

Research Article

Blended Teaching for Signal and System Course Based on Internet-Engineering Education

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Abstract: Aiming at the teaching difficulties of signal and system course, adapting to the new situation of the information age and the engineering education of outcome-based education (OBE), adhering to the traditional classroom teaching and making full use of the network teaching platform and internet technology, a blended teaching mode of internet-engineering education (BTM-IEE) is proposed. In this mode, we adhered to the educational concept of OBE, formulated teaching objectives, optimized teaching content, and built matching teaching resources. In three teaching stages: before class, in class and after class, online-offline blended teaching was effectively organized and implemented by using internet technology, network teaching platform, independently developed a comprehensive experimental system, remote virtual experiment platform, QQ group, etc. In order to ensure a good cycle of teaching quality, a multi-dimensional evaluation system is constructed. A variety of application examples and questionnaire data showed that BTM-IEE can achieve a deep integration of in class-out of class and online-offline, improve students' engineering application ability, autonomous learning ability, cooperation, communication ability, and cultivate innovative thinking. The horizontal and vertical comparison between the traditional and the improved teaching mode shows that the BTM-IEE can improve the teaching effect, the excellent rate is significantly increased, and the failure rate is significantly reduced. This mode provides a reference for the improvement of the teaching quality of professional courses and has important practical significance.

Keywords: signal and system, blended teaching mode, internet, engineering education, motivation

1. Introduction

With the development of information science and computer science, signal processing technology has developed rapidly and presented endless prospects. It is widely used in the fields of speech recognition, communication, robot vision sensing, earthquake, event-related potential (ERP) technology, industrial monitoring, and so on [1-6]. Signal and system course (SSC) provide basic theories and methods for the application of signal and system (SS) processing technology in these fields. It is an important basic course for information engineering majors and is the product of the combination of physical concepts, mathematical concepts, and engineering concepts. The course knowledge can guide students to transition from theoretical study to professional engineering practice, and cultivate students' overall view, system view, and creative thinking. This course mainly discusses the basic analysis methods of transmission and processing of determining signals through linear time invariant systems. Its core content is three transformations

(Fourier transform, Laplace transform, and Z transform) and state space analysis. This course can lay a solid theoretical foundation for many subsequent courses, such as digital signal processing, digital image processing, communication principles, etc. Therefore, the teaching modes and effects of this course directly affect the learning and application of subsequent professional courses. However, in the teaching practice of SSC at the Shandong University of Technology, it was found that the teaching of this course has the following difficulties: firstly, the whole process of signal analysis and processing is represented by abstract mathematical symbols. Many analysis methods require a lot of formula derivation. The course is highly theoretical and abstract, which requires students to have a good mathematical foundation. Therefore, students generally find it difficult to understand thoroughly, and often focus more on theoretical learning. Secondly, the course content comes from engineering practice, and the SS analysis method is applied to engineering practice. Therefore, the course is highly practical. However, traditional practical teaching has the following problems: fewer experimental hours, simple hardware experiments, fixed time and fixed place, more confirmatory experiments, and fewer experiments with expansion and engineering backgrounds. Therefore, it is difficult to achieve the ideal experimental effect, resulting in the weak practice and innovation ability of students. Thirdly, the traditional teaching mode is centered on teachers' teaching activities, which often ignores the leading role of students as knowledge constructors. As a result, students are only in a dormant position, and it is difficult to give full play to their enthusiasm and initiative. Finally, with the development of the information age, especially the progress of internet technology, the internet has increasingly become the norm in people's life. In addition, engineering education, whose concept is outcome-based education (OBE) has been widely recognized by the Ministry of Higher Education of China. Therefore, in the new educational environment, the educational concept, teaching means, and teaching methods are constantly updated. If we continue to adhere to the traditional teaching modes and evaluation models, it will be difficult to meet the needs of social development. Therefore, the traditional teaching of SSC faces great challenges.

In view of the difficulties faced by SSC, in order to adapt to the new situation of higher education, on the basis of traditional classroom teaching, it is very important to build a blended teaching mode combining internet technology with the OBE concept to improve the teaching quality of the course. This mode realizes the deep integration of in-classroom and online-offline, improves students' engineering application ability, greatly arouses students' enthusiasm for learning, and more easily cultivates students' knowledge, practical, and innovative ability.

In order to better understand the content of this paper, the following section introduced the arrangement of the paper. The current situation of SSC teaching is illustrated in Section 2. The design of the blended teaching mode of "internet-engineering education" (BTM-IEE) is described in Section 3. Section 4 describes the application of the teaching mode. Assessment and analysis of the blended teaching mode are discussed in Section 5. Section 6 draws conclusions.

2. Current situation of SSC teaching

For SSC teaching, many scholars have carried out reform and exploration research on the teaching mode of the course. For example, in order to better understand the concept and context of SS, some scholars have applied the concept learning method to SSC teaching and achieved better results [7, 8]. In the teaching process of SSC, some scholars adopt the teaching methods of team cooperation and mutual assistance to stimulate students' interest in learning, cultivate the sense of team cooperation and improve the teaching effect [9, 10]. In order to understand the application of signal, Luo applied the case teaching method of biological signal denoising to the signal processing teaching [11]. José and Kemel used the calculus method to provide a new analysis perspective for SS [12]. In this way, the problems of convolution and series in signal processing can be well understood. Based on teaching tools and learning approaches, different scholars have proposed a variety of teaching methods, such as computer-aided programming teaching [13], multimedia teaching [14], MATLAB (matrix laboratory) assisted teaching [15-17], etc. In addition, in the aspect of experimental teaching, many scholars have designed a variety of experimental systems based on hardware, software, and a variety of combinations to improve the experimental teaching methods [18-22]. To sum up, the above documents are all aimed at offline teaching methods or some aspects of experimental teaching, such as case teaching, multimedia teaching, MATLAB simulation experiment, hardware experiment, etc. These teaching reforms do not consider the widely used internet communication technology. At present, with the emergence of online open courses and learning platforms, hybrid learning is becoming more and more popular, and its breadth and depth are also expanding. Using rich network

resources, the traditional combination of face-to-face learning and internet technology has become the new normal of modern teaching [18, 23, 24]. Aiming at the teaching reform of the integration of internet technology and information technology in SSC, [25] has built a remote laboratory, and students submit their homework through the school learning management system (LMS). Warren et al. [26] described an online learning operating system, which can assess the transfer of mathematical knowledge from calculus and differential equations courses to required electrical engineering courses. Ogata and Usagawa [27] described a blended learning model based on information and communication technology, which can provide students with online learning results. Vatansever and Yalcin [28] provided a web based educational tool which allows students to conduct diversified learning. Rabenstein [29] described SYSTOOL, an online learning tool which enables students to learn in class and by self-learning through the Virtual University of Bavaria online learning. In addition to the new situation of distance education, engineering education originated in the United States is “student-centered” and “OBE” is the growing trend in global higher education [30, 31], which is also the main direction of China’s engineering education reform [32, 33]. Although it is found in the above research that the reform of SSC teaching mode has been carried out continuously, few blended teachings with OBE can be found. Moreover, there is no perfect way to adapt to the characteristics of each school. Therefore, aiming at the difficulties of SSC teaching, on the basis of adhering to the traditional classroom teaching, adapting to the new situation of higher education, combining internet and engineering education, a BTM-IEE is constructed in this paper. Based on this mode, a “whole process multi-dimension” curriculum evaluation system is also created. BTM-IEE relies on internet technology and makes full use of various resources to introduce the engineering education concept of “student-centered” and “OBE” into SSC teaching. In this mode of teaching, teachers can give full play to their guiding and teaching supervision role, attract students from the traditional passive learning environment to a new learning environment, and greatly mobilize students’ enthusiasm. This mode can cultivate students’ knowledge ability, practical ability and innovation ability through flexible interactive learning in various ways such as “online-offline, in class-out of class, layered-demonstration-engineering”.

