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Results-Oriented Teaching Reform of Fiber Optical Communication Course under the Engineering Education Certification

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Abstract: In the context of current engineering education certification, the "Optical Fiber Communication" course has undergone teaching reforms in content design and implementation to meet teaching objectives and graduation requirements. The 4A4S (Four Ability Four Skills) system, introduced for the first time, focuses on results-oriented teaching and evaluation. It involves analyzing graduation requirements, setting clear learning outcomes, designing suitable teaching methods, establishing a scientific evaluation system, and assessing the impact of teaching reforms. Post-reform, the class's excellent and good performance rate is 10% higher than others. Students now master optical fiber communication system design and analysis, apply theoretical knowledge and software to solve complex engineering problems, and meet graduation requirements. This study is a valuable reference for teaching reforms in engineering certification contexts.

1. Introduction

Engineering science and technology are important drivers to change our world [1-6], and rapid research advances and a changing workforce need to put pressure on the education and training systems that connect them [7]. Optic-based technologies are nowadays widespread and flourishing. In recent years, with the continuous development and update of mobile Internet networks, big data, artificial intelligence, and high-speed 5G or even B5G/6G mobile technology, large-capacity and high-speed optical fiber transmission technology is playing an increasingly important role [8-10], and this technology has become a hot research direction. Therefore, it is particularly important to take optical fiber communication as a professional basic course in the undergraduate teaching of communication electronics, it is necessary to train optical engineering talents who can adapt to the development of optical fiber communication, have knowledge of optical fiber and optical communication devices and analytical thinking, and can analyze and deal with practical problems with optical theoretical knowledge. To this end, our school has set up fiber optic communication courses to train the needed talents, and the teaching methods and contents in fiber optic communication courses need to be updated with the development of technology.

With the idea of "mass entrepreneurship and innovation" put forward, innovation and entrepreneurship education in colleges and universities has received great attention and achieved great development [11-17]. However, the survey found that there are still some problems in the current innovation and entrepreneurship education of college students and a scientific and reasonable talent training system for innovation and entrepreneurship has not been established, which affects the improvement of college students' innovation and entrepreneurship quality and ability. To effectively solve these problems, the General Office of the State Council issued the Guiding Opinions on Further Supporting College Students' Innovation and Entrepreneurship on September 22, 2021 [18]. The requirements are as follows: (1) The innovation and entrepreneurship education should run through the whole process of talent training, deepen the reform of innovation and entrepreneurship education in colleges and universities, improve the innovation and entrepreneurship education system in colleges and universities that integrates classroom teaching, independent learning, combined practice, guidance and assistance, and cultural guidance, and enhance the innovative spirit, entrepreneurial awareness and innovative entrepreneurial ability of college students;(2) Improve the teaching ability of teachers in innovation and entrepreneurship education, strengthen the teaching ability and quality training of college teachers in innovation and entrepreneurship education, reform teaching methods and assessment methods, and promote teachers to integrate international frontier academic development, the latest research results and practical experience into classroom teaching;(3) Strengthen innovation and entrepreneurship training for college students. On April 1, 2021, Director General Wu Yan once again stressed that curriculum is the core element of talent training at the 2021 National Higher Education Director Meeting of the Higher Education Department of the Ministry of Education, and the teaching reform changed to the depth of curriculum.

Optical Fiber Communication is an important professional course for the majors of communication engineering and information countermeasure technology at our university. Its main contents include the basic knowledge, basic principles, and development of new technologies of modern optical technology and optical communication. It is positioned to pay equal attention to theory and practice and requires students to have the basis of many pre-courses such as College Physics, Electromagnetic Field and Electromagnetic Wave, and Communication Principles. It involves more complex theoretical derivation, requires higher theoretical knowledge of physics, and undertakes the task of cultivating talents with solid theoretical knowledge and practical ability of optical fiber communication transmission. The mixed online and offline teaching mode is adopted to classify the training types of different students and design the teaching content, further promote the 4A4S teaching practice, improve the ability to apply knowledge to solve engineering problems, and enable them to adapt to the continuous development and update of mobile Internet, artificial intelligence, 5G/6G and other technologies as soon as possible after graduation [19]. By taking this course, students strengthen their skills in scientific research and innovation.

