



# Research and Practice on the Reform of “Teaching-Learning-Examination” Multi-linkage Practical Teaching Mode

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**Abstract.** Practical teaching is an indispensable part of teaching in higher vocational colleges. In order to solve the problems in the practical teaching link, such as low efficiency of classroom teaching in the experiment link, outdated teaching methods in the comprehensive practice link, unreasonable assessment methods in the practice link, the discipline competition and 1+X certificate training’s failing to be organically integrated with practical teaching, etc., this paper adopts the “flipped classroom” teaching mode in the experiment link, the multi-task and hierarchical teaching in groups in the comprehensive practice link, the assessment method of “two exams for each course”, as well as a series of reform strategies such as replacing exams with competitions, replacing exams with certificates, and implementing credit transfer. Through the exploration and practice of a semester of practical curriculum for some classes of Grade 2020 in a college in Shandong, the effect is remarkable and can be further promoted and applied to similar courses.

**Keywords:** Two exams for each course · Replacing exams with competitions · Replacing exams with certificates · Credit transfer · Flipped experimental classroom · 1+X certificate

## 1 Introduction

At present, there are different opinions in Chinese academic circles about the reform of the practical teaching mode in colleges and universities and many of them are innovative. For example, Zhu Zhengwei and others believe that it is necessary to carry out practical teaching from four aspects of improving the practical teaching system, perfecting talent training plan, increasing practical teaching funding, and building practical teaching bases; Zhang Li sums up the methods of optimizing practical teaching and puts forward the point of view of integrating classroom practical teaching resources; Cao Chenglong and others propose to ensure the practical teaching driven by “mass entrepreneurship and innovation” through collaborative cooperation and multiple assessments. Scholars’ research has enriched the results of the reform of the practical teaching mode [1, 2]. The

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“Outline of China’s National Plan for Medium and Long-term Education Reform and Development (2010–2020)” proposed to “innovate the talent training mode, adapt to the needs of national and social development, deepen education and teaching reform, and innovate education and teaching methods” [3]. In January 2019, the “Implementation Plan of National Vocational Education Reform” required to deepen the reform of the training mode of compound technical and skilled personnel and start the pilot work of the 1+X certificate system. The pilot work should further play the role of academic certificates, consolidate the foundation for sustainable development of students, and encourage vocational college students to actively obtain various types of vocational skill grade certificates while obtaining academic certificates, so as to expand their employment and entrepreneurship skills [4, 5]. In short, the reform of practical teaching in Chinese colleges and universities is in the ascendant. Many colleges and universities have carried out reform and exploration in terms of teaching ideas, teaching methods and quality management measures based on their own teaching status and teaching experience and have also achieved some remarkable results.

The foreign practical teaching thought and its development have a long history. “The formation of the concept of pan-practice teaching in foreign universities is a theoretical sublimation of practical teaching activities in universities and an inevitable trend in the long-term development of practical teaching in universities” [6]. MIT has always attached great importance to practical teaching, taking it as an important means to achieve “equal emphasis on hands and brains”. At the same time, it also provides opportunities for students to participate in practice as much as possible, ranging from small classes to large-scale practical projects, so as to make students not only use their brains, but also use hands, learn in practice, and innovate in practice. The practical teaching concept of equal emphasis on hands and brains encourages students to participate in projects, conduct independent learning, stimulate greater potential under strong pressure, and achieve students’ academic achievements as well as their career development. In short, in the process of exploring the development of the pan-practice teaching system, foreign universities have extensively strengthened the cultivation of students’ practical ability, penetrated the idea of practical education into all levels of the university and through the entire process of university personnel training, and established the development direction of the combination of knowledge and action, the combination of learning and thinking, the combination of inside and outside the classroom, and the combination of theory and experience in university education, providing ideological and institutional guarantees for universities to improve the innovation ability, practical ability and collaboration ability of talents.

## **2 Problems Existing in the Practical Teaching of Existing Engineering Courses**

Based on the current research status in China and foreign countries, the reform of practical teaching in colleges and universities has achieved remarkable results, but the research on practical teaching of engineering majors has not yet been specified, and the classroom teaching mode and assessment method of practical teaching can be further improved. This paper mainly focuses on the following aspects for reform:

### **2.1 Low Efficiency of Classroom Teaching in the Experiment Link**

In the past, the traditional teaching method of engineering experimental courses in colleges and universities was that the teacher first explained the theoretical knowledge related to this experimental course in the form of review and then explained the experimental content, steps and methods, and then the students did their own experiments. The disadvantage is that the explanation takes up a lot of time, which greatly shortens the time for students to conduct experiments by themselves and cannot extend in depth. Even some students can't complete the basic experimental content within the required time, resulting in unsatisfactory experimental results.

