Journal of Contemporary Educational Research, 2023, Volume 7, Issue 10
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

Study on the Exploration of Open Experimental Teaching Methods

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Abstract: Participating in open experimental teaching is essential in cultivating students' innovative ability and comprehensive quality. Participating in open experimental teaching takes students as the main body, which has a substantial effect on improving students' creative power and total quality, at the same time, it enhances the quality of experimental teaching. Based on the existing problems and shortcomings of traditional experiments in private universities, and through the role, methods, and implementation conditions of participating in open experimental education, this article also proposes a four-stage curriculum system of professional basic cognition, practical skills verification, comprehensive design, and technological innovation, to construct a five-in-one open experimental teaching model of "independent experiment-team collaboration-teacher guidance-science and technology competition-industry-university-research cooperation." Participating in the implementation of open experimental teaching has apparent advantages for students' abilities, the construction of teaching teams, and the development of laboratories.

Keywords: Participation; Open experimental teaching; Method

Online publication: October 19, 2023

1. Introduction

As society continues to develop, the teaching models of colleges and universities are quietly changing while adapting to the needs of the new situation. The 2023 National Education Work Conference proposed to build an educational power as the goal, focusing on comprehensively improving the quality of independent training of talents, accelerating the construction of a high-quality education system, and providing education that satisfies the people. This puts forward new requirements for cultivating talent in colleges and universities and it can boost the production of high-quality talent, which is a crucial indicator to measure the school's level of running. In the teaching system of engineering colleges, the proportion of participants in open experimental teaching is gradually increasing. In the open experimental teaching in which students participate, students are the main body of education, guided by teachers and teamwork to inspire students to continue to explore and discover science. This method changes students' dependence on teachers, enables them to have higher initiative and enthusiasm, and encourages them to understand themselves, adjust, and improve themselves.

2. Positioning of the traditional experimental teaching model

In the traditional curriculum concept, experimental classes are often arranged after the knowledge points of theoretical courses are completed, and practical operations are guided by theoretical knowledge. Practical teaching depends on academic education and is not taken seriously [1]. Nobel laureate Ting Zhaozhong once said when he received the Nobel Prize: "I hope that my receiving the Nobel Prize will improve the Chinese people's understanding of experiments. In the past, Chinese people have been taught since childhood that 'he who uses his brain will govern, and he who uses his strength will be governed.'" Influenced by his viewpoint, people generally do not pay attention to experiments and think that theory is more advanced and more profound than experiment. Everyone feels that learning means learning theory, and it has never been said that learning means learning experiments as well. "I was the first to win a Nobel Prize through my experiments. It is a bonus. I won the prize this time, and I hope that from now on, I can get rid of the old tradition of Chinese people despising experiments and paying too much attention to theory [2]." Experiment is the only criterion for testing truth. Even in today's society, his words are still realistic guidance.

Theoretical teaching is the mainstay, and experimental teaching is supplemented. Practical teaching accounts for very little of the total class hours of the entire course, often only a few class hours. This teaching system has been the teaching model of the country's colleges and universities for many years. Most of the experimental projects are cognitive and verification experiments. Few designs and comprehensive investigations cannot stimulate students' interest in experiments, and students are not enthusiastic about active participation [3]. Regarding experimental course settings, practical courses are attached to theoretical approaches, and testing courses are set up based on academic classes. Students think that the theoretical methods have been learned well, and studying experimental procedures will no longer be necessary. This makes the practical systems tend to be verification-oriented, and students lack innovation and problem-solving skills.

In recent years, under the national teaching reform system, most colleges and universities have begun to emphasize the design and comprehensiveness of experimental teaching. However, because the teaching system is imperfect, it is more of a formality. It does not and cannot affect the actual experimental education. It only satisfies the training of students' practical skills and limits the cultivation of students' innovative skills [4]. Therefore, it is imperative to reform experimental teaching content and teaching methods to cultivate students with practical, problem-solving, and creative skills.

3. Participation in open experimental teaching methods

The best way to learn is to participate in it. "Participation in open experimental teaching" is based on students as the main body and the teacher as the leader. Students participate in the entire experimental process, including the preparation of the experiment, the pre-review of the investigation, the operation of the inquiry, the analysis of the experiment, and the organization of the laboratory. It is no longer a simple model in which "teachers speak and students listen; teachers act and students watch; students act and teachers manage, and students submit reports for evaluation." "Participating in open experimental teaching" can stimulate students' potential abilities and turn passive learning into active learning. Students are the leading operators of the experiment and can make full use of students' teamwork and problem-solving skills during the investigation [5]. In "participation in open experimental teaching," the teacher's leading role focuses on inspiring and guiding students, changing from the traditional "giving them a fish" to the real "teaching them to fish," thus maximizing students' enthusiasm and creativity.

