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Teaching Reform and Practice of TBL-BOPPPS-CDIO Teaching Mode in the Course of "Principle and Application of Single Chip Microcomputer"

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Abstract

"Principle and Application of Single Chip Microcomputer" is an important professional backbone course for electronic information majors. Given the characteristics of this course and the limitations of the existing teaching and evaluation methods, this study will apply TBL (Team-Based Learning) teaching method The combination of BOPPPS (Bridge in, Objective, Pre-assessment, Participatory Learning, Post assessment, Summary) teaching mode and CDIO (Conceive, Design, Implement, Operate) engineering education mode is used for the reform and practice of this course to cultivate students' solid theoretical knowledge and practical ability. Under the condition of TBL grouping, the reform of BOPPPS teaching mode is introduced into classroom teaching to improve students' theoretical knowledge level through participatory learning. The practice link after class is based on CDIO teaching mode and is carried out with the idea of "project as the carrier, teacher as the guide, and student as the center" to cultivate students' abilities of hands-on operation, innovative design, team cooperation, etc. At the same time, explore the teaching mode of combining curriculum with competition to enhance students' comprehensive practical ability and ability to solve complex engineering problems. Finally, a diversified assessment method focusing on process evaluation is constructed to reasonably evaluate the performance of students in the experimental process. The teaching reform and practice of this course have achieved good results, which can provide a reference for the construction of electronic information courses.

Keywords: *Principle and application of single chip microcomputer, TBL, BOPPPS, CDIO, Reform in education*

1. Introduction

From the education and training plan for outstanding engineers to the construction of new engineering disciplines, since China joined the Washington Agreement in June 2016 and became a formal signatory of the agreement, cultivating high-quality and versatile new engineering talents with strong practical ability, innovative ability, and international competitiveness has become one of the important directions of China's engineering education reform and development. As the main position of talent training and gathering, it is imperative to cultivate college students' engineering thinking and ability to apply theoretical

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knowledge to solve practical problems to further adapt to the actual needs of the industry and enterprises.

The electronic information specialty is an important branch of undergraduate and vocational higher education. According to incomplete statistics, more than 500 higher education institutions have opened this specialty, and the number of graduates is close to 1 million every year. To meet the high-quality development of the electronic industry, colleges and universities have set up a series of professional courses to cultivate innovative and practical engineering talents required by the electronic industry [1]. The course "Principle and Application of Single Chip Microcomputer" at Heilongjiang Bayi Agricultural University has been set up since the establishment of the electronic information engineering specialty in 2003. It is open to electronic information engineering, communication engineering, electrical engineering, agricultural electrification, and other specialties, and is one of the main courses of each specialty. This course is an application course that pays equal attention to theory and practice. It is characterized by strong engineering practicality, and it is also a stepping stone for students to enter the electronic industry from school. Due to the lack of solid theoretical knowledge and weak practical ability, the design ability of the SCM application system cannot be effectively improved, which is the basic quality that electronic industry practitioners should have.

The traditional teaching mode based on teaching has been difficult to adapt to the actual needs of engineering talent training in the electronic industry. It is imperative to explore new teaching modes to improve the teaching effect. TBL (Team-Based Learning) teaching method, also known as the group cooperative learning method, is a creative teaching theory and strategy widely adopted by many countries in the world. It focuses on cooperative and exchange learning and focuses on eliciting students' thinking and interest in learning [2]. BOPPPS (Bridge in, Objective, Pre-assessment, Participatory Learning, Post assessment, Summary) teaching mode originates from the ISW project in British Columbia, Canada [3]. At present, this teaching mode has been introduced into curriculum practice in more than 30 countries and has achieved good results in improving teaching efficiency and students' deep participation in learning [4][5]. In the field of engineering education, the CDIO (Conceive, Design, Implement, Operate) engineering education model jointly established by four universities, including MIT, focuses on students' "learning by doing" and "project-driven learning", and pays attention to cultivating students' practical ability. It is one of the most influential achievements of the reform in the field of engineering education in recent years, with outstanding performance in cultivating students' comprehensive design ability and innovation abilities [6][7].