2. 4A4S model of fiber optic communication course

The teaching objectives and teaching methods of the optical fiber communication course revolve around the following three questions :(1) What kind of talents should be cultivated;(2) How to make students become the needed target talents;(3) How to evaluate the curriculum effectively. The answers to these three questions run through the instructional design of the entire fiber optic communication course shown in Figure 1.

To determine the target training talents of the proposed curriculum, we must first classify the types of talents, then find out the target areas of talent shortage, and finally consider what kind of knowledge and ability these talents need. The teaching team combined the characteristics of fiber optic communication courses, "student-centered", and referring to the characteristics of students'

employment positions after graduation and different ability requirements under the needs of further study, the course team designs a 4A4S model based on fiber communication teaching goals. 4A (4 Abilities), namely four abilities, the ability to "think, design, solve problems innovatively, and write scientific research papers". The 4A model focuses on the cultivation of innovative ability at the theoretical analysis level and trains students to establish scientific thinking and the ability to analyze and explore problems in the field of optical communication devices and systems. 4S (4Skills) are four skills: Reflected in the four skills of "problem finding, team cooperation, problem-solving, and results presentation", the 4S model focuses on the cultivation of innovation ability at the application level, so that students can systematically exercise their ability to solve practical problems with optical communication knowledge. The design concept of the course follows the requirements of gold course construction repeatedly emphasized by Director Wu Yan [20].

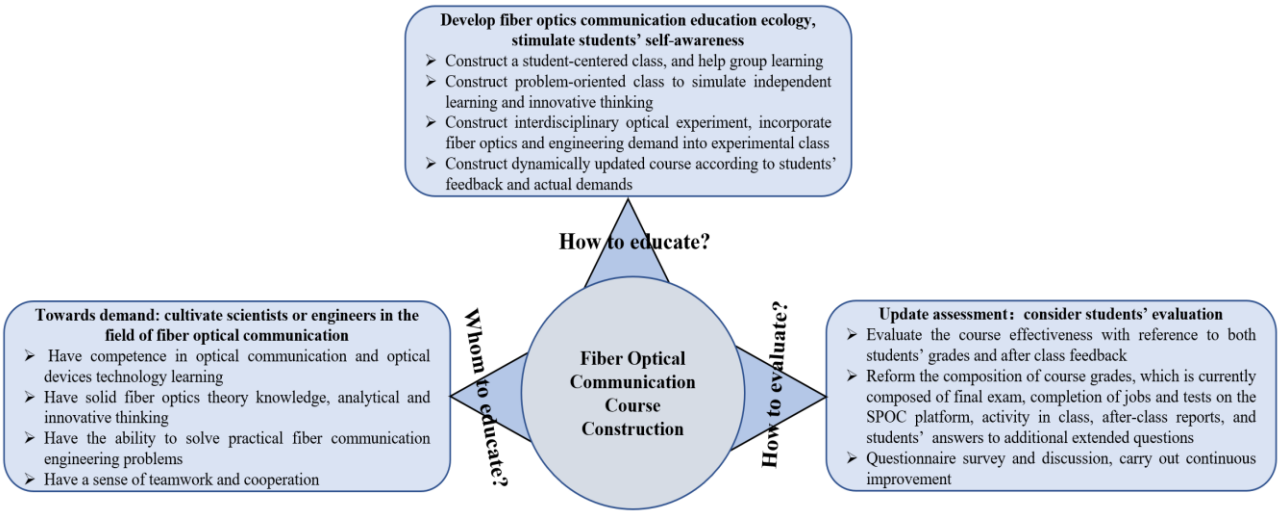


Figure 1 Construction of fiber optical communication course.