### **2.2 The Teaching Method in the Comprehensive Practice Link (Practical Training) is not Conducive to Teaching Students in Accordance with Their Aptitude**

In the existing practical training link, the overall teaching of large classes has been adopted and all students work together to do one task. The disadvantage is that due to the different levels of students, it is very easy to cause some students to be "not full" and some students to be "indigestible".

### **2.3 Unreasonable Assessment Methods in the Practice Link**

The evaluation of score of the practice link has always adopted a vague evaluation method, which is usually based on the one-semester experiment, the one-week practical training or the classroom performance of the course design, the writing of the experimental report, and the quality of the product or project. However, due to the large number of students in the class, it is difficult to accurately evaluate the classroom performance. Some students' experimental reports and works also copy from each other, which is not conducive to the final and accurate score evaluation.

### **2.4 The Discipline Competition and 1+X Certificate Training's Failing to be Organically Integrated with Practical Teaching**

Discipline competitions corresponding to engineering majors in colleges and universities have achieved remarkable results in cultivating students' abilities and a group of outstanding engineering and technical personnel have emerged. After joining in work, students show super innovative R&D and design ability. However, only some students can participate in the competition, which belongs to "elite education" and cannot be oriented to all students, resulting in low enthusiasm and participation of students [7].

The 1+X certificate system of colleges and universities fails to organically integrate the certificate content and practical teaching, resulting in the "two skins" of certificate and teaching. Students can't get the X certificate successfully by using only short-term certificate training, or they just get the certificate but don't meet the technical skills required by the certificate.

### **3 Measures to Improve the Quality of Practical Teaching**

In view of the problems existing in the existing practical teaching process, combined with the author’s many years of teaching experience, the following reform measures have been explored and preliminarily practiced:

#### **3.1 The Classroom Teaching in the Experiment Link Implements the “Flipped Classroom” Teaching Mode**

The so-called “flipped classroom” refers to a teaching form that breaks the traditional teaching mode and inverts the teaching structure of the traditional teaching mode, and adopts an exploratory learning method that allows students to learn actively [8]. That is, students complete the learning of the textbook content independently after class, and the classroom becomes a place for interaction between teachers and students, including knowledge application, question and answer, etc., thereby improving classroom efficiency and achieving better educational effects. In today’s “flipped classroom”, students can efficiently use information technology and digital equipment to conduct independent learning according to the course content planned by teachers and their own learning pace. Teachers change from leaders to organizers, guides and helpers of student learning. The traditional “teacher-centered” teaching mode is turned into a “student-centered” innovative teaching method, which reflects the “people-oriented” teaching concept [9].

Referring to the “flipped classroom” teaching mode, combined with the characteristics of engineering courses, the “flipped classroom” of experimental courses can be carried out as follows. The teacher first records the theoretical knowledge review content and experimental tasks related to each experiment course into a video and posts it on the Internet. Before class, students can watch the teaching micro-lecture video outside the class through a computer or mobile phone and think about how to complete the experimental task. The video can be played repeatedly, which is convenient for recording the learning content. In the experimental class, students operate the experiment by themselves. The time saved can be used to continue to deepen or expand the experimental content, which greatly improves the quality and efficiency of the experimental course and most importantly, stimulates the students’ interest in learning, and the result is bound to get twice the result with half the effort.

At present, the video of the “flipped classroom” in the experiment link is being recorded. The screenshots of some of the recorded video courseware are shown in “Fig. 1”, and the video screenshots are shown in “Fig. 2”.

#### **3.2 The Comprehensive Practice Link (Practical Training) Adopts the Teaching Mode of Group, Multi-task and Hierarchical Teaching**

The comprehensive practice link (practical training, curriculum design) usually has a large number of students and a large class teaching is not conducive to teaching students in accordance with their aptitude. Therefore, group teaching is adopted to encourage students to achieve strong combinations and weak combinations. Teachers assign tasks of different degrees of difficulty in a targeted manner, that is, hierarchical teaching, so that students at different levels can master the tasks assigned to them. This is not