3. The design of BTM-IEE

3.1 Course objectives

SSC of the Shandong University of Technology takes classes in the second semester of the second year of electronic information engineering major. The course adheres to the requirements of the university for training senior professionals. Based on the engineering certification standards, professional training objectives, graduation requirements, and the concept of building morality and cultivating people, the teaching objectives of the course are as follows:

- Students can use mathematical tools such as function, differential equation, and difference equation to establish the SS model, and can judge the characteristics of the model and solve it in time domain. Thus, students have the ability to model and solve in time domain.
- Students can use Fourier series and Fourier transform as tools to analyze signals and design systems with signal processing and transmission. Thus, they have the ability to do frequency domain analysis and processing. Furthermore, students’ engineering consciousness can be cultivated.
- Aiming at complex engineering problems in the field of electronic information, students can analyze continuous and discrete SS through Laplace and Z transforms, build experimental circuits for test and analysis according to the system model, so as to analyze and process continuous and discrete SS in S and Z domain. Furthermore, a rigorous and serious scientific attitude can be cultivated.
- Students can use various analysis methods and the simulation software to analyze and design the SS, and explain the obtained experimental data. According to the simulation results, the effectiveness and limitations of the method can be judged, and the improvement scheme can be put forward. Among them, students’ ability to solve complex problems and innovation can be cultivated.

3.2 Teaching mode design framework

In order to achieve the course objectives, the overall BTM-IEE of this course is designed. With the help of the

teaching resources construction, this mode makes full use of network teaching platform, remote virtual simulation platform, independently developed online courses and comprehensive experimental system, MATLAB software to build a multi-dimensional classroom through discussion, flipped classroom, project exploration, flash animation, comprehensive simulation homework, multimedia display, platform interaction, and other teaching links. By constructing a reasonable teaching evaluation system, we can realize the continuous improvement of course quality. Thus, BTM-IEE characterized by “knowledge, practice and innovation” can be constructed, as shown in Figure 1.

The mode is mainly divided into three parts: pre-design, process design, and evaluation design. Among them, pre-design mainly determines the teaching objectives and teaching content according to the OBE concept. In order to effectively implement the teaching process, before class, we need to design the learning process flexibly according to the students’ learning situation analysis (including initial ability, learning style, general characteristics, etc.). In this way, it is conducive to the completion of curriculum objectives. Learning process design is divided into three stages: before class, in class, and after class. Among them, before class is generally to complete the learning task assigned by the teacher, in class is to complete the teaching contents of the application, analysis, evaluation and creation, and after class to complete the consolidation of the course content. The three stages are mainly online, offline, and online-offline hybrid learning. Generally speaking, the design of learning process should focus on “resource design” and “student-centered teaching activity design”, and encourage students to carry out autonomous learning, cooperative learning, and interactive learning. The evaluation design includes the formative evaluation of online learning and offline learning, and the overall evaluation combined with offline final examination. Curriculum evaluation is to evaluate the achievement of curriculum teaching objectives based on students’ learning output data, and its results are an important basis for the continuous improvement of curriculum teaching. It can provide feedback not only to the front design of teaching objectives and teaching contents, but also to the specific learning process design. In this way, a teaching circle within the curriculum is formed to realize continuous improvement.

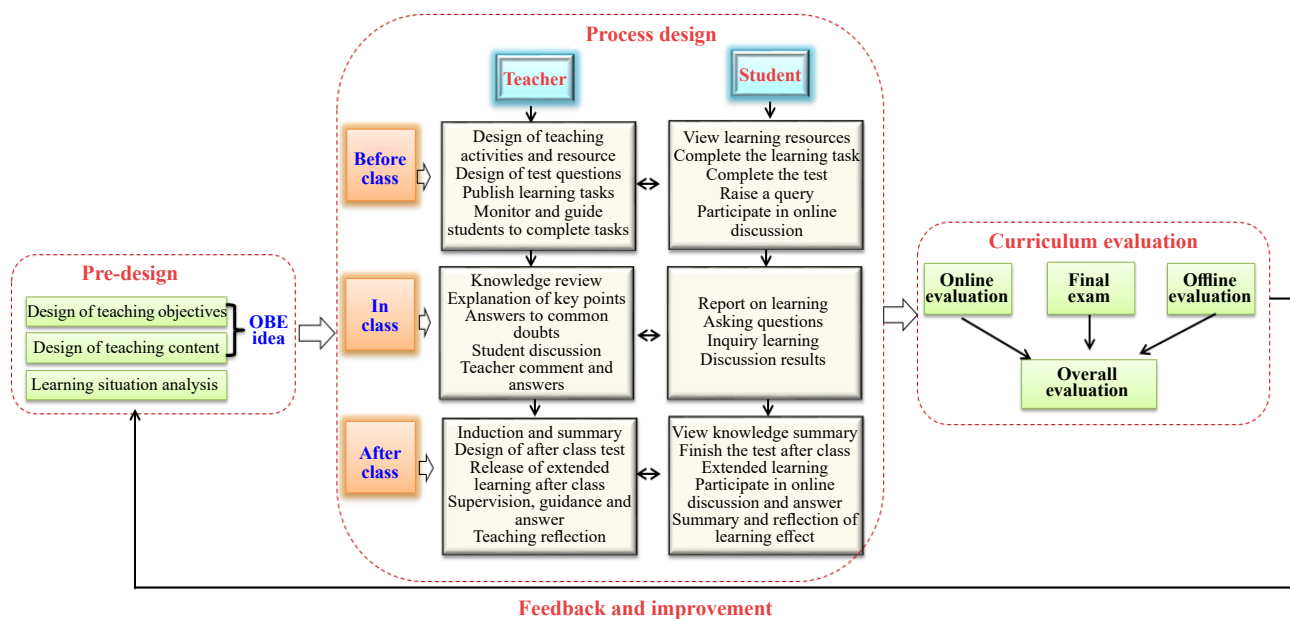


Figure 1. Framework design of BTM-IEE

3.3 Teaching resources

Learning resources are an important support to achieve the goal of talent training and an important basis for blended teaching. The offline textbook of SSC is “Signal and Linear System Analysis (Fifth edition)” edited by Wu DZ, which is correspondingly equipped with learning instructions. The offline hardware experiment adopts RZ8664

hardware experiment box of SS. The textbook includes four modules: basic module, continuous SS analysis module, discrete SS analysis module, and state variable analysis module, as shown in Figure 2. At the same time, according to BTM-IEE of SSC, relying on the campus comprehensive teaching platform and wisdom tree teaching platform, there are abundant network resources for teaching sharing, including syllabus, assessment syllabus, teaching electronic courseware, electronic teaching plan, independently developed online open course (1,000 minutes), test paper library, test question library, experiment guidebook, learning guidance resources, solutions to exercises after class, learning guidance, postgraduate entrance examination materials, expanded learning materials, etc. In order to more effectively stimulate students' potential and cultivate students' practical and creative ability, we have independently developed a comprehensive experimental system (IDCES, 21 experimental projects, covering basic, comprehensive and engineering categories), and are equipped with system operation instructions and experimental instructions. The system can not only be used for in class-out of class demonstration, but also students can carry out multi-level practice according to their own ability anytime and anywhere. In addition, students can also make full use of the remote virtual experiment platform (RVEP) of Beijing University of Posts and Telecommunications to expand practice.