The teaching team took the opportunity of the certification of engineering education and the reform of new engineering courses, combined with the trends and achievements of the development and reform of engineering education at home and abroad, actively changed the teaching philosophy, explored the teaching reform and practice of TBL-BOPPPS-CDIO in the "Principles and Applications of Single Chip Computers" combined with the teaching mode, aiming to mobilize students' enthusiasm, improve their theoretical knowledge level, hands-on practice, innovative thinking The ability of teamwork and solving complex engineering problems can provide some ideas and references for the teaching reform of relevant electronic information courses.

2 Current Situation and Existing Problems of the Course "Principle and Application of Single Chip Microcomputer"

After several rounds of revision of the teaching plan, at present, the course "Principle and Application of Single Chip Microcomputer" in our school is offered in the fourth semester, and no separate experimental course is offered. The integration of theory and experiment totals 64 class hours. The course is carried out in the single-chip microcomputer laboratory, and the content involves microcomputer principle and interface technology, single-chip C language programming technology, electronic technology analysis, signal, and system testing, circuit design, and program design. It is a collection of technologies The main course integrating engineering development, application, and language programming have the characteristics of strong practicality and wide adaptability. In recent years, the research group has been committed to the teaching reform and exploration of this course to improve students' learning effect. Although some achievements have been made, there are still some problems in the course teaching, which is also the difficulty and challenge that other colleges and universities generally face in the course "Principles and Applications of Microcontroller" [8][9][10].

First of all, the curriculum content is outdated, and the experimental project is unscientific. The teaching content and experimental equipment are mostly explained and practiced based on the MCS-51 single-chip microcomputer, which has been out of touch with the trend of 8-bit single-chip microcomputers or 32-bit single-chip microcomputers widely used in the industry. Due to the outdated teaching content and experimental equipment, some experimental items are simple in content, lacking practicality and specificity, unable to closely connect with the modern electronic industry, and difficult to cultivate students' engineering awareness and ability to solve complex engineering problems. Moreover, most of the experiments were simple modifications and transplants of the contents explained by teachers, which were not sufficiently combined with engineering practice, leading to low enthusiasm and enthusiasm of students. In particular, the experimental projects are independent of each other, with poor relevance and few comprehensive experiments, resulting in limited space for students to improve their innovation ability.

Secondly, the teaching means are not rich and lack guidance. Usually, the teacher first explains relevant theoretical knowledge and then demonstrates relevant experiments. The teacher does them, and the students see them. Then the students repeat them one by one according to the teacher's demonstration steps. The spoon-feeding teaching mode forms an invisible barrier between teachers and students. Students in a passive learning state lack subjective initiative in the whole process, leading to poor theoretical knowledge and practical operation, and an inability to use SCM technology to solve practical engineering problems. Especially now, it is easy for students to reproduce the teacher's experimental program, but when the teacher puts forward a new requirement, students often do not know where to start the program, Some schools have set up practice links after class in groups, where multiple students jointly complete the design and production of electronic products such as "traffic lights" and "password locks". Under the premise of the unclear division of labor in groups and lack of an effective participation assessment system, some students tend to be formalistic, participate less in the practice process or publicize the lessons according to the book, and do not master the basic principles and practical ideas, It is unable to achieve the purpose of effectively exercising their comprehensive practical ability.

Finally, the student achievement evaluation mechanism is not perfect, and the assessment method is difficult to comprehensively evaluate the students' learning effectiveness. The existing course assessment methods are mainly based on the final examination, supplemented by the usual scores, and often only for each student. The team is rarely involved in the evaluation. For courses that pay equal attention to theory and practice, it is impossible to reasonably evaluate all the student's performance in the learning process, which is not conducive to fully mobilizing the enthusiasm of students. As a highly practical course, "Principle and Application of Single Chip Microcomputer" involves many learning links, including a preview before class, theoretical knowledge and practical programming learning in class, hands-on practice of software and hardware operation, software and hardware debugging, team communication, problem analysis and solution, homework after class and summary of this class. At the same time, the practical work after the group class also includes data access, scheme analysis, and design, component selection Circuit diagram design and drawing, component purchase and welding, programming of supporting software, overall debugging of software and hardware, writing of practice report, PPT production of the class report, oral defense and work display, etc. Therefore, the assessment method of the course should cover the above links, focusing on process evaluation.