4. Significance of participating in open experimental teaching

The significances of participating in open experimental teaching are as follows.

(1) Improving students' comprehensive quality

In experimental teaching, students are the main subjects. When encountering problems, students must use the knowledge they have learned to quickly analyze and solve the problems, which invisibly stimulates students' potential abilities and improves students' enthusiasm for experiments, it can also further enhance students' interest in investigations. Moreover, participating in open experimental teaching must allow students to take charge of themselves, from the preparation of the inquiry, the pre-review of the experiment, the operation of the investigation to the analysis of the experiment, and at the same time, they must also solve unexpected problems that arise during the experiment. Students' comprehensive quality can be continuously improved through such learning and exercise.

(2) Improving students' scientific research capabilities

Participating in open experimental teaching combines theoretical teaching with practical instruction, enabling students to master the laws and methods of scientific research, and cultivating students' rigorous learning attitude and scientific research spirit. The experiment strengthens the spirit of teamwork and facilitates students' ability to work together to solve problems, and their scientific research and innovation capabilities.

(3) Cultivating students' independent learning abilities

The opening of the laboratory also includes introducing experimental resources such as experimental instruments and equipment. Students can appropriately arrange their work and rest time, use their free time to carry out experimental work in the laboratory, analyze experimental data, and better complete practical tasks in the laboratory. If there is inadequate time in class, students can further research and study in the laboratory. They can produce and debug their competition works. The extracurricular practice venue provided by such a laboratory further improves students' independent learning ability.

(4) Cultivating a team of high-quality practical teachers

While students' abilities are improving, the improvement of experimental teachers' professional level and practical skills cannot be neglected. While enriching their knowledge, experimental teachers should also be able to answer questions raised by the students professionally and accurately, develop experimental projects, and increase comprehensive and designed experiments, guide students to create experimental plans, and develop practical teaching into diversified teaching. To meet the requirements for teachers participating in open experimental education, experimental teachers should continuously strengthen their learning and improve their professional capabilities, thereby establishing a group of high-quality experimental teacher teams.

(5) Improving the utilization rate of laboratory experimental equipment [6]

In traditional experimental teaching, laboratory experimental equipment will only be used when there are practical arrangements. After the experimental class of this semester, the testing equipment will no longer be used during this semester, until there are practical classes next semester, which results in low utilization of experimental equipment and a waste of laboratory resources. Participating in open experimental teaching requires that the laboratory be available 24 hours a day, allowing students to enter the laboratory for study and scientific research at any time, thus significantly improving the utilization of existing experimental equipment. Laboratories will be merged and transformed, single experimental teaching in laboratories will be eliminated, and diversified and comprehensive laboratories will be born. The diversification of laboratories greatly accelerates the construction of laboratories.

5. Conditions for participating in open experimental teaching

Participating in open experimental teaching involves all factors that affect experimental education and the entire experimental teaching process. Participating in public experimental education is a reform of the experimental teaching system.

(1) Changes in the type of experimental projects

Experimental teaching is no longer dependent on theoretical teaching. However, it should have an independent experimental teaching system according to the curriculum and develop experiments of different project types according to students' abilities. The existing categories of experimental projects include demonstration, verification, comprehensive, and designed experiments [7]. These four types of experiments are a process from the outside to the inside, from easy to complex. Existing experiments are written as comprehensive and designed experiments regarding experimental project types at this stage, but they often tend to be demonstration and verification experiments in the teaching process. Demonstration and verification experiments are the lowest level of experiments and cannot achieve the true meaning of experimental teaching. Comprehensive experiments integrate multiple courses, while designed experiments allow students to organize their teams, search for information, and write and verify experimental plans through given valuable topics. Students change from passive to active learning and actively deal with problems when encountering them, cultivating their creative abilities. To implement open experimental teaching, the type of practical projects must first be changed to achieve comprehensive and designed experiments.

