Research on Teaching Mode Innovative Reform of College Physics Under the New Engineering Background

Xiaomin Zhang[1,*], Chuan Liu[2], Yao Chen[1], Mengli Pang[1]

[1]School of Artificial Intelligence, Wuhan Technology and Business University, Wuhan, Hubei, 430065, China
[2]School of Software Engineering, Hubei Science and Technology College, Wuhan, Hubei, 430074, China

*zhangxiaomin@wtbu.edu.cn

Abstract. Under the background of new engineering, the college physics course reform adheres to the "student-oriented, moral and human" educational philosophy as well as the principle of education according to the ability to teach. The high-quality applied talents should be provided as the direction of cultivation in order to support local economic and social development. To solve the pain points into college physics teaching, this paper integrates teaching contents and builds the curriculum. The creation of a "hierarchical task, three-dimensional and six-segment" innovative teaching model, deepening specialized civics construction and the establishment of a multi-dimensional assessment system are also done, which leads students toward independent, collaborative, and inquiry-based learning, achieves the "three-in-one" learning objectives of process and method, affective attitude and values, knowledge and skills, and carrying out the fundamental task of fostering morals and educating students. Exploration, innovation and reform of college physics teaching in new engineering majors can ensure the effective realisation of the teaching objectives of the course and enhance students' learning efficiency.

Keywords: new engineering; college physics; modular teaching; teaching mode reform

1 Introduction

Responding to the challenges of the new round of scientific and technological revolution as well as the industrial change, the country actively promotes the construction of new engineering [1]. The concept of new engineering requires that intersection and integration, coordination and sharing, inheritance and innovation are the main ways to cultivate comprehensive, applied and innovative talents with profound specialisations [2]. In 2016, the ministry of education put forward the concept of building "new engineering disciplines", with the goal of cultivating innovative engineering talents who can adapt to and lead new technologies and industries. In 2017, the ministry of education conducted several seminars on the development strategy of engineering education

Y. Kuang et al. (eds.), *Proceedings of the 2024 5th International Conference on Education, Knowledge and Information Management (ICEKIM 2024)*, Atlantis Highlights in Computer Sciences 22,
https://doi.org/10.2991/978-94-6463-502-7_10

in colleges, and successively put forward the "Fudan Consensus", "Tianta Actions" and "Beijing Guidelines", thus determining the specific direction of the construction of new engineering disciplines, and forming a consensus that "the strengths of engineering disciplines should play a major role in engineering science and technology innovation and industrial innovation" [3]. In 2018, the ministry of national education released the implementation plan for accelerating the modernisation of education (2018-2022), which further put forward new-era requirements for the quality of talent cultivation and the ability of colleges to serve economic and social development [4].

The college physics course, which is based on the fundamentals of physics, has an undervalued role in developing students' thinking skills and scientific literacy, correctly understanding objective things and forming a materialistic world view [5]. On analysing the abilities and elements needed by job groups in the AI industry, and using this as a basis for combining the basic requirements of the majors of the school of artificial intelligence in our university, there are the following four pain point problems in the teaching of traditional college physics:

- The course material is abstract, the system is uninteresting, students show little interest in studying, and it is out of step with professional knowledge.
- Teacher-centred, outdated teaching resources and techniques and low student participation.
- Emphasis on knowledge transfer, neglecting value shaping, imperfect function of the curriculum in educating students.
- Single way of evaluating the curriculum, focusing on results rather than process.

Therefore, under the background of new engineering disciplines, in order to meet the students' professional needs and learning interests, to ensure the effective achievement of the teaching objectives of the courses, and to stimulate the diversified development of the students, it is imperative to reform the college physics course content, teaching mode, course civics, assessment and evaluation.