3. Design and Implementation of Teaching Content

3.1. Overall objectives of curriculum construction

To solve the problems in the teaching of the course "Principle and Application of Single Chip Microcomputer", the model of single chip microcomputer widely used in the current industry is selected as the teaching content. In the practical link, it focuses on the design and comprehensive experiments, organically integrates the electronic professional knowledge, practical skills, and comprehensive literacy, and emphasizes the cultivation of student's ability to solve complex engineering problems through a process-oriented all-round assessment, Strive to get through the "last mile" from profession to industry. This course first introduces the TBL teaching method, divides the class students into small learning teams, then introduces the BOPPPS teaching mode in the classroom teaching, enhances the teacher's guiding function, shapes the students' ability to participate in-depth, introduces the CDIO engineering education mode in the after-school practice link, and strives to cultivate the student's ability to apply professional knowledge to solve practical problems. At the same time, the TBL teaching method will be fully used in the class and after-school teamwork, Stimulating students' sense of competition, teamwork, and innovation.

3.2. Teaching content design

To highlight the novelty of the teaching content, in addition to the inherent knowledge of the internal structure of SCM, CPU, memory organization, parallel port, interrupt, timer/counter, and serial port principle, the interface knowledge of LED, nixie tube, and keys is weakened, and I2C protocol, SPI protocol, single bus protocol, 485 communication protocol, ZigBee protocol, an infrared interface, Bluetooth interface, WiFi interface, USB interface The post knowledge commonly required in the PWM control industry is guided by the needs of enterprises, and the experimental projects and practical tasks in the classroom practice link are reformed to give students more independent space so that they can fully display their innovative design and comprehensive practical ability. For example, in the practice of "smart small fan" design after class, the students organically combine the principle knowledge of single chip microcomputer with the motor control interface, PWM control technology, nixie tube display technology, and the whole process from overall scheme design to intelligent fan production, covering a series of practical contents such as component selection, hardware circuit design, and drawing, software program design, circuit board welding, and overall circuit debugging, To better exercise the students' understanding and control of the integrity of the design process of the SCM application system.

To improve the students' engineering awareness and engineering ability, so that the practical projects after class can closely connect with the electronic industry, we have purchased new instruments such as an oscilloscope, electronic load, RLC measuring bridge, 4-digit half multimeter, and various new models of single-chip computers, electromechanical control modules, drive modules, sensor modules and other materials for students. Thanks to the update of equipment and materials, in the past off-class practice of "access control system design", we have changed the previous password lock design focusing on keys, memory, nixie tube, and SCM encouraged students to join in programmable machine vision hardware modules such as OpenMV and changed the key password to face recognition. Through independent learning of the use of trendy new hardware, we can not only expand to more high-end SCM but also contact Python language and applications, By comparing the performance and price of the traditional key type password lock and the new face brushing password access control, the students further trained their engineering practice ability, deepened their engineering awareness and improved the quality of engineers.

To highlight the innovation of the curriculum, innovative after-school practice in the form of competition is added. For example, in the practice after the class "Intelligent Tracker", the college has set up the "Intelligent Tracker Competition" relying on the course "Principle and Application of Single Chip Microcomputer". Students of all grades of the college can form teams to participate in the competition. Students of the course "Principle and Application of Single Chip Microcomputer" sign up for the competition as a group divided by TBL. Under the guidance of teachers, the group students organically combine the principle knowledge of SCM with the motor control interface, PWM control technology, photoelectric identification technology, etc, According to the characteristics of the track, we will continue to innovate the tracking and control methods, and finally complete the design, production, and competition of intelligent vehicles. The innovative practice originates from the curriculum content and is higher than the curriculum content. It is the further extension of the curriculum content and focuses on training students' innovative design ability and comprehensive practical ability.