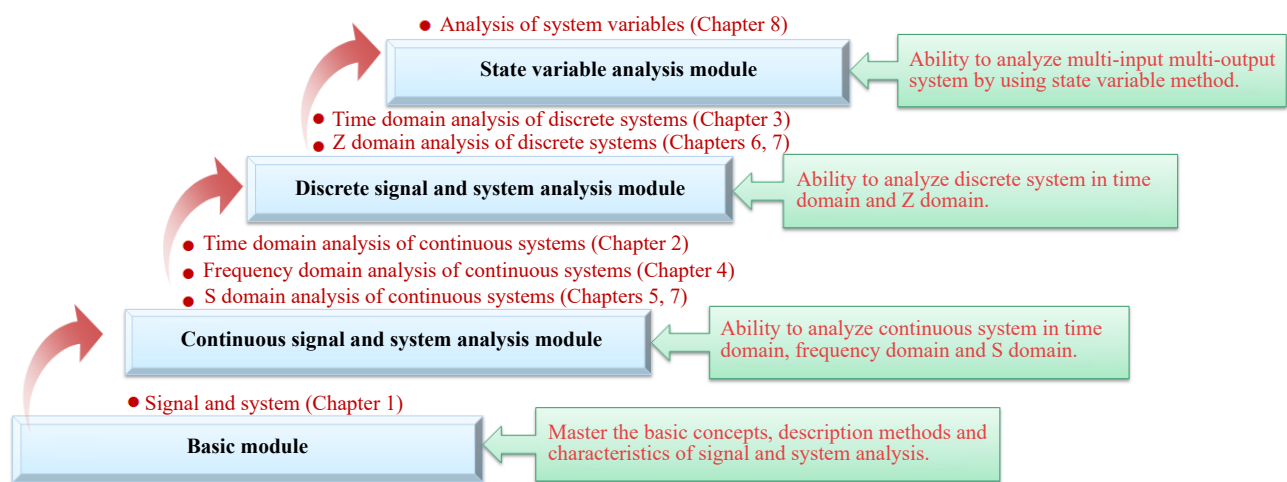


Figure 2. Teaching modules of SSC

3.4 Implementation process and teaching organization

After the design of teaching activities and resources of BTM-IEE is completed, the implementation stage of blended teaching will be entered. The specific implementation process is as follows. (1) Online teaching: the teachers will release the designed curriculum resources through the network platform (campus platform, wisdom tree). After receiving the learning tasks, students will obtain resources for independent learning, group learning, etc. The teaching tasks include knowledge module learning, testing, special discussion, practical activities, research projects, remote experiments, etc. After the learning content of each module is completed, certain online tests are supplemented to test students' self-study and mastery of basic knowledge. During the whole learning process, students can communicate and interact with teachers and other companions in time through network course platform or other network communication tools. (2) Offline teaching: the teachers mainly focus on the explanation of key and difficult knowledge, cognitive development and comprehensive practical activities, and carry out discussion teaching, research teaching and hardware experiment teaching. The main teaching tasks include three aspects. (I): the teacher answers the difficult and common problems encountered by students in the process of online learning, organizes students to discuss and study in groups, and encourages students to adopt divergent thinking; (II): the teachers arrange special experiments and comprehensive experiments, carry out research teaching, and train students' ability to comprehensively use their knowledge and skills to solve practical engineering problems, so as to cultivate students' innovative thinking; (III): the students summarize, report and display offline learning achievements, and teachers evaluate students' learning achievements. Based on

BTM-IEE, teachers make full use of the wisdom tree platform, campus network platform, RVEP, IDCES, QQ group to organize teaching. The main implementation process is shown in Figure 3.

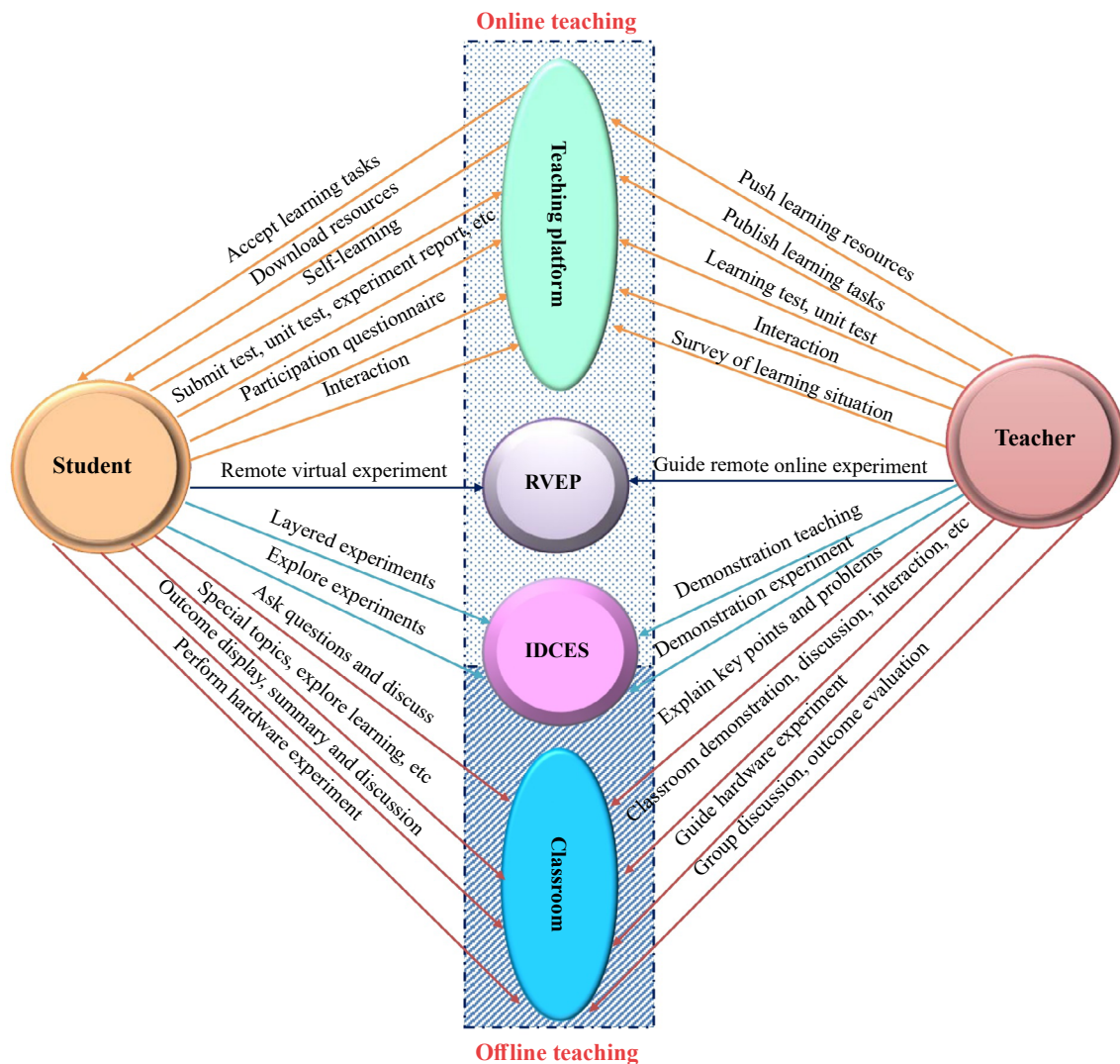


Figure 3. Implementation form of BTM-IEE

3.5 Learning evaluation

The diversified evaluation method of “formative-summative” is implemented in the SSC: formative evaluation accounts for 40%, including classroom performance, unit examination, online test, handwritten homework, inquiry comprehensive simulation homework, experiment, etc. The summative evaluation is the final examination, accounting for 60%. The evaluation method fully reflects the diversity and scientificity, as shown in Figure 4. Among them, online tests, unit tests, and handwritten homework focus on the examination of the mastery of basic theoretical knowledge points; the classroom usual performance such as interaction, display and discussion focus on the examination of knowledge mastery, cooperation ability and summary ability; the explore simulation homework such as research projects and comprehensive simulation projects focus on the examination of the ability of integrating theory with practice and innovation ability; the hardware laboratory practice course focuses more on the verification of basic theory and the cultivation of practical ability. The theoretical written test score (60%) focuses on the examination of the mastery of basic concepts, basic calculations and basic principles.