(2) Update of experimental equipment

Obsolete experimental equipment and backward functions are a problem that exists in many universities. Even the experimental equipment that has been eliminated is still in use. This makes it challenging to update the practical projects and increase students' enthusiasm. The update of experimental equipment can support scientific research, and the economic benefits of scientific research results affect the improvement and update of testing equipment. There is a mutually reinforcing relationship between the two. Therefore, experimental equipment must keep pace with the times and be updated according to contemporary social development. When experimental equipment is diversified, the number of projects that can be developed will increase, such as incredibly comprehensive and designed experiments, thus expanding students' choice of practical tasks. Students will be more independent and efficient in creating experimental plans and designing the completed program.

(3) Changes in the experimenter's thinking

Nowadays, many university experimental centers are affiliated with various colleges. The essential job of the experimenter is opening and closing the laboratory door and regularly maintaining the testing equipment. Only when the teacher's workload is relatively heavy can he participate in teaching the managed laboratory. For researchers, opening the laboratory increases the burden and may cause resistance. Therefore, it is essential to change the laboratory staff's thinking. Experimenters should open the laboratory independently and complete it as part of their job. The laboratory is not just a place to store experimental equipment but a critical teaching place. Implementing participation in open practical teaching requires experimenters to devote a lot of energy because participation in open experimental teaching is a process rather than a result. Their contribution is not temporary but continuous and consistent. Therefore, it is necessary to change the thinking of the experimenters and increase their enthusiasm. This can be implemented by formulating relevant reward policies, developing new experimental projects to increase the workload, and changing the laboratory staff's

working system to a duty system.

(4) Opening of the laboratory

In order to develop, laboratories must be open, closely connected with society and production departments, and conducting scientific research. For the sustainable development of the laboratory and maximizing its various efficiencies, on the premise of prioritizing meeting the needs of the laboratory's research and development work, the established research platform and resources will be used for industry and open use.

Firstly, laboratory is open to students for sharing. The laboratory is open to all students in the school and multiple disciplines and majors. First- and second-year students mainly train their independent learning and practical skills, while junior and senior students focus on cultivating innovation and scientific research skills. Additionally, laboratory is open to teachers for sharing. Teachers can break the boundaries of colleges (departments) and laboratories, and fully use laboratory conditions for teaching research, scientific research, and technology development so that high-quality resources can be fully shared and efficiently utilized, which is conducive to improving the quality of experimental teaching. The laboratory is also open to the public for sharing. The laboratory fully utilizes its human, material, and technological advantages to be open to society. It carries out activities such as scientific research cooperation, technical services, and personnel training to improve the social and economic benefits of the laboratory.

6. Reform and innovation of participatory open experimental teaching

Traditional experimental teaching is only a means to verify theoretical knowledge and it plays a role in consolidating and deepening theoretical understanding. The practical projects are relatively single, primarily cognitive and verification experiments. Each experimental project is independent of the others, it lacks hierarchy, and does not form a logical and complete system [6,8].

6.1. Division of experimental course system

The participatory open experimental teaching course system can be divided into four stages, including the professional basic cognitive stage, the practical skills verification stage, the comprehensive design stage, and the technological innovation stage. While satisfying basic professional cognition, the breadth and depth of experiments are expanded, thus allowing students to actively participate in investigations and explore experiments in order to cultivate skills and be brave in innovation. Taking the vehicle engineering major in colleges and universities as an example, the detailed division of the participatory experimental teaching course system is shown in **Figure 1**.

(1) Professional basic cognitive stage

For the introductory courses of the vehicle engineering major, teachers fully integrate theoretical teaching with experimental teaching through course experiments, automobile construction internships, metalworking internships, etc., so that students can understand and master the course learning content, their ability to apply knowledge can be cultivated and the cultivation of students' practical skills can be strengthened.

(2) Practical skills verification stage

Training is mainly based on automobile disassembly and assembly internships, automobile repair internships, automobile circuit electronics internships, etc. These internships require students to learn multiple professional courses to integrate knowledge points, allowing them to deepen their