3.3. Implementation of teaching content

3.3.1. Classroom teaching reform based on TBL-BOPPPS teaching mode

To mobilize students' enthusiasm for classroom learning, the teaching class was first divided into several small teams of 3-5 people, and a competition mechanism was introduced in the classroom. Students' subjective initiative was stimulated through procedural assessment scores. The teacher-centered indoctrination teaching method was transformed into a student-centered all-around participation method. In combination with classroom practice, the classroom teaching of this course was reformed and explored.

The teaching team divided the course content into several items, including traffic lights, quick answer scorers, digital electronic clocks, digital voltmeters, digital thermometers, irrigation controllers, digital signal generators, digital compasses, infrared remote controllers, grid water level monitoring nodes, etc., organically integrated the course knowledge points into each project, and reasonably arranged the project sequence to effectively link knowledge and skills. Apply the BOPPPS teaching mode to the classroom teaching design of each project, make appropriate adjustments according to specific projects, and focus on students' deep participation in the classroom through "participatory learning". Generally, the teaching idea of "teachers/students asking questions - team analysis and discussion - inter-group interaction - team practice - concluding" is specifically implemented in teaching. Through teacher-student interaction and student-student interaction, students' participation in the classroom is improved, so that students can master solid professional knowledge and promote students to internalize knowledge into the ability to solve practical problems.

Taking the learning of the digital electronic clock project as an example, BOPPPS curriculum design and modular decomposition of the classroom teaching process (Table 1). By showing the course contents of the introduction of different timing devices (Bridge in), students can think about the internal structure and principle of electronic watch timing and how to make timing devices. Then, the objective of this lesson is to grasp the structure, working principle, and timing control method of the timer inside the microcontroller, so that students can accurately grasp the learning direction. Due to the tasks assigned before the class, let the students review the previous learning contents and the relevant knowledge of this class in advance, preview the principle and application of the single-chip timer, understand the students' preview situation through the pre-assessment, and adjust the follow-up teaching activities of this class according to the preview situation. Participatory learning is the core content of classroom teaching. Students' enthusiasm is aroused through teacher-student interaction, team discussion, and practice. For example, students have mastered the working principle of timers and the use of registers, but many students are still not clear about the call mechanism of the timer interrupt service program. Teachers should guide students to think about the role of interrupt entry address, the form of the whole process of interrupt call in C language, etc. Each team can answer by discussing and combining practice. Similarly, for other key knowledge points, The teacher also puts forward preset questions to guide students to think independently, participate in in-depth communication and discussion, and finally, the teacher explains them in detail. It needs to be emphasized that teachers still play a leading role in this link, and teachers' teaching design before class and effective guidance in class are important prerequisites for students to deeply participate in learning. Post-assessment and summary are conducted in the latter part of the classroom teaching so that students can achieve the goal of understanding.

Table 1. Timer teaching design based on BOPPPS teaching mode

	Time/min	Teacher activities	Student Activities
Bridge in	3	Introduction course: show different timing devices Cause thinking: How does the internal structure of the electronic watch work? If you make a timer by yourself, you can set the timer by default.	Share common timing devices to quickly enter classroom roles
Objective	2	Knowledge objective: master the structure and working principle of the timer inside the microcontroller Ability objective: master the method of designing timing devices by using timers Emotional goal: cultivate good engineering quality	Keep the course objectives in mind and grasp the key and difficult points
Pre-assessment	5	Question 1: Interrupt system, interrupt source, and related registers of a single-chip microcomputer Question 2: Timing methods and differences Problem 3: The number and difference of timers inside the microcontroller	Participate in the interaction between teachers and students to fully demonstrate mastery of the content
Participatory	30	Principle 1: Internal structure and working principle	Conduct analysis,