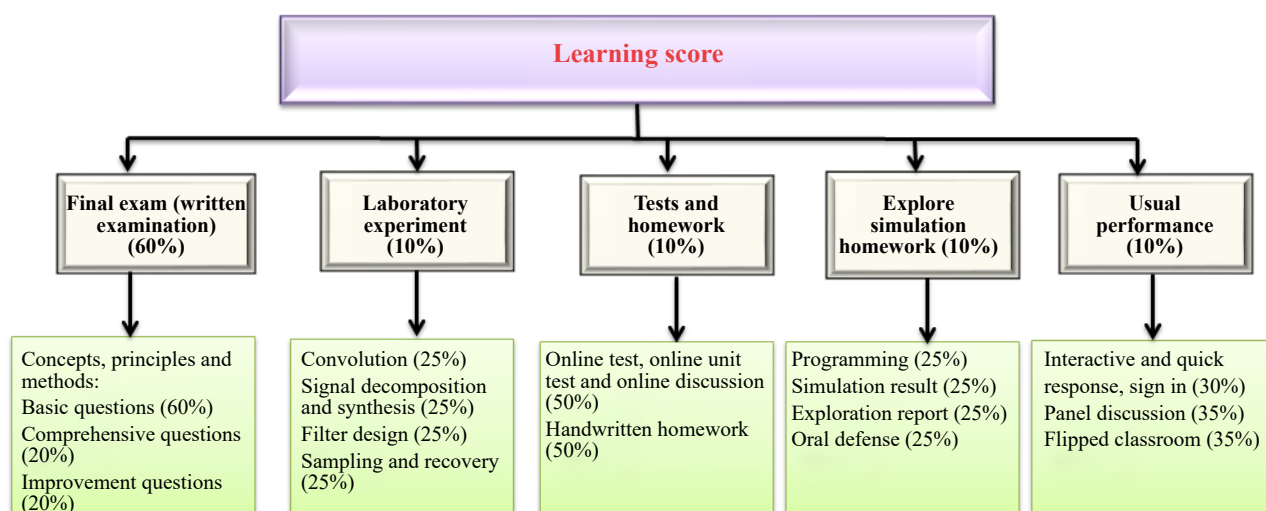


Figure 4. Learning dimensions evaluation of BTM-IEE

4. Application of teaching mode

4.1 Teaching implementation

This paper takes the course of signal sampling and reconstitution as an example to illustrate the teaching implementation of the course. The sampling theorem is a bridge between continuous time signal and discrete time signal. Through the learning of this course, students need to understand the conditions of continuous time signal discretization, the method of sampling signal reconstruction, and the application of sampling theorem. Therefore, the teaching design for the learning of this knowledge point is carried out, and the teaching design scheme and teaching process diagram are shown in Table 1 and Figure 5. Some case pictures in the course teaching are shown in Figures 6 and 7. After this class, the learning effect needs to be evaluated. The teaching effect evaluation highlights the main role of students in learning and the main role of teachers in continuous improvement. The teaching evaluation is carried out at different levels from the aspects of teaching preparation, teaching implementation, group discussion, testing, classroom discussion and homework. The main evaluation system is shown in Figure 7.

Table 1. The teaching design scheme of sampling theorem in time domain

The 19th class		Sampling theorem in time domain	
Course	Signal and linear system analysis	Teacher	Wang Yajing
Class hour	2	Teaching class	Electronic information engineering 1801, 1802
Teaching content			
Content: Time domain sampling, sampling theorem, application of sampling theorem Key points: Sampling theorem condition, sampling recovery method, sampling frequency and its interval calculation, sampling theorem application Difficulties: Calculation of sampling frequency, application of sampling theorem, difference between sampling and modulation model			
Course objectives and requirements			
Course objective: 2 Requirement: <ul style="list-style-type: none"> Understand time domain sampling, ideal sampling and rectangular sampling Master the spectrum and characteristics of time domain sampling signal Master the condition of sampling theorem and the method of sampling recovery Skilfully use the time domain sampling theorem Distinguish sampling and modulation models and understand their application characteristics 			

Table 1. Continued

Analysis of learner characteristics	
<ul style="list-style-type: none"> Students have learned the spectrum of continuous signal, and have the ability to perform signal spectrum analysis Students have mastered the system frequency domain analysis method and have the ability to perform system spectrum analysis The students have learned the knowledge of filter and have the ability to filter the signal 	
Teaching environment and resource preparation	
Textbook, teaching courseware, teaching video and computer MATLAB software	
Teaching process	
Process	Teacher activities, student activities, design intent
Pre-class	<p>Teacher: Publish task (review old knowledge, group discussion, etc), test questions</p> <p>Student: Preview relevant knowledge, consult the information about the analog and digital signals, sampling examples and analog to digital converter (ADC), complete the relevant discussions, perform platform test</p> <p>Design intent: Preliminary understanding of sampling and sampling conditions</p>
Introduction in class	<p>Teacher: Combined with the advantages of digital processing methods such as digital TV, video conference, digital storage, mobile phone and other cases in the current era, the problem is raised (problem driven pre-class learning feedback)</p> <ul style="list-style-type: none"> Why sampling? (block diagram of discretization process) How to sample? (example demonstration of real continuous signal discretization) What conditions are needed? (demonstration of image and sine signal discretization) Feedback on the students' learning problems before class, and give the course objectives and teaching contents, teaching key points and difficulties <p>Student: Bring out a question, discuss problems, listen, watch and think</p> <p>Design intent: Through examples, students are guided to explore the sampling theorem</p>
Discussion in class	<p>Teacher: Through the combination of traditional teaching and multimedia teaching, discussion and interactive teaching on what is sampling? How to sample? Sampling conditions? Inquiry learning stage</p> <p>Student: According to the questions raised by students and teachers, students actively participate in discussion, testing, voting, brainstorming and rushing to answer</p> <p>Design intent: Enhance the flexibility of students' thinking, improve students' ability to communicate, and deepen the understanding of sampling conditions. Through Nyquist's contribution to the scientific community, the scientific spirit of rigorous scholarship is instigated in the students</p>
Demonstration discussion in class	<p>Teacher: using MATLAB, IDCES and flash demonstration for harmonic and triangular wave signal, sampling theorem and recovery conditions are deepened</p> <p>Student: Students listen, watch, think, discussion, answer, voting, brainstorming</p> <p>Design intent: Consolidate the sampling theorem</p>
Engineering application in class	<p>Teacher: Taking the sampling of speech signal as an example, the teacher put forward the exploration and discussion on the selection principle of sampling rate in engineering practice; the teacher further proposed the technology barrier discussion of sampling device ADC</p> <p>Student: Students listen, watch, think, discussion, answer, voting, brainstorming</p> <p>Design intent: Through the discussion of speech signal under different sampling rates, the actual selection principle is obtained; through the discussion of ADC knowledge and technical barriers, students' determination to explore science and technology can be stimulated</p>
Application discussion in class	<p>Teacher: Through the combination of traditional and multimedia teaching, discussion and interactive teaching, the sampling theorem is applied in the form of exercises</p> <p>Student: According to the teacher's questions, students actively participate in testing, voting, brainstorming and rushing to answer</p> <p>Design intent: Application of consolidation sampling theorem</p>
Comparative discussion in class	<p>Teacher: Guide the students to compare and analyze the sampling model and the modulation model</p> <p>Student: According to the teacher's questions, students actively participate in testing, voting, brainstorming and rushing to answer</p> <p>Design intent: Consolidate the application of sampling model and modulation model to avoid confusion</p>
Summary in class	<p>Teacher: Course summary</p> <p>Student: The interaction between teachers and students</p> <p>Design intent: Class summary, echo before and after</p>
Consolidation after class	<p>Teacher: Assignment 4.48, 4.49, Section 4.9 online test, simulation task</p> <p>Student: Handwritten homework, platform testing</p> <p>Design intent: Application of consolidation sampling theorem</p>
Tracking and reflection after class	<p>Teacher: Reflection and improvement, release simulation task and teaching effect test questions effect testing</p> <p>Student: Complete simulation task, platform testing</p> <p>Design intent: Continuously improve teaching methods, focus on tracking and "early warning" for students with poor learning effect, and help them by taking targeted measures</p>