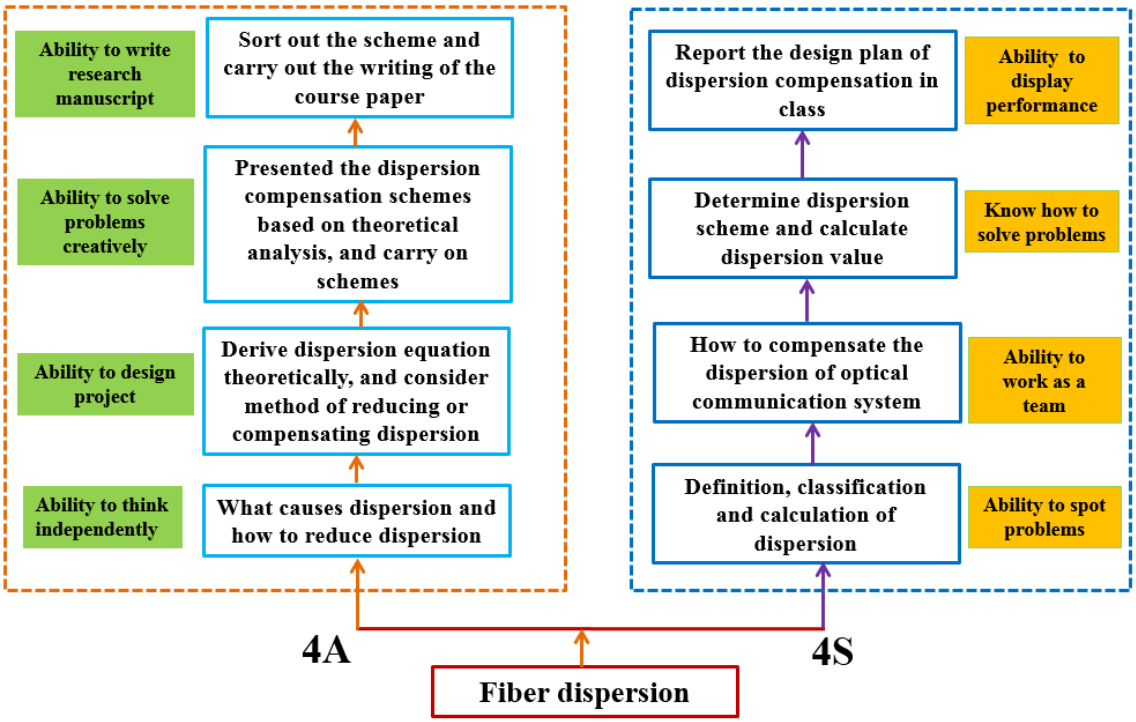


Figure 2 4A4S model constructed with the knowledge of " Fiber Dispersion ".

The following takes “optical fiber dispersion” as an example to explain the design idea of the 4A4S model in detail, as shown in Figure 2. The design idea of the 4A model is to start from the causes of dispersion, guide students to establish a theoretical model analysis method of optical fiber dispersion, deduce the impact of dispersion on the optical fiber communication system combined with the transmission equation, and then propose different dispersion compensation methods through intra-group cooperation, finally, this knowledge point is summarized in the form of a paper report. 4A highlights the ability to train students to conduct scientific research and innovation based on mastering the basic concepts and calculation methods of dispersion. The design idea of the 4S model is based on the definition and calculation method of dispersion, so that students can understand how to calculate the dispersion size of optical fiber lines and the limitation of the transmission distance of the system during the design of optical fiber communication system, and finally report the designed system scheme limited by optical fiber dispersion. The outstanding aspect of 4S is the training of students' knowledge application ability to solve complex engineering problems based on mastering the basic concepts and calculation methods of dispersion.