Learning		of timer Principle 2: Working mode of timer and principle of related registers Method 1: Timer initialization method Method 2: Writing method of the timer interrupt service program	discussion, software and hardware programming and debugging practice in a team, and fully interact with teachers
Post-Assessment	3	The teacher will analyze and discuss the curriculum mastery of each team according to the report of each team and the debugging results of the designed timing device	Display the timing device and analyze the practice results of the team
Summary	2	Analyze and summarize the common problems in the curriculum, and summarize the experience and lessons in combination with the curriculum objectives.	Record the teacher's summary

3.3.2. After class practical teaching reform based on TBL-CDIO

Due to the limited time in class, given the importance of practice in this course, adding team practice links after class plays a vital role in cultivating students' engineering ability, innovative thinking, team cooperation, and other abilities. Based on the engineering education concept of CDIO, the practice team divided the practice links after class into Conceive - Design - Implementation – Operate [11][12], implemented them according to the idea of "project as the carrier, teacher as the guide, and student as the center", and encouraged students to "learn by doing" in practice [Figure 1]. The design and implementation of after-school practice projects are completed by the team cooperation determined in the implementation of classroom teaching. It is required to clarify the team division of each after-school practice project, and specify the requirements that different practice projects must change the responsibilities of team members.

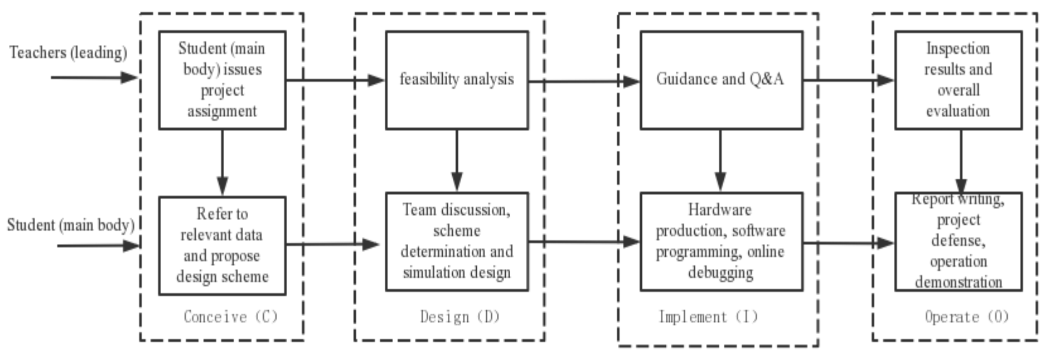

Figure 1. CDIO Off-class practice project implementation process

Taking the off-class practice project of "Access Control System Design" as an example, the teacher first issues the practice assignment, and issues the basic requirements and materials of the relevant design. The person in charge of the student team leads the students in this group to further find and collect the relevant materials for the access control system, conceive the design content and form a preliminary plan according to the requirements of the assignment book. The teacher judges the feasibility of the plan organizes the students to discuss and gives necessary guidance. On this basis, each team determines the final design plan through further data review, analysis, and discussion. At this stage, students' self-learning ability The goal of the ability to think and analyze problems independently. After the project design scheme is determined, the team members shall reasonably divide the work and give full play to their strengths. Through communication and discussion, unity and cooperation, they can carry out component selection and draw circuit schematic diagrams. They can also further use Proteus software for simulation. Teachers can guide students at any time according to the problems they encounter. In this stage, students' knowledge application ability and team cooperation ability are mainly cultivated. After the preparation of components for the circuit diagram drawing, the project will be implemented. Teachers will provide students with the College Students' Innovation and Entrepreneurship Center Laboratory as the implementation site. Team students will weld the circuit, write software code, download and debug the functions of each component, and then conduct overall joint debugging. The teams can also communicate with each other, learn from each other, and optimize the system. Teachers can guide students in the laboratory at any time so that students can learn by doing. In this stage, students' innovation ability and engineering practice abilities are mainly cultivated. After the design and debugging of the work are completed, each group will make a reply according to the project requirements, and make a corresponding report. The report demonstration will be completed under the watch of teachers and other groups. Each group and teacher will check and evaluate, and propose improvement measures. In this stage, students' communication ability and practical operation abilities will be mainly cultivated.