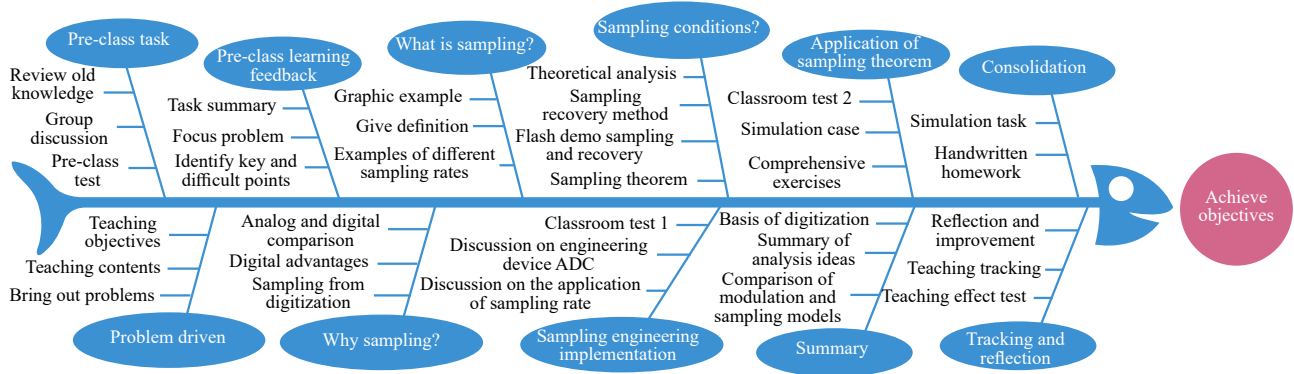


Figure 5. The teaching process diagram of sampling theorem in time domain

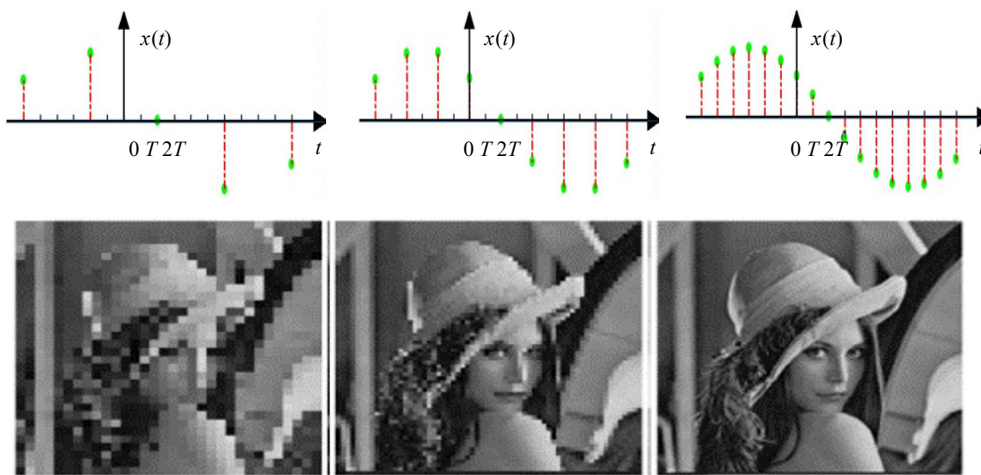


Figure 6. Discrete signal graphics of at different sampling frequency

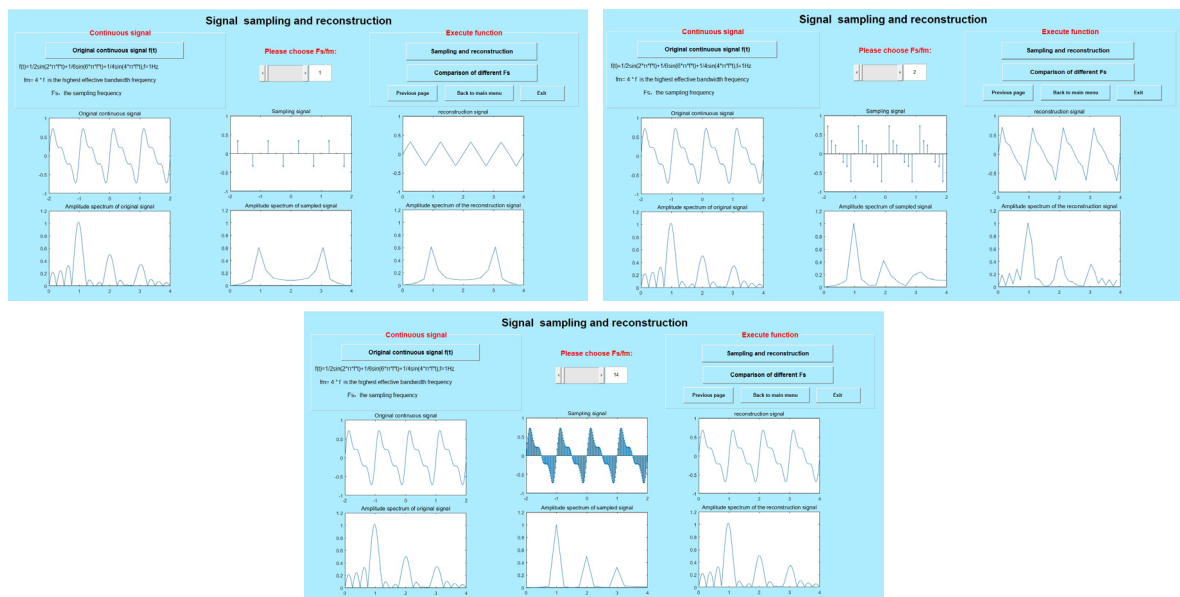


Figure 7. Sampling and reconstruction signal cases at different sampling frequencies

It can be seen from Table 1 and Figures 5 to 7 that in the teaching of sampling theorem, various teaching methods, such as question inspiration, flash, demonstration, comparison, simulation and discussion, are comprehensively used. Through many interactive methods such as testing, voting, brainstorming and rush answer, the theorem is studied and explored from the simple to the deep and step-by-step according to the idea of “why, what is sampling, how to sample, and what conditions?”. At different stages pre-class, in class and after class, blended teaching is carried out by combining online and offline methods. Through the multi-dimensional evaluation of teachers’ teaching effects and students’ learning effects in different aspects as shown in Figure 8, students can deeply understand the sampling theorem, achieve the course objective, and enable teachers to constantly improve teaching quality. At the same time, through independent preview, problem discussion, demonstration, exploration and interaction in class, students’ comprehensive abilities in many aspects are cultivated.