3. Online and offline mixed teaching practice of "Optical Fiber Communication" course based on 4A4S model

The purpose of the hierarchical classification of "Optical Fiber Communication" course based on the 4A4S model is to reflect the "student-centered", and to achieve differentiation and cultivate students' innovative ability through the design of 4A and 4S models. First of all, the follow-up survey of the graduates of communication engineering in our school in the past 10 years shows that more than 2/3 of the students are actively employed. Most of the graduates in the employment category work in software and hardware technical support and design and development. Optical fiber communication is one of the characteristic professional courses of communication engineering. The training of students should satisfy in 5 g communications equipment maintenance, optical fiber network engineering planning and construction, synchronous digital system (SDH, Synchronous Digital Hierarchy) system is set of maintenance, telecommunications, core network and access network engineering maintenance work of the demand of the applied talents. For students who are employed after graduation, the teaching content design focuses on cultivating students' hands-on ability and the ability to solve practical problems. For further study graduates, the course focuses on cultivating students' ability in theoretical analysis, reasoning, and innovative design during project design. Teaching content in the appropriate add some new technology such as intelligent optical network (ASON, AutomaticallySwitchedOpticalNetwork), multiple wavelength fiber laser (finally MFL, MultiwavelengthFiberLaser) small topics, and microwave photonics, etc.

3.1 Teaching design

The teaching design of the scaffolding teaching mode under the constructivist learning theory adopted in this course is shown in Figure 3. The teaching design consists of five processes: scaffolding,entering the situation, independent exploration, collaborative learning, and effect evaluation. Before class, the teacher designed the pre-class task list based on the knowledge points, and the thinking questions on the task list introduced the students to the situation. In the class, the teacher adopts the flipped classroom teaching mode to discuss the problems raised or discuss in groups, guide students to reflect on and analyze the current learning content, and enable students to have a more comprehensive and correct understanding of the knowledge, to complete the construction of the meaning of the knowledge. After class, students complete online homework and tests to realize the summary of knowledge, further find problems, raise problems, and solve problems, to achieve the extension and expansion of knowledge, and organize students to conduct self-evaluation or mutual

evaluation to evaluate the learning effect, adjust and continuously improve the teaching process.