3.3.3 Combination of curriculum and competition drives teaching reform

Based on TBL-BOPPPS-CDIO teaching reform, the design of the class practice project "Intelligent Tracker" of the student team is closely combined with the discipline competition of the college, encouraging the student team to independently design the competition scheme according to the competition rules, and solving various problems encountered in the competition process. The competition closely combines the theme of "strengthening the style of study, improving the quality, and promoting innovation". The student team expands based on what they learned in the early stage of the SCM course, integrates motor drive, photoelectric sensor, PID control, and other knowledge, and continuously optimizes the software program through the whole process of the design of the SCM application system. On the day of the competition, according to the rules of this competition, the complete tracking of the preset track is achieved. Those who complete the race in a short time win. Figure 2 shows the competition works and the competition scene of the students in the SCM learning team in recent years. In this process, teachers play a guiding role in the feasibility of the scheme, software and hardware optimization, etc. Through the competition, students will be encouraged to combine theory, practice, and innovative thinking deeply, and more deeply control the systematicness of curriculum theory and practice. Since 2019, the Smart Tracker Contest has been held four times, which has played a very good role in promoting the classroom teaching effect of "Principle and Application of Single Chip Microcomputer". The competition has enhanced the students' sense of self-challenge, cultivated the spirit of exploration, enhanced their psychological quality, and strengthened their ability to the organization, coordinate, and communication. The reform of the teaching mode of combining courses and competitions provides diversified teaching means and organization methods for the course construction of "Principle and Application of Single Chip Microcomputer", and also provides beneficial exploration for the construction of electronic information-related courses.

Figure 2. Competition works and scene

4. Assessment Method and Effect Evaluation

The assessment method is an important basis for testing students' learning effect, and also the key to improving teaching quality [13]. In the past, the assessment method was composed of two parts: usual performance (including attendance and classroom performance, 30%) and final computer examination (70%). The lack of systematic assessment of students' learning ability and comprehensive quality in the whole learning process led to the low participation of some students in the classroom theory and practice learning process, and they fell into a vicious circle of "sudden learning before the examination, and will not be used after the examination" Professional comprehensive application training and graduation design have caused adverse effects.

Through the construction of a diversified assessment method focusing on process evaluation, it focuses on students' knowledge learning and skills mastery in the whole process of theoretical and practical learning, as well as their abilities in innovative design, teamwork, and solving complex engineering problems [Table 2]. After the teaching reform, the proportion of process evaluation has increased to 60%, including attendance (10%), classroom theory and practice performance (30%), and after-class practice performance (20%). The proportion of final online examinations has decreased to 40%. (1) Attendance assessment is a traditional assessment content. Strengthening attendance assessment is very necessary for serious classroom discipline and maintenance of daily teaching order. If students are absent from class without reason or are late for 10 minutes, 1 point will be deducted for attendance. (2) Classroom theory and practice performance assessment require students to understand the principle and operation of the classroom learning link. The team-based BOPPPS participatory learning and classroom testing are two aspects to investigate students' mastery and application of professional knowledge. (3) The practice performance after class mainly examines the following three aspects: first, the student's skills in drawing circuit diagrams, chip welding, software programming, and overall system debugging in the process of independently designing the SCM application system; Secondly, the ability of students to discuss and analyze problems and propose solutions when they encounter problems in practice after class; Finally, in the way of combining teacher evaluation, student self-evaluation, and intergroup evaluation, we will investigate the division of labor, participation, cooperation and completion effect of the practice team after class. (4) The final exam is a computer-based open-book exam. After obtaining the tags randomly distributed by the system, students can independently complete the software and hardware design of the two design questions required in the tags based on the single-chip microcomputer experiment box and computer hardware equipped in the laboratory. Each question is required to indicate that the invigilator checks the consistency between the software and hardware debugging results and the requirements of the test questions. The invigilator gives scores according to the actual results of the students' debugging. Before the end of the exam, The students will name the project files and C files related to the exam according to the signature and upload them to the designated FTP path for archiving. The exam will last for 90 minutes.