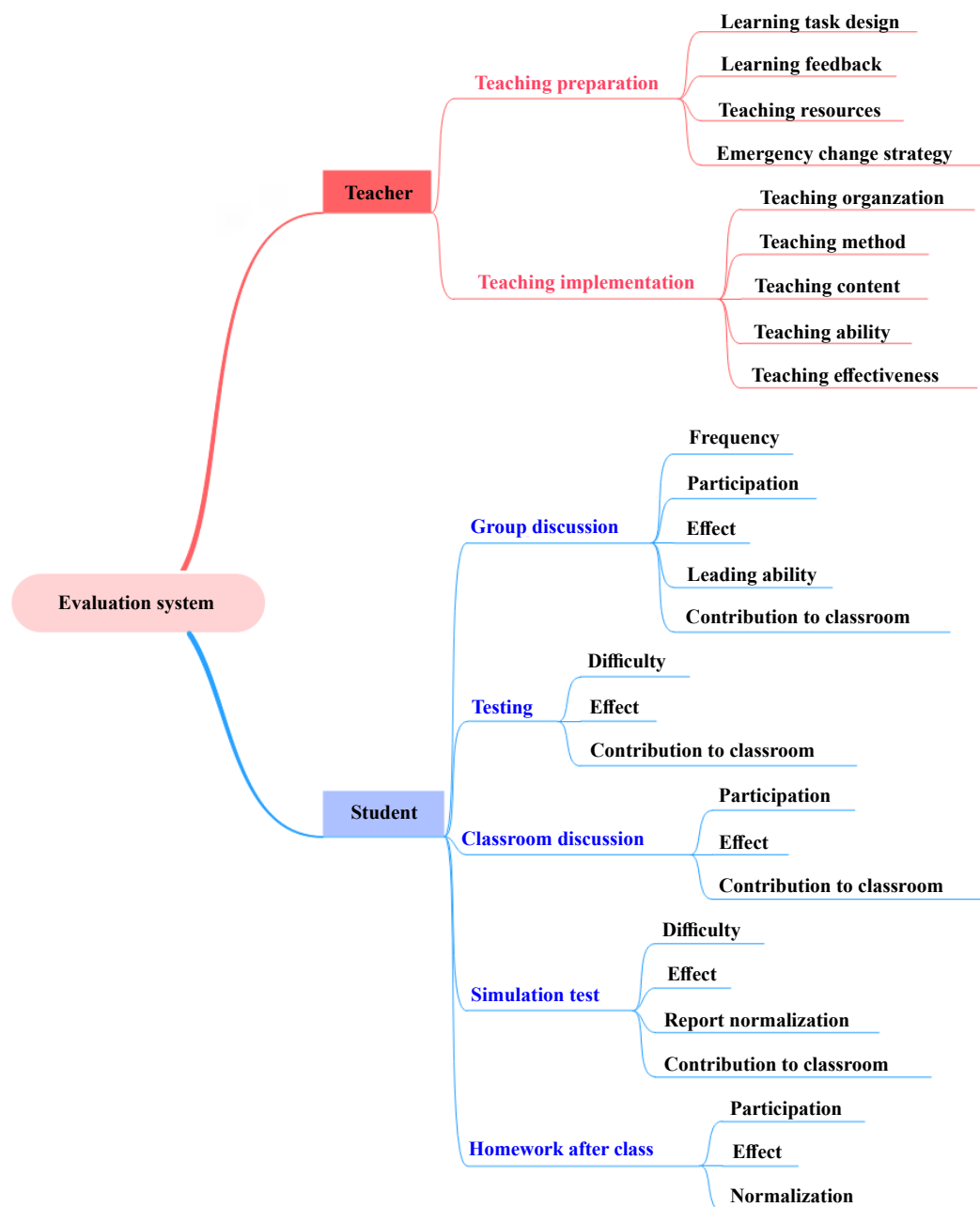


Figure 8. The evaluation system of sampling theorem in time domain

4.2 Flipped classroom

In the process of teaching implementation, some teaching designs are organized in the form of flipped classroom. The flipped classroom generally has two learning forms: course content and project inquiry. For the learning of course content, the teacher condensed several questions according to the teaching content in advance, and distributed tasks to the group in the form of task list, including watching videos, teaching resources, tests, etc. Then, with the help of resources, the group carries out labor division and cooperation, and summarizes the problems to be discussed. In class, each group will show the learning results and discuss under the guidance of the teacher. Finally, the learning effect is checked and summarized through the test. The flipped classroom of project is a practical exploration closely combined with teaching content. The projects of each group can be freely selected according to their interests or designated by the teacher. The flipping classroom design of practice project consists of three parts: pre-class project preparation, in class project presentation and after-class project expansion. The whole process is dominated by students and supplemented by teachers. The partial examples of presentation outcomes of students in flipped classroom are shown in Figure 9. In flipped classroom teaching activities, teachers assign tasks and answer questions online, student teams explore and learn offline and share learning achievements in class. Students participate in the discussion and teachers evaluate the learning results. This way not only improves students' participation, experience and sharing, but also greatly stimulates students' learning interest and exploration potential, and cultivates students' sense of teamwork and practical innovation ability through the combination of classroom content and project practice.

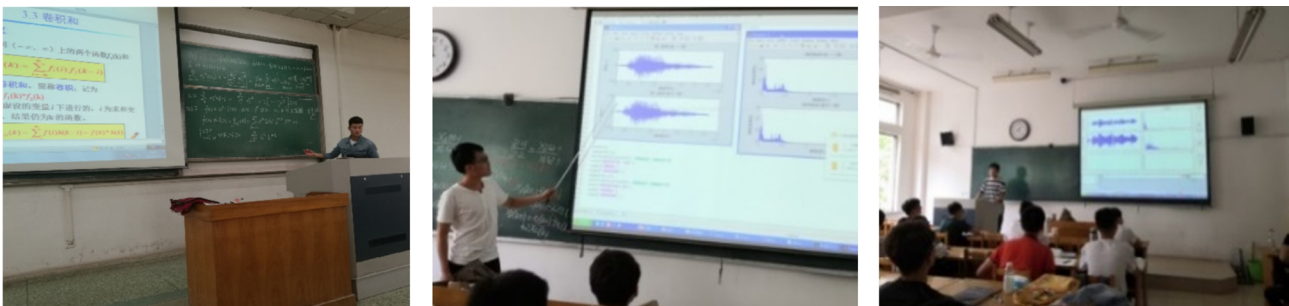


Figure 9. Partial example of presentation results of students in flipped classroom

4.3 Teaching implementation multi-level experiment mode of remote virtual and combination of software and hardware

In order to make students better understand the knowledge points of SSC and improve students' practical ability, the experimental teaching of this course adopts the multi-level experimental mode of remote virtual and the combination of software and hardware. The hardware experiment needs to be completed by students in a fixed laboratory at the fixed time. The remote virtual experiment is completed on RVEP developed by Beijing University of Posts and Telecommunications through the network. The software experiment is completed by MATLAB simulation software and IDCES. The partial examples of multi-level experiment mode are shown in Figure 10. It can be seen from the figure that the multi-level experiment mode of remote virtual experiment and software experiment is adopted in teaching. On the one hand, teachers can use IDCES for demonstration teaching, and implant some experiments into theoretical teaching in the form of classroom demonstration, which not only makes the abstract theory more intuitive, but also expands the experimental content and makes up for the shortage of traditional experimental hours. On the other hand, students can make full use of their spare time to conduct basic, comprehensive and engineering multi-level virtual and simulation experiments anytime and anywhere according to their own interests and abilities, so as to improve their engineering application ability and cultivate their innovative thinking.



Figure 10. Partial examples of multi-level experiment mode

4.4 Interactive teaching between teachers and students based on network teaching platform

In the interactive teaching between teachers and students based on BTM-IEE, the use of campus network platform and wisdom tree platform can improve the classroom teaching experience. In this way, the interaction between teachers and students is increased and the teaching atmosphere is more relaxed. SSC carries out panoramic teaching design of before-in-after class through campus network platform, wisdom tree. The design plans two parts teaching: online course and offline classroom. The learning tasks are distributed in the form of task list and course notice, and a variety of classroom interaction scenarios are supported through the functions of sign in, roll call, rush answer and announcement. Through the test, unit examination and so on, we can check the learning content. Through the form of discussion and question answering, we can communicate and answer questions online. Various homework and unit learning summaries files can be uploaded and the learning situation can be feedback through questionnaires, so that teachers can adjust the learning strategy, as shown in Figure 11.