### 知识回顾

定时计数器T0方式1连接结构图

(3) 根据需要开放中断, 中断方式时, 对IE赋值; 查询方式时, 此步骤没有。

D7	D6	D5	D4	D3	D2	D1	D0
EA		ES	ET1	EX1	ET0	EX0	

D7	D6	D5	D4	D3	D2	D1	D0
TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

(4) 对TR0或TR1置位, 启动定时/计数器工作。

### 一、定时计数器的初始化

#### 1、基本步骤

(1) 确定T0和T1的工作方式, 对TMOD赋值。

D7	D6	D5	D4	D3	D2	D1	D0
GATE	$C/\bar{T}$	M1	M0	GATE	$C/\bar{T}$	M1	M0

(2) 计算初值, 并将初值写入TH0、TL0或TH1、TL1。

#### 2、计算初值X

(1) 计数功能  
 $X = \text{最大计数值}N - \text{计数值}n$

(2) 定时功能  
 $X = \text{最大计数值}N - t/T$ , 其中t为定时时间; T为机器周期。

Fig. 1. Part of the recorded “Flipped Classroom” courseware.

Fig. 2. Recorded video clips of “Flipped Classroom”.

only conducive to cultivating high-level skilled students, laying the foundation for the school’s discipline competitions and selecting talents, but also making students with average academic performance gain a sense of gain and satisfaction, which can be said to kill two birds with one stone.

**Table 1.** Tasks of each group of electrical control and PLC practical training

Task	Task content of each group	Degree of difficulty
Task 1	· Three lights are lit in a cycle with an interval of 2 s	Easy
	· Three-phase asynchronous motor forward and reverse operation	Moderate
	· Unloading unit design	Difficult
Task 2	· Three lights start in sequence and stop in reverse order with an interval of 1 s	Easy
	· Three-phase asynchronous motor star-delta starts	Moderate
	· Capping unit design	Difficult
Task 3	·The digital tube displays 0–9 digits cyclically	Easy
	·Three-person responder controlled by the host	Moderate
	·Dowelled unit design	Difficult
Task 4	·Three-person responder displayed by digital tube	Easy
	· Water tower water level control	Moderate
	· Telescopic reversing unit design	Difficult
Task 5	·Mixed liquid simulation control device	Easy
	· Transmission line control device	Moderate
	· Sorting unit design	Difficult
Task 6	·Automatic feeding and loading control with four control bits	Easy
	· Graphic image unit design	Moderate
	· Loading unit design	Difficult

The project is based on the “Programmable Controller” training course of a class in Grade 2020 of a college in Shandong Province as a pilot. There are 30 students in the class, divided into 15 groups. According to the ability level of each group, tasks of different degrees of difficulty are assigned. The students are very interested in learning and highly motivated. This hierarchical teaching method respects the individual differences of students and teaches students in accordance with their aptitude, and the effect is obvious. The specific learning tasks are shown in “Table 1”.

### 3.3 Reform of Examination Methods in the Practice Link

Course assessment is a very important link in the teaching process of each course, which has five functions of evaluation, detection, diagnosis, feedback and motivation in teaching, which cannot be replaced by other teaching links. It can not only evaluate the knowledge mastery of students after completing a stage of learning, but also check the teaching level and teaching effect of teachers, give feedback to various information in the process of teaching and learning, and find problems in the teaching process, which

plays an important role in motivating students to learn and improving teachers' teaching methods [10]. However, in the actual process of practical teaching in colleges and universities, the assessment has not played its due function, resulting in unsatisfactory practical teaching effect. Therefore, the reform and research on the practical teaching assessment link is crucial.

In order to improve the efficiency of students' experimental courses and enhance their sense of gain, and explore the method of gradually changing the single centralized one-time examination at the end of the term, this paper adopts the assessment method of "two exams for each course" for engineering majors and changes the course assessment into a final theoretical exam plus a procedural assessment. Among them, the procedural assessment can include the completion of the homework, the usual performance, the performance of the practice link and so on. According to the characteristics of engineering courses that have high requirements for hands-on practical ability, the results of the practical examination can be regarded as the procedural assessment results and the final specialized course adopts the assessment method of "two exams for each course" (theory + experiment). That is, the final assessment of each professional course consists of theoretical assessment and practical assessment. Students who fail the practical assessment will be banned from taking the relevant theoretical course examinations. That is, it can take practical teaching reform as a breakthrough to stimulate students' initiative in learning theoretical courses and at the same time effectively realize the transformation of students' theoretical knowledge into practical application ability, and promote two-way promotion, so as to realize the linkage mode of teaching-learning-examination system.