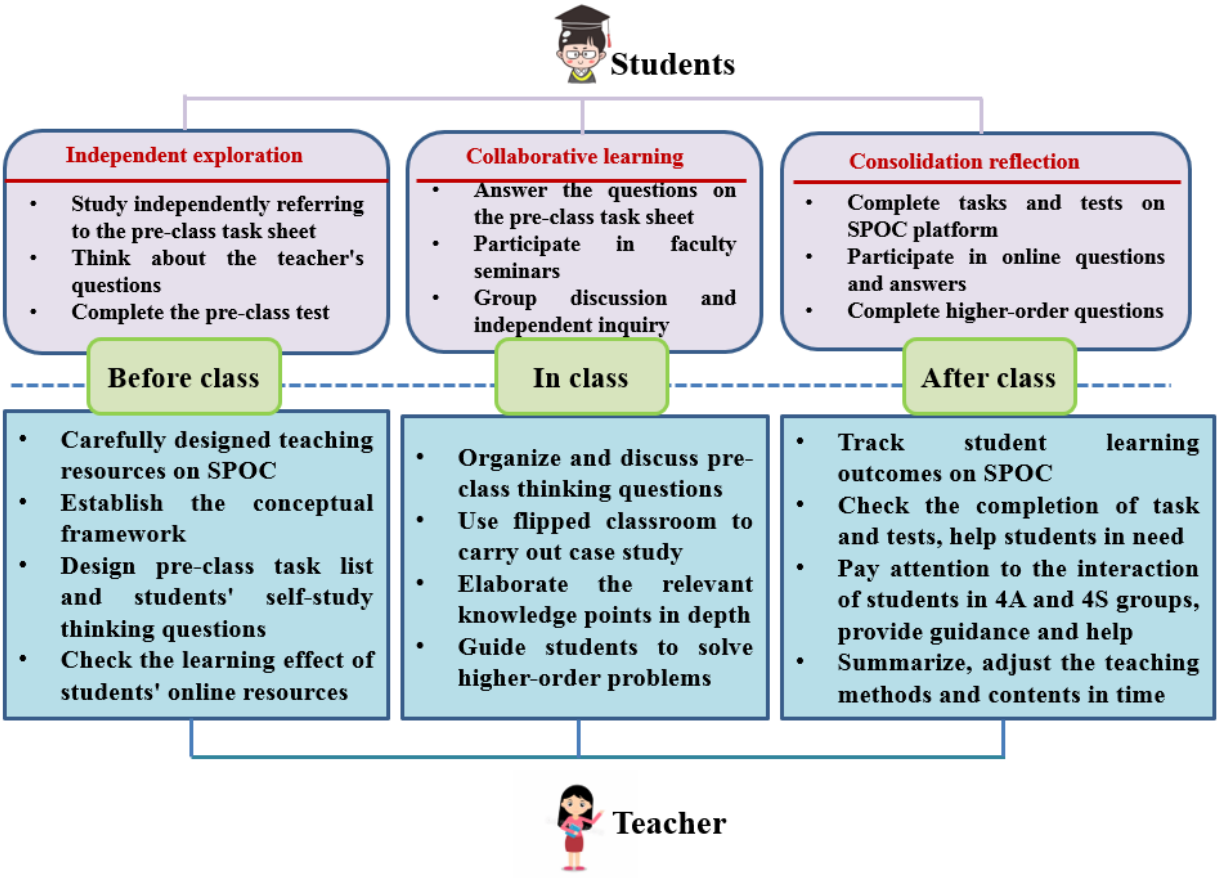


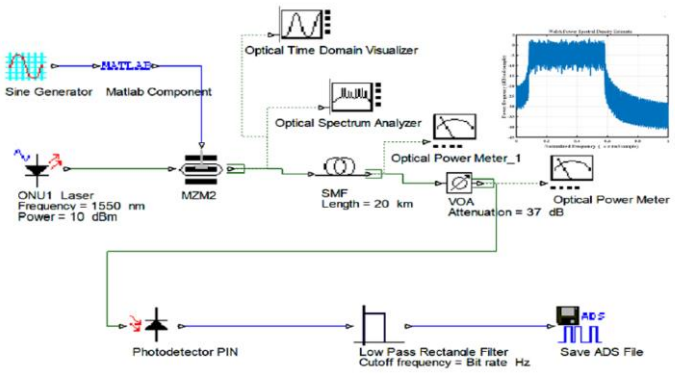
Figure 3 Theoretical teaching of optical fiber communication based on the SPOC platform of online and offline mixed teaching mode.

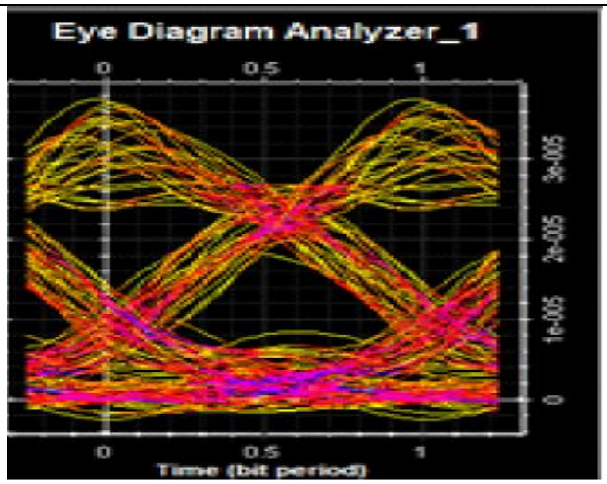
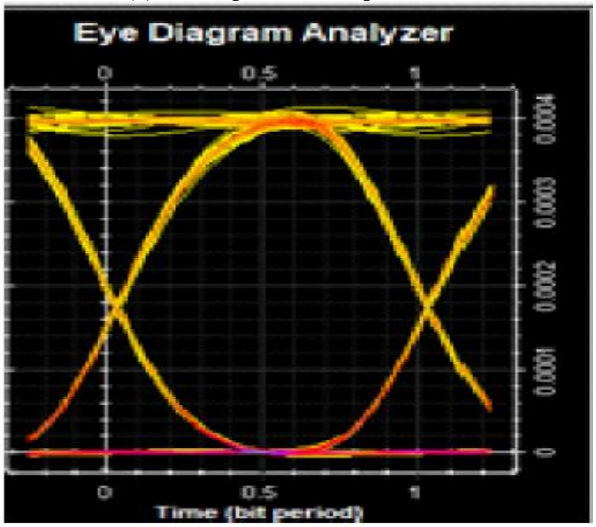
3.2 Implementation of 4A4S teaching cases based on the SPOC platform