Table 2. Assessment method of the course "principle and application of single chip microcomputer" for electronic information engineering

	Composition of achievements	percentage	Assessment items	Evaluation method
Process evaluation	Attendance	10	Attendance	Teacher evaluation
	Classroom Theory and Practice	30	Participatory learning In class test	Teacher evaluation/student evaluation Teacher evaluation
	Practice performance after class	20	Practical skills, problem analysis and resolution, teamwork	Teacher evaluation/student self-evaluation/student mutual evaluation
	Final test	40	Overall knowledge fusion and autonomous program transplantation	Teacher evaluation

Before the reform, the evaluation basis of students' usual performance was single. Most of the ordinary performance (2017, 43 students) was between 70 and 90. After adopting the diversified evaluation method focusing on process evaluation (2020, 43 students), the number of outstanding students, especially those with 90 to 100 scores, increased significantly, and the students with poor performance only got 60 scores (Figure 3A); In terms of the total curriculum score, compared with that before the reform, the number of students in high stages has increased significantly [Figure 3B], and the number of students who fail is 0, which reflects the significant improvement of the teaching effect of the curriculum. This is due to the TBL-BOPPPS-CDIO combined teaching mode and the curriculum competition combined teaching mode, which effectively improves the enthusiasm and participation of students, and cultivates students' solid theoretical foundation and practical ability, more reasonable evaluation of student performance in the process of theory and practice.

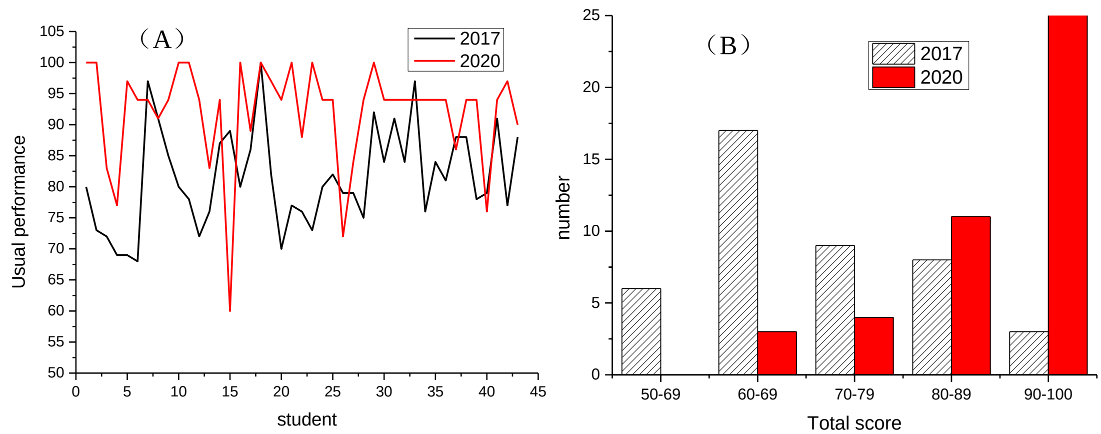

Figure 3. Comparison of students' usual performance (A) and total scores (B) before and after the implementation of the reform

5. Conclusion

In the course "Principle and Application of Single Chip Microcomputer", we carried out the exploration and practice of TBL-BOPPPS-CDIO combined teaching mode, combined with the diversified evaluation system focusing on process evaluation, students changed from inefficient and passive learning mode to efficient and active learning mode, greatly improved students' classroom participation, and achieved remarkable results in strengthening students' theoretical knowledge level, innovative design, teamwork and solving complex engineering problems. At the same time, we will explore the teaching mode of combining curriculum with competition, effectively promote the improvement of students' comprehensive practical ability, and strive to get through the "last mile" from the major and industry. This research can provide an effective way for the cultivation of innovative and practical electronic engineering talents.

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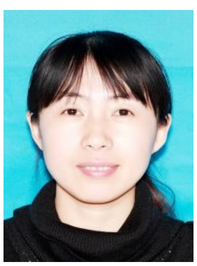

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