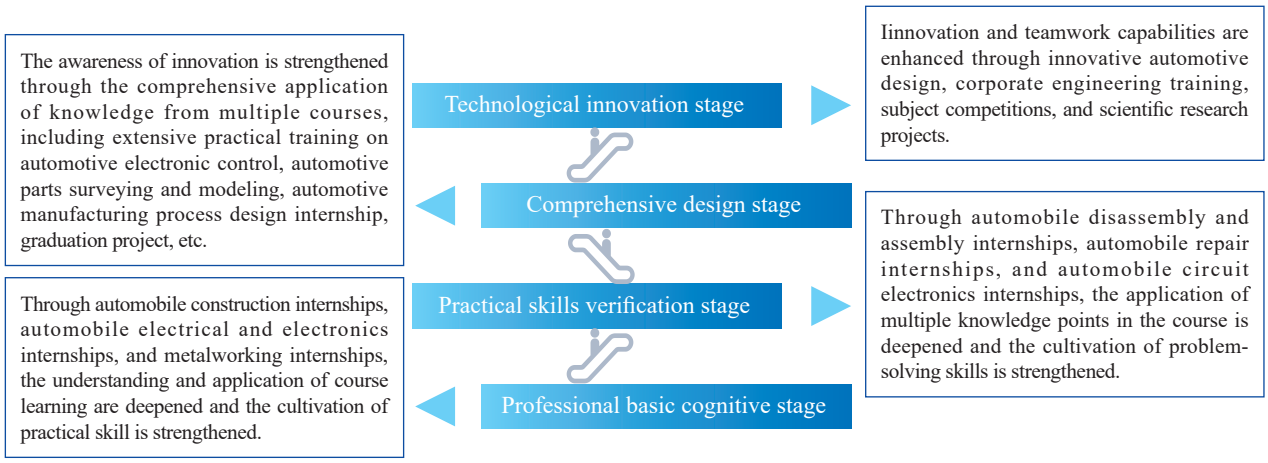

Figure 1. Division of experimental teaching course system

comprehensive understanding and application of the knowledge points they have learned and cultivate students' ability to solve problems when encountering them, thus further developing students' designing and hands-on skills.

(3) Comprehensive design stage

This stage is mainly focusing on comprehensive practical training in automotive electronic control, automotive parts mapping and modeling, automotive manufacturing process design internship, and graduation project (thesis), the project content involves multiple courses and it is carried out through teacher preparation or students' independent design experiments. Comprehensive and designed experimental project analysis, in the process, improves students' complete ability and engineering practice ability, and strengthens students' awareness of innovation.

(4) Technological innovation stage

By focusing on subject competitions, scientific research projects, innovation and entrepreneurship projects, etc., through teacher guidance, existing experimental equipment will be developed to conduct innovative experiments. Students are encouraged to participate in teachers' scientific research projects and enterprise-related projects. They also cultivate students' innovation, entrepreneurship, and teamwork based on improving their engineering practice ability. Participating in open experimental teaching improves students' knowledge structure, promotes innovative and entrepreneurial skills, and improves scientific research capabilities.

Taking experiments related to automobile manual variations as an example, teachers carry out experimental teaching step by step according to the four stages of the experimental course system. **Table 1** shows the experiments and competency goals related to automobile manual variations.

Table 1. Automobile manual variable experiments and competency goals

Experimental teaching course system level	Course	Competency goals
Basic cognitive level	Car structure	To master the structure and principle of manual variable
Practical skills level	Car disassembly and assembly internship	To master the disassembly and assembly steps of manual variable speed controllers and to understand common faults
Comprehensive design level	Automotive computer-aided design (CAD) / computer-aided engineering (CAE), graduation project	To master the design method of manual variable and structural analysis of principal components
Science and technology innovation level	Science and technology competitions, scientific research projects	To master the optimal design and innovative design of manual variables

6.2. Construction of a five-in-one participatory open experimental teaching model

Constructing an excellent experimental teaching model is crucial to the role of experimental teaching in cultivating students. Based on the above four-stage experimental course system, after practical exploration, a five-in-one open experimental teaching model of "independent experiment-team collaboration-teacher guidance-science and technology competition-industry-university-research cooperation" was constructed, as shown in **Figure 2**.

Figure 2. Five-in-one experimental teaching model

(1) Independent experiment

Participating in open experimental teaching allows students to gain full learning autonomy. Students can independently choose practical projects, design plans, implement experimental processes, analyze experimental data, and obtain experimental results according to their empirical focus and interests. The original beneficial course arrangement will no longer restrict the students. They will use their spare time to conduct more profound experimental research, consolidate existing knowledge, expand new knowledge, broaden personal horizons, and test ideas. At the same time, students use online resources to study relevant videos, search for relevant literature, and prepare for experiments in advance to avoid errors during the investigation and draw conclusions quickly. It can also transform passive learning into active exploration and stimulate students' potential, it is conducive to students' independent learning and to cultivating students' hands-on practical skill and analytical problem-solving skill.