### 3.3.1 The Experiment Link Mainly Adopts Random Selection of Experimental Topics for Assessment

After the experiment of a course is over, students randomly select a topic from the experiment topics or question bank they have done this semester for assessment. The teacher will quantify the points according to the difficulty of the experimental topics selected by the students and the examination situation. The final grade consists of 70% of the exam grade and 30% of the experimental report grade.

In the first semester of the 2021–2022 academic year, a pilot program of "two exams for each course" is implemented for the "Fundamentals of Mono-Chip Computers & Applications" course of a Grade 2020 class in a Shandong college. At the beginning of the semester, students are informed that this course will be assessed by the method of "two exams for each course" and they can make an appointment in advance to the laboratory to conduct open experiments. Students' enthusiasm for learning in experimental classes has been significantly improved and at the same time, it has also stimulated the "head-raising rate" of theoretical classes. The laboratory is open all day one week before the experimental examination and students spend almost all their spare time reviewing and debugging programs in the laboratory. According to statistics, the number of open experimental hours due to the course assessment reform pilot program has reached 120 h. The examination is in the form of drawing lots, and the question drawn by this pilot class is Question 4 — Simple stopwatch programming, as shown in "Table 2". Most of the students can successfully debug and simulate within 30 min of the required time and pass the test with full marks. Only 5% of the students have some small problems during

**Table 2.** Examination topics in the experiment link through drawing lots

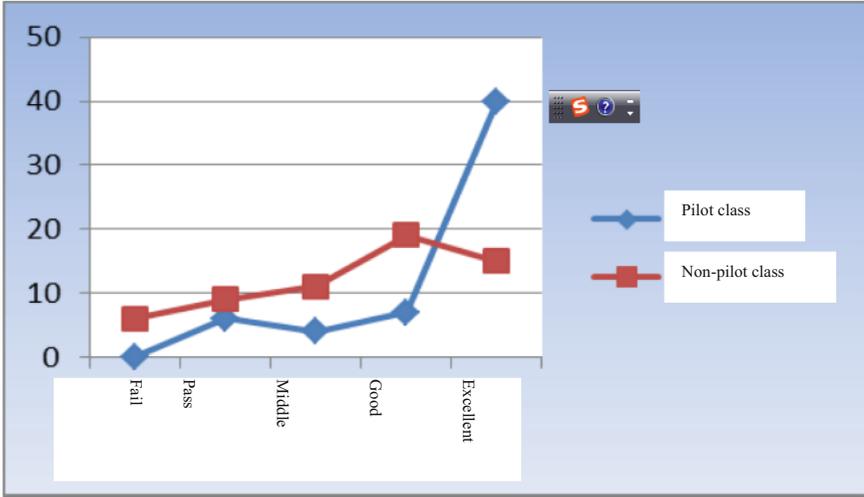
Topic	Experiment topics through drawing lots
Topic 1	Flowing water light programming: The P1 port is connected to eight light-emitting diodes, and the common anode connection is adopted. The programming requires starting from P1.0, the lights are turned on in sequence, and only one light is on at a time to realize the control of the flowing water light.
Topic 2	Two-digit digital tube display programming: Two digital tubes are used to display the number of keystrokes. When the number exceeds 20, the digital tubes are reset to 0 and count again. The P1 port is connected to the digital tube to display the thousand digit and the P2 port is connected to the digital tube to display the single digit.
Topic 3	External interrupt programming: The P1 port of the monochip is connected to 8 light-emitting diodes, and the common anode connection is adopted for flowing water light control. Each time an external interrupt 0 occurs, the high and low four bits of the P1 port alternately flash 3 times.
Topic 4	Simple stopwatch programming: P1 port is connected to a digital tube to display the tens digit, P2 port is connected to a digital tube to display the single digit, and after counting to 60, it will be reset to zero and count again.
Topic 5	Timer programming: The crystal oscillator frequency of the monochip system is 12 MHz and the timer T0 (mode 1) is used to output a square wave with a period of 1ms on the P1.0 pin and observe the waveform with an oscilloscope.
Topic 6	Serial port programming: 74HC164 is used to realize top-down flowing water light control.

the debugging process. In short, the exam grade has been greatly improved compared with the parallel classes that fail to implement “two exams for each course”. The analysis of the test results in the class experiment link of the implementation of “two exams for each course” is shown in “Fig. 3”.

From the comparative analysis chart of the two classes, it can be seen that the pass rate and excellent rate of the class that implements “two exams for each course” have been significantly improved, and more importantly, the students’ enthusiasm for learning has been mobilized.