The teachers of the course team built the SPOC course of Optical Fiber Communication for our students on the MOOC of a Chinese university and combined the online and offline teaching with the online teaching video. Under the guidance of the scaffolding teaching mode of constructivism learning theory, the student's learning objectives, thinking modes, and cognitive characteristics are fully considered, and the complex learning tasks are broken down so that the students can gradually achieve the higher-order teaching objectives. In the process of teaching practice, it emphasizes student-centered, organizes students to carry out independent learning and intra-group collaborative learning, constantly enhances students' awareness of inquiry and innovation, and improves students' scientific research ability and ability to solve complex engineering problems.

In this paper, we take the dispersion knowledge of optical fiber as an example to explain the specific implementation process of 4A4S in this course, as shown in Table 1. First of all, the knowledge points are decomposed into different types of tasks, such as basic, exploratory, and applied.The basic tasks are targeted at students with both 4A and 4S abilities, while the exploratory tasks are mainly focused on training students with 4A abilities, while the applied tasks are targeted at students with 4S abilities.

Table 1 Implementation process of 4A4S teaching " Fiber Dispersion "based on classification teaching.

Step	Task decomposition	Requirement details	For 4A group	For 4S group
1)	Before class: Complete task sheet----Fiber Dispersion	● The concept of dispersion ● The classification of dispersion ● The calculation method of dispersion	√	√
2)	Before class: Thinking question	● What Causes the dispersion? ● What is the theoretical model of dispersion? ● How to reduce dispersion?	√	
		● What is the difference in the calculation method of different dispersion? ● What is the effect of dispersion on optical communication systems?		√
3)	In class: Confusion and discussion(ARCS model)	● A(Attention): By watching the video and the dispersive flash video animation of optical fiber, the students were asked why the transmission rate in the optical communication system could not be increased without limitation, to attract the students' attention to this lesson. ● R(Relation):By recalling the structure of optical fiber and the mechanism of optical fiber transmission, the students are guided to solve the problem of the dispersion-limited transmission rate of optical communication system by using geometric optics; ● C(Confidence): Case studies, such as explaining why the transmission distance of the first optical fiber drawn by Charles Kao can only be within a few meters. Why can optical communication systems reach 40GHz? ● S(Satisfaction): According to the feedback of pre-class tasks, students are encouraged to summarize and summarize the precautions in calculating dispersion by themselves through group discussion or class explanation, to deepen their understanding of mode dispersion, material dispersion, and waveguide dispersion.	√	√
4)	In class: Case design and analysis	● With the help of optisystem software, an optical transmission system model is built to demonstrate the system eye view before and after dispersion compensation 	√	√

		 (a) No dispersion compensation  (b) With dispersion compensation		
		● Consideration: Design an optical communication system, how to calculate the optical communication system due to dispersion bandwidth-limited transmission distance? ● What are the requirements for optical fiber selection in transmission links?		√
		● Consideration: Using geometric optics to analyze the theoretical model of dispersion, how to compensate for the dispersion in the line? ● How to carry out dispersion compensation in existing 5G communication technology?	√	
5)	After class: Summary and inspiration	● Complete jobs and tests on the SPOC platform ● Talk and discuss in the forum	√	√
		● Analyze and complete the thinking problems in class in the group and form a report ● Enlightening thinking: except for the compensation in the optical domain, can dispersion be compensated in the electrical domain?	√	
		● Analyze and complete the thinking problems in class in the group, and draw a detailed simulation diagram ● Analyze the simulation results and prepare to report		√