(2) Team collaboration

Students form teams of 3–4 people each, select a team leader, and participate in open experimental teaching as a team. There are three benefits to carrying out group collaboration experimental education. Firstly, it can exercise and improve students' awareness and spirit of teamwork, and at the same time, they can explore personal strengths and better complete experimental projects. The

second benefit is to deepen the understanding of existing knowledge points, expand new knowledge, broaden individual thinking, and improve the ability to analyze and solve problems. The third benefit is to improve the utilization rate of experimental equipment. In short, when encountering crucial and complex issues, team members can discuss with each other, use their expertise, and work together to complete the experimental project. Completing the experimental task can exercise students' engineering practice ability, improve their problem-solving skill, and cultivate their sense of teamwork.

(3) Teacher guidance

Participating in open experimental teaching changes the instructor's role from leading to guiding. In the past, before experimenting, the teacher prepared the experimental site and testing equipment. The teacher explained the empirical content and demonstrated the experimental operation method through physical objects during the experiment. The students followed or directly recorded the experimental data. Now, by letting the students read the investigation and the project guide by themselves, they can formulate practical plans and implement experimental projects. Teachers no longer lead them and only provide specific guidance when students require assistance. This requires teachers to have theoretical knowledge and rich practical engineering experience in experimental teaching projects. To combine theory and practice, they can guide practice through theoretical knowledge and apply it to practice. Therefore, instructors should have a higher professional level. They can introduce intermediate and senior technical personnel from vehicle and parts design and production enterprises and hire them as part-time instructors. Each can draw on their strengths through coordination and cooperation with theoretical course teachers, thus enriching the team of "double-qualified" experimental teachers.

(4) Science and technology competition

Science and technology competitions are conducive to stimulating students' enthusiasm for innovation, training students' innovative thinking, enhancing students' creative awareness, and thereby improving students' practical skills [9]. Science and technology competitions pay more attention to practice than professional subject learning. By participating in open experimental teaching, students can significantly improve their level of participation in science and technology competitions and win awards. The opening of the laboratory can provide a higher platform for scientific and technological competitions, allowing students to study independently, exercise subject abilities, and improve professional skills. Through the conceptual design, product design, animation design, and physical production of the entries, students have gone through the entire process of the object in the idea stage, implementation stage, production stage, and assembly and debugging step, giving full play to students' creativity and initiative, and providing students with practical skills that lay the foundation for future use [10].

(5) Industry-university-research cooperation

Deepening the integration of industry and education and conducting industry-university-research cooperation are inevitable trends in developing private higher education. From the economic perspective of enterprises, carrying out industry-university-research cooperation improves social production efficiency while continuously updating technology and talent reserves to create more value. From the standpoint of colleges and universities education, it can enhance students' comprehensive abilities and provide more talent to the country [11].

Building majors according to industrial needs and reforming teaching content according to technological development are new requirements for enterprises to have knowledge and skills systems for

engineering application talents in the new era. Participating in open experimental teaching integrates the advantages of school, industry, and enterprise resources, carries out school-enterprise cooperation, and promotes in-depth integration between industry, academia, and research through rich and diverse experimental equipment and a high-quality teaching team. As the cradle of talent training, colleges and universities deliver many graduates to companies every year. Through school-enterprise cooperation, students can learn about corporate jobs in advance, and colleges and universities can implement targeted training of students according to the needs of companies, thereby achieving mutual benefit and win-win results between schools and enterprises [12].

7. Conclusion

Participating in open experimental teaching is an innovative model of traditional experimental education. Based on the characteristics of colleges and universities and the shortcomings of existing training methods, this paper expounds on the processes, functions, and teaching conditions of participating in open experimental teaching. On this basis, it puts forward the four-stage division of the experimental course system, and the construction of a five-in-one participatory open experimental teaching model not only improves students' observed level, independent learning ability, and problem-solving skill but also comprehensively enhances students' comprehensive practical skill, and scientific research and innovation capabilities play a significant role in improving the teaching quality and teaching effect of experimental teaching in colleges and universities. We should also continue to explore and summarize open experimental teaching model, and it is imperative to participate in the reform of open experimental education, which will provide more high-quality talents for the country.

Funding

Research on Open Experimental Teaching Model of Automotive Engineering by Wuhan Huaxia Institute of Technology (Project number: 2210)

Disclosure statement

The author declares no conflict of interest.

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