### 3.3.2 The Intensive Practice Link (Practical Training) is Mainly Assessed by Means of Defence

In order to avoid the drawbacks of the fuzzy assessment that has always been used in the intensive practice link, the assessment method of defence can be adopted. The teacher randomly asks several typical questions about the content and works of the one-week practical training. From students’ defence, the teacher can accurately evaluate students’ practical training and curriculum design effect. The final grade consists of 70% of the defence grade and 30% of the practical training report grade. The defence questions for different tasks are shown in “Table 3”.



**Fig. 3.** Comparison of the grades of the pilot class and non-pilot class of “two exams for each course”.

**Table 3.** List of defence questions for different tasks in the comprehensive practice link

Task	Content of defence
Task 1 Defence	· Time interval becomes 5 s
	· Point out the self-locking and interlocking parts in the ladder diagram
	· Point out what kind of sensor is of the pallet and workpiece detection in the unloading unit and the relevant position should be pointed out in the program
Task 2 Defence	· Point out the part of the program that implements sequential start and reverse order stop
	· Describe the principle of star-delta startup program
	· Point out which sensor detects the top cover in the capping unit and indicate the relevant position in the program
Task 3 Defence	· Identify the part of the program that implements the loop
	· Tell how the part of the program that prepares the answer is realized
	· Point out which sensor detects the dowel in the dowelled unit and indicate the relevant position in the program
Task	Content of defence
Task 4 Defence	· How to display digits of 4, 5 and 6
	· Describe the principle of the water tower water level control program
	· In the telescopic reversing unit, detect which sensor the manipulator conveys the workpiece in place and indicate the relevant position in the program

(continued)

**Table 3.** (continued)

Task	Content of defence
Task 5 Defence	· Indicate the position of the outflow part in the program after the two liquids are mixed
	· Describe how the sequential stop of the transmission line is achieved
	· Point out how to distinguish quality and inferior-quality products in the sorting unit and indicate the relevant position in the program
Task 6 Defence	· Point out what kind of sensor is used to detect the feeding trolley running to the specified position and briefly describe how to realize it
	· Describe graphic image unit programming ideas
	· Describe how the manipulator part of the loading unit realizes workpiece grasping

### 3.3.3 Replacing Exams with Competitions and Implementing Credit Transfer

College students often participate in various competitions during their school days. Students who can participate in the competition and get the rankings have strong practical ability and even high professional level. For such students, teachers may consider supplementing certain practice credits according to their grades or even exempt the study and assessment of relevant practice courses. This way of credit transfer not only stimulates students' interest in participating in the skills competition, but also improves students' practical ability, which can be said to kill two birds with one stone.

### 3.3.4 Replacing Exams with Certificates and Implementing Credit Transfer

Under the guidance of the national vocational education reform policy of 1+X certificate, students can be encouraged to obtain vocational qualification grade certificates of related majors during their stay in school. Vocational qualification grade certificates should be established through the combination of schools and enterprises and the in-depth cooperation between schools and enterprises, truly involving enterprises. The relevant technical standards and training assessment content of the vocational qualification grade certificate should be formulated by enterprises, and schools can incorporate the relevant content into the normal teaching, so that the students can really apply what they have learned. At the same time, those students who can obtain relevant certificates have reached a standard of practical ability. In the practical assessment of related courses, teachers can try to use vocational certificates to exchange practical credits, implement credit transfer, and also stimulate students' enthusiasm for taking examinations for certificates [11].

## 4 Conclusion

This paper studies and practices the practical teaching classroom teaching mode and assessment method of engineering majors in a college in Shandong Province. The one-semester practice teaching reform of core specialized courses such as “Fundamentals of

Mono-Chip Computers & Applications” experiments and “Programmable Logic Controller” practical training has achieved remarkable results, and the efficiency of experimental training courses has been significantly improved, which has greatly mobilized students’ enthusiasm for learning and better explained the new teaching concept of taking students as the main body, teachers as the leading, and teaching students in accordance with their aptitude. However, the existing pilot program is only a reform for some engineering courses and fails to cover the whole. The specific implementation policy of the credit transfer system of replacing exams with competitions and replacing exams with certificates also needs to be further determined. Next, the author will further carry out teaching reform on other similar practical courses based on the continuous summarization of experience and continue to explore the practical teaching reform methods of other types of courses using the reform research of such courses as a template.

**Authors’ Contributions.** Chunguang Wei designed the research scheme and drafted the paper; Jian Qin contributed to revising and editing.

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