4. Teaching reform effect analysis

To cultivate students' innovative abilities, the key point is to stimulate students' learning interests and cultivate students' desire and curiosity for knowledge and science. In the course of teaching, and guiding students to carry out projects and online discussions, this course introduces some natural phenomena and scientific problems related to the course, arouses students' curiosity, drives their learning passion, and enables students to develop the habit of actively exploring scientific knowledge and become the master of learning and scientific research. In particular, the design of the teaching content starts from the perspectives of 4A and 4S, and constantly integrates the new knowledge of the industry, the new progress in the field, and the new trend of employment, leading students to integrate and apply their professional knowledge to solve problems and scientific and technological innovation. The 4A model introduces challenging problems with an important "stuck neck" to inspire students to think, and the 4S model focuses on the development of new areas of the industry, such as complex engineering problems brought by 5G technology, and guides students to think. Through the implementation of 4A4S teaching practice in the past five years, the achievement of course teaching objectives and students' achievements have been significantly improved. Through questionnaires and discussions, it is found that students' innovation ability and recognition of independent learning psychology have been greatly improved.

4.1 Achievement of teaching objectives

The course adopts a multi-dimensional process assessment method to evaluate the achievement of the teaching objectives. The evaluation of the achievement of the course objectives comes from the teaching video learning, online discussion, online homework, online unit test, online final exam, classroom performance, project presentation (project paper), and final exam on the SPOC platform, and assigns corresponding weight coefficients to each module. To further illustrate the advantages of adopting this classified teaching method, we conducted a comparative analysis of the total evaluation results of the four teaching classes in the semester of 2022-2023-2, as shown in Table 2. Among them, ZXF's class adopts 4A4S online and offline mixed teaching methods, while the other three classes adopt ordinary teaching methods. As can be seen from Table 2, the performance of the teaching reform class is significantly better than that of other classes, especially in the excellent rate.

4.2 Course questionnaire result

To acquire the impact of the 4A4S classification teaching method on students' academic performance and obtain students' feedback on the teaching reform of this course, we conducted a questionnaire survey on students after the teaching of this course, and finally obtained 40 questionnaires, of which 40 were valid questionnaires. The questionnaire consisted of 12 multiple choice questions, and their answer is listed on a five-level Likert item, with 5 means strongly agree and 1 strongly disagree. We classify 4 and 5 as positive answers and 3 as neutral answers. The contents of the questionnaire include students' grasp of online and offline teaching modes, classified teaching methods, classroom knowledge, and student's ability to use the knowledge in the classification. The 12 survey questions and students' answers are shown in Table 3.

Table 2 Comparison of final total scores of different classes.

	LYX's Class		YSN's Class		BMH's class		ZXF's class	
Score level	student numbers	percentage	student numbers	percentage	student numbers	percentage	student numbers	percentage
90-100	0	0.00%	0	0.00%	0	0.00%	5	12.50%
80-89	2	5.00%	4	11.43%	4	11.76%	2	5.00%
70-79	0	0.00%	10	28.57%	6	17.65%	7	17.50%
60-69	1	2.50%	9	25.71%	6	17.65%	11	27.50%
Below 60	37	92.50%	12	34.29%	18	52.94%	15	37.50%
Top score	82		86		87		98	
Lowest score	5		31		6		10	
Average value	37.80		63.04		55.19		61.70	
Variance	16.50		13.56		20.46		22.10	

Table 3 Five-level Likert item-based questionnaire and students' feedback.