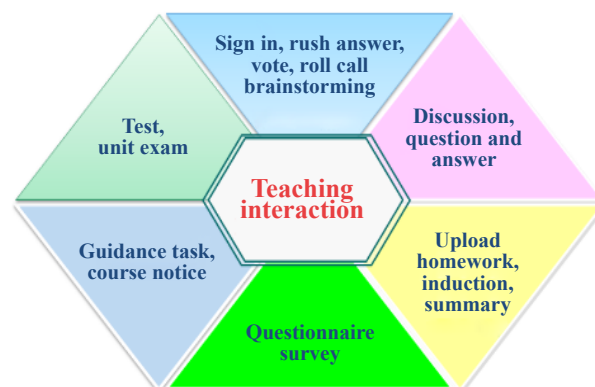


Figure 11. Teaching interaction of BTM-IEE

5. Assessment and analysis

In order to verify the implementation effect of BTM-IEE, after the completion of the overall course, the teaching effect and acceptability of the course are evaluated through online questionnaire survey from different angles. Taking classes 1801+1802 of electronic information engineering major of Shandong University of Technology taught by the author as an example, 85 students participated in the survey. Among them, the results of the partial questionnaire are shown in Figure 12. In the statistical analysis of the survey results, 92.94% of the students are satisfied with the learning effect of this course. 91.77% of the students like mixed teaching mode very much, and 92.94% of the students believe that the remote and self-developed signal processing simulation experiment platform are very helpful to their understanding of knowledge and improvement of practical ability. 95.29% of the students believed that they have mastered solid basic theories and have better understanding on SS analysis and processing ability through the study of the course. 89.42% approved that the mixed teaching mode expands their knowledge and improved their interest in learning. 88.24% of the students agreed that BTM-IEE is not only conducive to cultivating their practical ability, cooperation ability, communication ability, but also can stimulate their learning initiative and creative thinking.

In order to further illustrate the effect of BTM-IEE, taking the teaching of students majoring in electronic information engineering as an example, the horizontal and vertical comparison between BTM-IEE and the traditional teaching mode is also carried out. Classes 1801+1802 (85 students) and classes 1901+1902 (85 students) adopted BTM-IEE, and classes 1701+1702 (79 students) and 1803+1804 (85 students) adopted the traditional teaching mode. After the examination, the distribution results of the final grade are shown in Figure 13, and the mean and standard deviation of corresponding scores are shown in Table 2. By comparing the horizontal scores of students in the same grade in Figure 13(a), it can be seen that compared with the scores of classes 1803+1804 in traditional teaching, the scores of classes 1801+1802 are mainly distributed between 70 to 89, and the scores of classes 1803+1804 are mainly distributed between 60 to 79. From the perspective of excellence rate and failure rate, the excellence rate of classes 1801+1802 is higher and the failure rate is lower. A similar phenomenon can be obtained through the vertical score comparison in Figure 13(b). The scores of classes 1701+1702 in traditional teaching are mainly 60 to 79, accounting for 68.36%. The scores of mixed teaching class 1801+1802 and 1901+1902 are mostly concentrated from 70 to 89, accounting for 74.12% and 76.47% of the total number, respectively, and the failure rate is significantly reduced and the excellence rate is significantly improved. This shows that BTM-IEE can significantly promote learners at all levels. In addition, the comparison between the mean and standard deviation of scores of traditional teaching classes and improved teaching classes in Table 2 can also show the effectiveness of BTM-IEE. The horizontal comparison of the four classes from 1801 to 1804 shows that, compared with the performance of the traditional teaching classes 1803+1804, the mean score of 1801+1802 has increased by 4.85 points and the standard deviation of the score has decreased by 1.01 after adopting the improved teaching method. This shows that the students in the improved teaching classes have better scores and tend to be consistent. The vertical performance comparison of 1701+1702, 1801+1802 and 1901+1902 levels also draw a conclusion similar to the horizontal comparison. Compared with the traditional teaching class 1701+1702, the mean scores of the classes 1801+1802 and 1901+1902 with improved teaching methods were significantly improved, and their standard deviation of scores also decreased to varying degrees. Therefore, from the perspective of mean and standard deviation of scores, BTM-IEE can significantly improve students' academic performance.

Table 2. Mean and standard deviation data of horizontal and vertical comparison between BTM-IEE and traditional teaching mode for electronic information engineering students

Class	Mean	Standard deviation
1701+1702	70.28	12.94
1801+1802	76.12	11.24
1803+1804	71.25	12.25
1901+1902	77.78	11.13

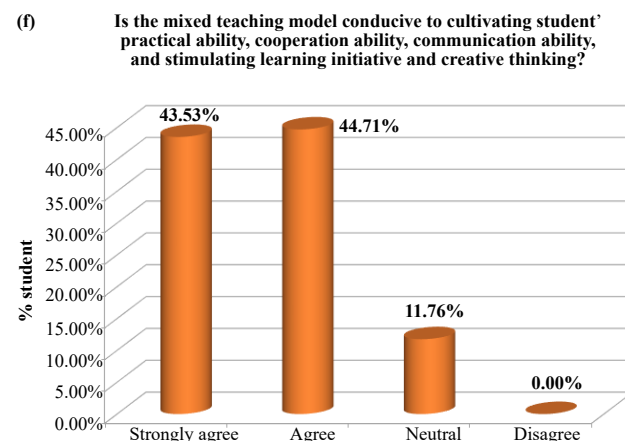
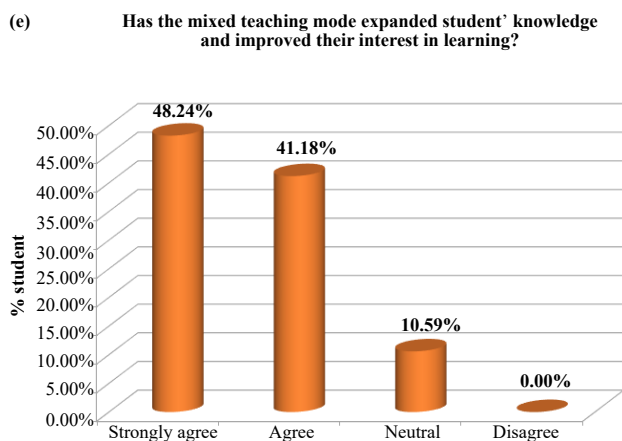
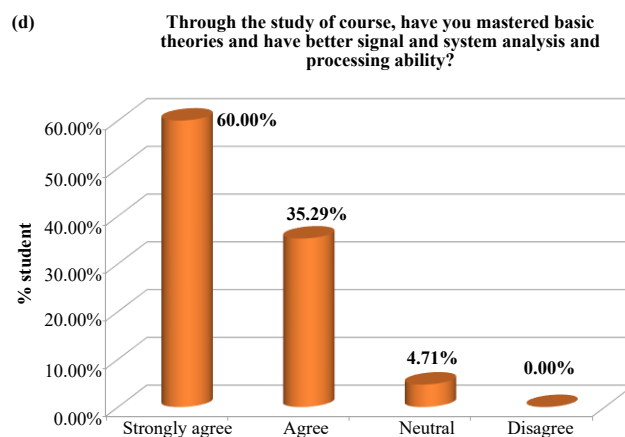
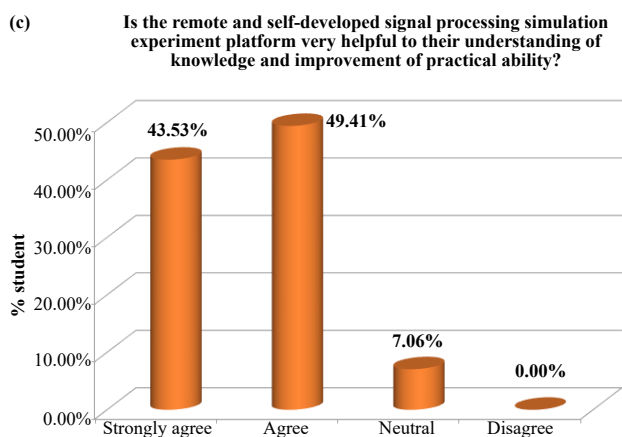
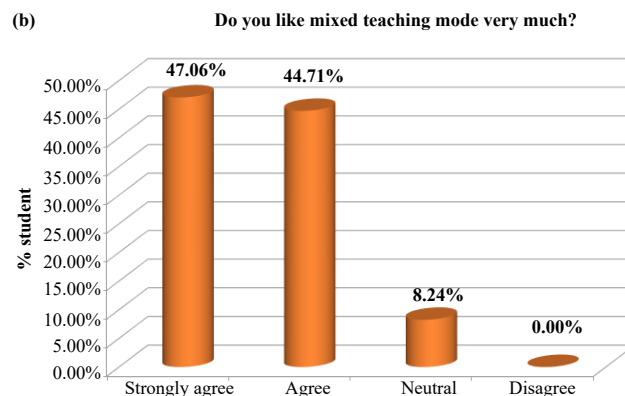
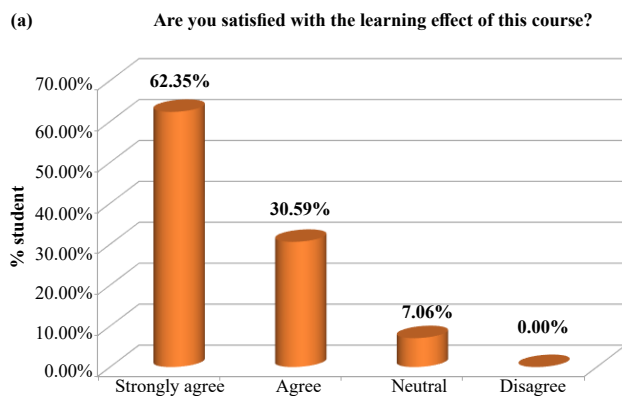


