carry the experiment and obtain experiment results independently during PE course?
7	Are you satisfied with your experiment process and reports after PE course?
8	Do you think the PE teaching method can train your brain and abilities effectively?
9	Do you think the PE teaching method can give you sufficient self-display space?
Answer options for the questions	A. Yes B. Noncommittal C. No

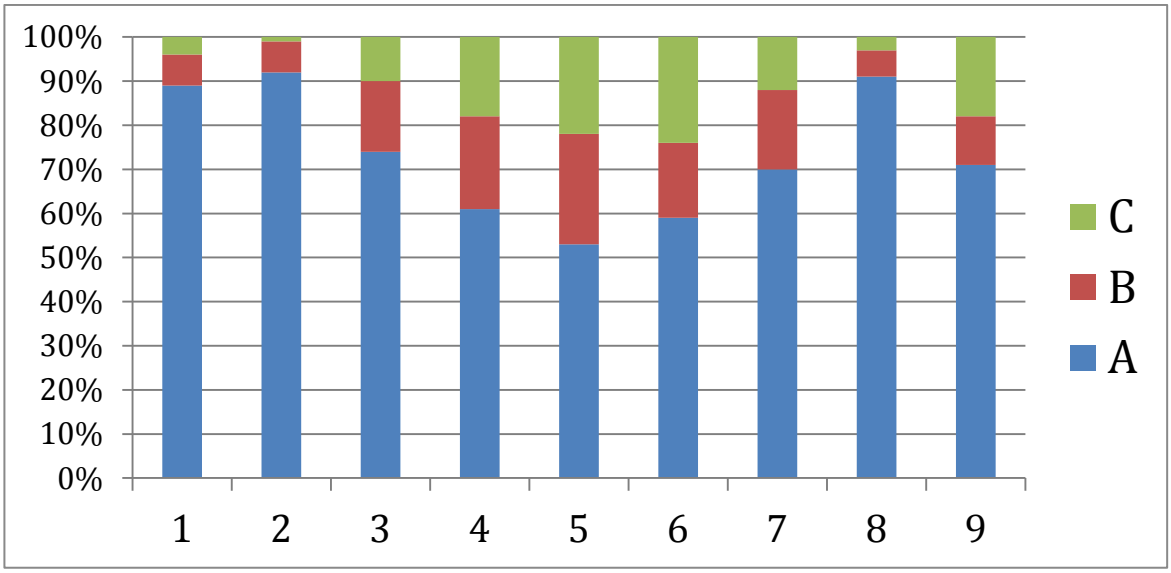

Figure 4. Result of students' survey

For students' survey, it was conducted in around 500 students of different grade. The result indicates that most of students have considered the PE teaching model is good and is helpful to train their abilities. More than half of students have had active learning during the process of PE course.

Table 4. Questionnaire survey for teachers

Numbers	Teacher type	Questions
1	Teachers involved in PE course	How do you think of the current PE teaching mode?
2		Do you think the PE teaching mode can train students' brain and abilities effectively?
3		Do you think the PE teaching mode can achieve the goal of the PE course better?
4		Do you think the PE teaching mode can increase the students' interest in PE course?

5	Teachers involved in professional experiment courses	Do you think the students in Grade 2012-2014 have more enthusiasm in the professional experiment class?
6		Do you think the students in Grade 2012-2014 show better scientific thinking abilities in the professional experiment class?
7		Do you think the students in Grade 2012-2014 show better experiment skills in the professional experiment class?
Answer options for the questions	A. Yes B. Noncommittal C. No	