Item	Statement	5	4	3	2	1	Ave.
Q1	I think this course is necessary to setup	15	20	5	0	0	4.250
Q2	This course helps with the understanding of fiber optical communication devices, systems, and related conceptions.	13	25	2	0	0	4.275
Q3	The categorical teaching method helps with my learning in class and improves my ability	16	15	5	2	0	3.975
Q4	The course is more interesting and innovative than traditional teaching class	20	18	2	0	0	4.450
Q5	The course has aroused my interest in further Optics communication learning	12	25	2	1	0	4.200
Q6	The course develops and promotes my further thinking of applying fiber communication theories and concepts to solving practical fiber communication problems	10	10	15	4	1	3.575
Q7	I think the overall flow of the fiber communication course is well-designed	21	15	3	1	0	4.400
Q8	This course does not bring me additional learning pressure	10	18	10	1	1	3.850
Q9	The course has aroused my interest in further learning or research in Fiber Optical Communication	10	11	15	1	3	3.525
Q10	This class helps me with further studying fiber optic communication theories and its applications	10	20	8	1	1	3.900
Q11	I think I can apply one of the fiber optical communication theories or concepts to the practical measurements after carefully thinking	10	14	10	3	3	3.550
Q12	Speaking, I think the course achieves its teaching goal	15	20	5	0	0	4.250

Among the 12 questions, six questions were given an average score of 4-5; six of the questions gave an average score between 3.5 and 4. It shows that only half of the students have a positive evaluation of this course, and they approve of the teaching methods and teaching effects of this course, which has a positive effect on promoting students' theoretical learning, improving students' problem-solving ability, and stimulating students' learning interest. Only question 9 has an average answer

score of 3.525 on a scale of 1-5, which indicates that only a small number of students believe that they will continue to engage in research and technology related to optical fiber communication in the future.

According to the open-ended questions listed in the questionnaire, we collected the reasons why students were unwilling to continue their research and work related to optical communication after studying the course. 15 students said that this course is too abstract, and the lack of a real communication experiment environment to help the learning of theoretical courses, and also affected by the social demand for talents, they are more willing to engage in machine learning-related work. For the reliability of students' feedback in Table 2, we calculated Cronbach's alpha[21]. In terms of reliability, Cronbach's α coefficient must be 0.70 or above, and it is suggested that there are four dividing points for reliability results: extreme reliability (0.90 or above), high reliability (0.70-0.90), medium reliability (0.50-0.70), and low reliability (0.50 or below). Cronbach's alpha coefficient of the questionnaire was 0.935, indicating that the questionnaire had high reliability.

5. Conclusion

The teaching reform based on the cultivation of innovative ability is the inevitable trend of deepening the reform of higher education in our country. This paper takes the course of optical fiber communication as the main body, starting from the concrete teaching practice, and puts forward the view of cultivating students' innovative ability by classification and differentiation. For students who are actively employed, theory and practice are combined in the design of teaching content, current engineering technology development content is introduced into the classroom and some optical devices are displayed in class to stimulate students' learning interest. Meanwhile, corresponding small topics or experiments focusing on cultivating hands-on ability are designed to give full play to students' subjective initiative and innovation. For students who continue their studies, interest-oriented, corresponding research-oriented topics are designed to cultivate students' innovative thinking. At the same time, students can be attracted to participate in teachers' scientific research projects, to realize that scientific research feedbacks teaching and strengthens students' independent learning ability and scientific research accomplishment. In addition, the information network construction of optical fiber communication is convenient for students to make full use of extracurricular time to consolidate knowledge points. A questionnaire was designed to collect feedback from students. The analysis shows that the results of the questionnaire have high reliability. According to the questionnaire, most of the students who participated in this experiment course chose positive among the 12 questionnaires, which indicates that most of the students believe that the classified teaching method of this course is reasonable and the course goal is achieved, which is helpful to cultivate their ability to design and analyze optical communication devices and systems by applying optical theory. It further shows that this teaching method can stimulate students' interest in learning, avoid the traditional boring teaching mode, and further promote the cultivation of students' innovative thinking on the premise of completing the teaching requirements.

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