Figure 12. Results of the questionnaire of classes 1801+1802 in electronic information engineering

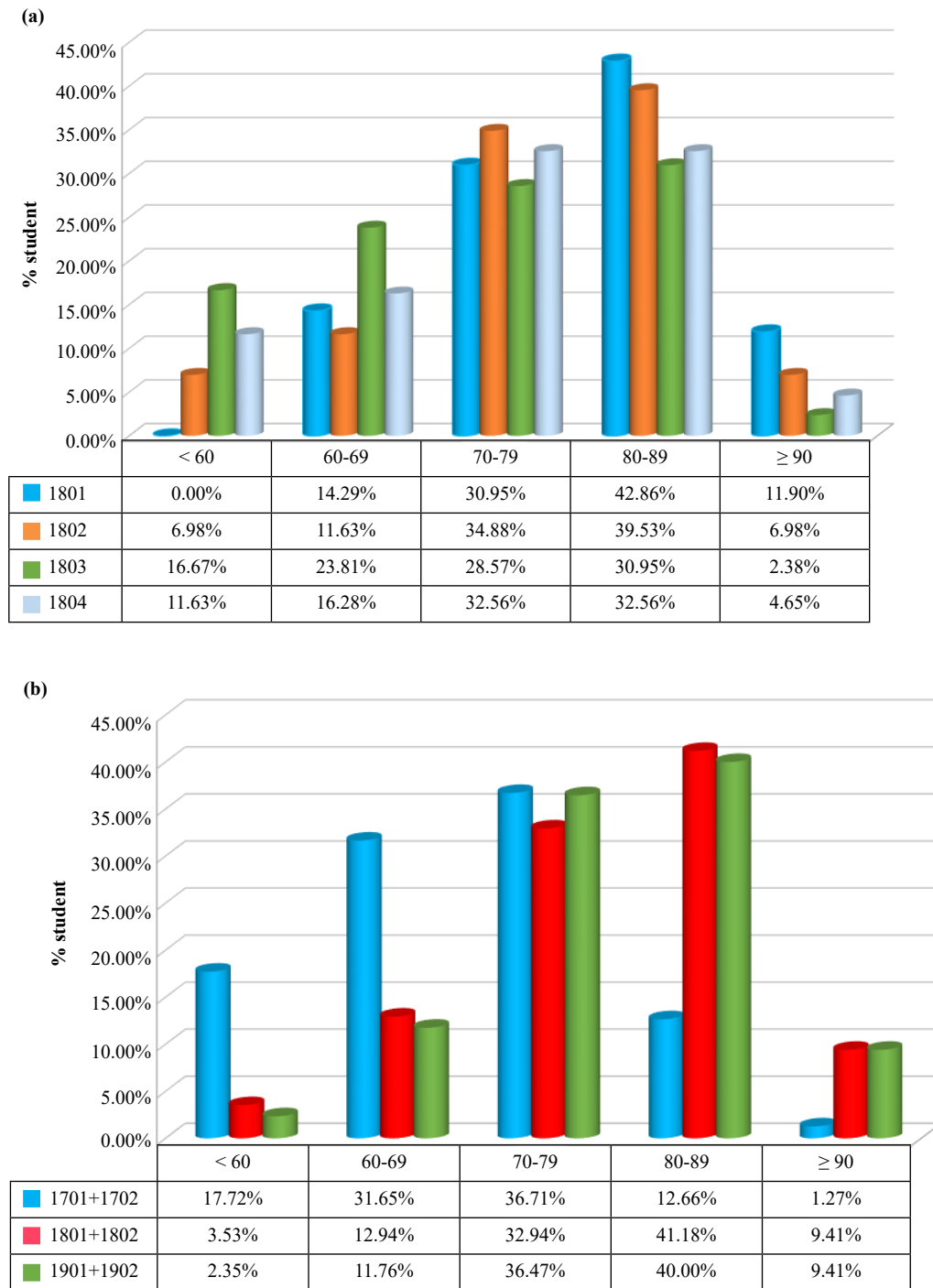


Figure 13. Horizontal and vertical comparison between BTM-IEE and the traditional teaching mode for electronic information engineering students:
(a) horizontal comparison (b) vertical comparison

6. Conclusions

Aiming at the teaching difficulties of SSC, in order to adapt to the new situation of higher education in the information age and the engineering education concept of “student-centered” and OBE, on the basis of adhering to the traditional classroom teaching, the BTM-IEE is constructed. In this paper, firstly, the design framework, teaching resources, teaching organization implementation, and teaching evaluation methods of BTM-IEE are introduced in detail.

Then, a variety of application examples show the implementation of BTM-IEE. Finally, the effectiveness of BTM-IEE is verified by data analysis. According to three years of teaching practice and continuous improvement, the following conclusions are drawn:

(1) BTM-IEE has realized the deep integration of in class-out of class and online-offline. Based on the rich network platform resources, BTM-IEE adheres to student-centered, the main position of the classroom, organically combines classroom teaching with online learning, and realizes students' multi-dimensional interactive learning of "in class-out of class, online-offline".

(2) BTM-IEE can improve students' engineering application ability and cultivate innovative thinking. The multi-level experiment mode of BTM-IEE can make full use of the MATLAB, RVEP, IDCES to implant the experimental teaching demonstration into the classroom. According to their own ability, students use their spare time to design "hierarchical, engineering and inquiry" experimental projects anytime and anywhere. In this way, the experimental content can be expanded, the students' engineering application ability can be greatly improved and innovative thinking can be cultivated.

(3) BTM-IEE can better improve students' autonomous learning ability, cooperation and communication ability. During the implementation of BTM-IEE, some tasks need to be completed independently by consulting a large number of literatures. Some tasks need to be completed by students' teams and show learning results to all students. In continuous learning, the completion efficiency is higher and higher, and the display results are better and better. In this way, we can effectively cultivate the ability of autonomous learning, cooperation and communication.

(4) The course evaluation system of BTM-IEE can give full play to the role of motivation and feedback to students. This evaluation system implements the diversified evaluation method of "formative + summative". The teaching evaluation runs through the whole teaching process and fully reflects the diversity and scientificity. The evaluation emphasizes student-centered, OBE and personalized development. According to the evaluation at different stages, students can master their learning situation, and teachers can track students at any time and take help strategies. This mode greatly mobilizes students' learning enthusiasm and is easier to cultivate students' knowledge ability, practical ability and innovation ability.

(5) BTM-IEE provides a reference for the improvement of teaching quality of professional courses, and has important practical significance.

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Conflict of interest

We authors hereby declare that we do not have any conflict of interest with the content of this manuscript.

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