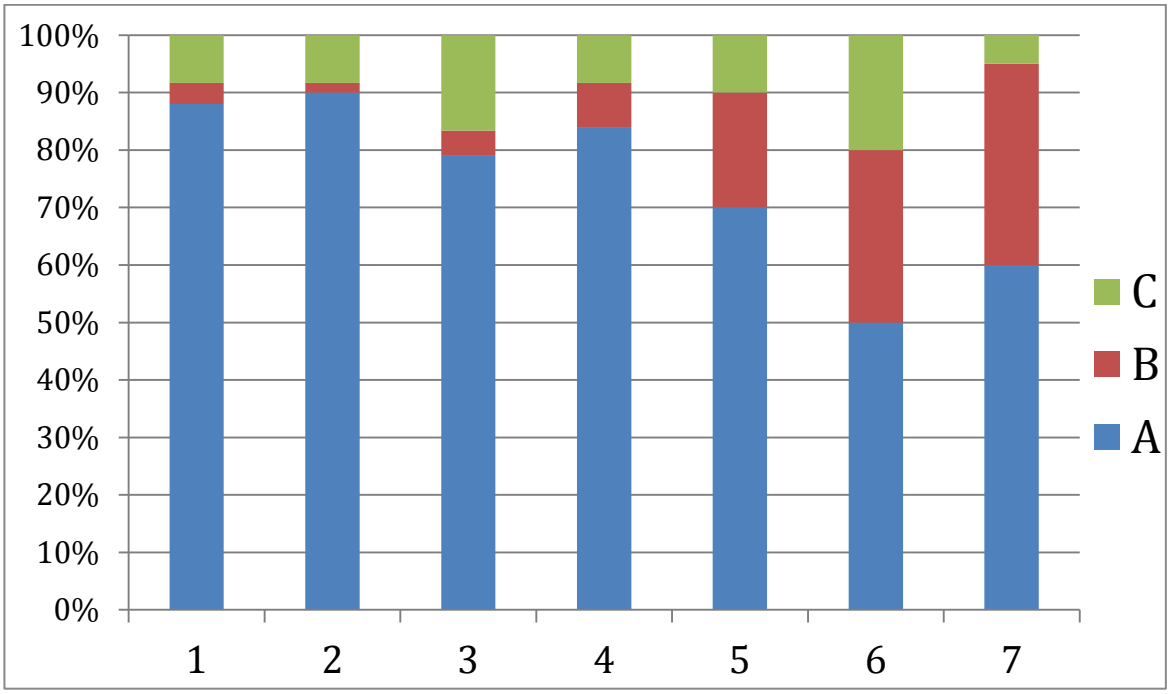

Figure 5. Result of teachers' survey

For teachers' survey, it was conducted in 15 teachers involved in PE course and 20 teachers involved in professional experiment courses. The result indicates that the involved teachers have positive attitude to the innovation of PE course. The PE teachers consider the PE teaching mode can train students' brain and abilities effectively and achieve the goal of the PE course better. More than half of the teachers of professional experiment courses consider the students who were taught with new PE teaching mode have better scientific thinking abilities and experiment skills than the students who were not.

RESULTS

Combined with conception and method of CDIO engineering education, we have innovated PE teaching model on curriculum design, teaching method and outcome assessment. An ability-oriented teaching pattern for PE course is proposed, and four-level projects are constructed, which are elementary physics experiment, knowledge application experiment, system design experiment and innovation experiment, which are responsible for the training

of students' experimental skills, laboratory research methods, scientific thinking and creative abilities respectively. In the PE course, students carry an active learning by doing Concept, Design, Implement and Operate for every experimental project, and the process evaluations are used to assess the outcomes of knowledge and abilities of students. The surveys for students and teachers indicate that the students and teachers have positive attitudes to the reform of PE course. More than half of PE students have had active learning during the process of PE course. Most of the teachers consider the students have better experiment skills and abilities after the innovation of PE course. Therefore, the 7th and 8th CDIO standards are enhanced in this CDIO practical course.

REFERENCES

[1] Edward F. Crawley, Johan Malmqvist, William A. Lucasand Doris R. Brodeur (2011). The CDIO syllabusv2.0.*Proceedings of the 7th International CDIO Conference*, Copenhagen, June 20-23.

[2] HaraldurAudunsson, Andrei Manolescu (2014). CDIO spirit in introductory physics courses in engineering. *Proceedings of the 10th International CDIO Conference*, Barcelona, June16-19.

[3] Luisa García, Alejandra González, Francisco Viveros and Gloria Marciales(2014), An integrated curriculum, learning assessment and program evaluation model.*Proceedings of the 10th International CDIO Conference,* Barcelona, June16-19.

[4] Jin Li, Min Chen (2012). Project-based learning on comprehensive engineering training. *Proceedings of the 8th International CDIO Conference*, Brisbane, July 1-4.

[5] Pham Ngoc Tuan (2012). Developing innovative graduation projects based on CDIO approach. *Proceedings of the 8th International CDIO Conference*, Brisbane, July 1-4.

BIOGRAPHICAL INFORMATION

Min Chen is a Professor in Material Science and a teacher in the Department of Optoelectronic Technology at Chengdu University of Information Technology. She works on topics related to engineering education reform in the department, and focuses on the curriculum design and the improvement of teaching in recent years. She is also the education administrant of Chengdu University of Information Technology. Her current research focuses on implementing of CDIO engineering education model in the University.

Jijun Zhou is a senior experimentalist in the Department of Optoelectronic Technology at Chengdu University of Information Technology. He works on the topics related to the reform and innovation of college physics experiment. He is also the director of physics experiment center of the university. In this paper, he conducted the implement of new PE course.

Xiaolin Zheng is a Ph.D. in Material Science and a teacher in the Department of Optoelectronic Technology at Chengdu University of Information Technology. In this paper, he involved in the design of teaching system, standards and pattern of PE course.

Lei He, Jianan Sheng and Xiuying Gao are lecturers in the Department of Optoelectronic Technology at Chengdu University of Information Technology. In this paper, they are the exact executor of new teaching program of PE course.

Corresponding author

Prof. Min Chen
Chengdu University of Information Technology
No. 24, 1 block, Xuefu road
Chengdu, Sichuan, 610225, China
86-28-85966385
minchen@cuit.edu.cn