2 Pain Point Problems in Traditional College Physics Courses

College physics, as a basic general course compulsory for new engineering majors, mainly cultivates engineering students' scientific way of thinking and methods of researching problems, equips students with a certain degree of scientific literacy and innovation ability, and lays the foundation for the development of the breadth and depth of their future professional fields [6]. College physics, in turn, provides a theoretical foundation for the subsequent study of relevant specialised courses. However, the current situation of college physics teaching in local universities is not in line with the requirements of the new engineering discipline. There are four pain point problems in teaching traditional college physics courses as follows:

First, the course material is abstract, the system is uninteresting, students show little interest in studying. For scientific and engineering majors, the college physics is a necessary public general studies course [7]. However, the course requirements may range in terms of hours and focus depending on the major. Specifically, first-year students at private universities have varying fundamental and cognitive abilities, and the professional core courses that follow for various majors emphasize distinct aspects of the need for physics understanding and knowledge. For example, microelectronics majors focus on quantum mechanics, thermodynamics and statistical physics, IoT and communications majors focus on optics and electromagnetism. Thus, it is imperative that the practical concerns of various majors be resolved and that discipline-based and professional core courses be effectively integrated.

Second, teacher-centred, outdated teaching resources and techniques and low student participation. Undergraduates of private universities, with relatively weak physics fundamentals, are accustomed to passive learning, focusing on exercises as well as exams and neglecting practical operations. Students emphasis on theoretical results over process derivation in course work. Therefore, how to mobilise students' motivation to learn and make use of the existing teaching resources to fully address the traditional physics classroom teaching atmosphere is an urgent problem to be solved.

Third, emphasis on knowledge transfer, neglecting value shaping, imperfect function of the curriculum in educating students. Teachers in traditional physics courses focus on the transmission of knowledge, but the emotional values of students do not guide in-depth, and the effect of the course is not significant parenting [8-11]. In addition, the course material is abstract, dull, and hard to understand. It is also disconnected from reality and does not correspond with the course's stated topic and the development of the times. Therefore, how to introduce the elements of civics and politics into the college physics course in a silent manner is an urgent problem to be solved.

Finally, the course assesment is single. Too much emphasis on selection, elimination and screening; too much differentiation between the good and the bad, but neglecting the motivational role of evaluation; too much emphasis on students' academic performance and outcome evaluation, but neglecting the overall evaluation of students. At the same time, the evaluation mode is rigid, over-emphasis on test papers, focusing on knowledge but not ability, results but not process; focusing on the teacher's teaching but neglecting the students' learning. The curriculum focuses on quantitative evaluation and neglects qualitative evaluation through other flexible and free means. Therefore, how to improve students' knowledge, ability and emotion in multiple ways is an urgent issue that needs to be addressed through assessment methods.

3 Teaching Reform Measures of College Physics Under the Background of New Engineering

Aiming at the long-existing pain point problems in teaching, this paper provides teaching reform and innovation measures for college physics courses.

3.1 Creation of a "Hierarchical Task, Three-Dimensional and Six-Segment" Innovative Teaching Model

Under the background of the new engineering disciplines, the integration of college physics teaching content and the construction of a new system of college physics courses are based on the principles of compression of classics, enhancement of modernity, and broadening of engineering applications in accordance with the orientation of the professions. Modularised teaching is done in the course, which is based on the developmental characteristics and needs of different professions. Under the modular teaching paradigm, each module's depth of instruction is modified to meet the requirements of various majors. The teaching syllabus consists of force, heat, electricity, magnetism, and light modules that are chosen separately by the professional course leader in order to prevent a gap between the content of college physics courses and the requirements for professional expertise.

The modular teaching reform of the college physics is shown in Fig.1. According to the actual needs of our university, the physics group has actively explored and practised the modular teaching reform of the college physics course, which is divided into two semesters, with two main modules and eight sub-modules. The basic module and the application module are the two main modules. The basic module is divided into two sub-modules, namely mechanics and electromagnetism, which will be slightly adjusted according to the teaching difficulties and content focus of different majors in the course of specific lectures. The application module is divided into six sub-modules, namely vibration, fluctuation, optics, thermodynamics and statistical physics, quantum mechanics, college physics experiment. Among them, the college physics experiment module is a compulsory module for the whole university, and all colleges can choose the experimental projects according to the actual needs. The rest of the modules will be combined with two modules chosen by each college of the university based on the principle of professional knowledge demand.

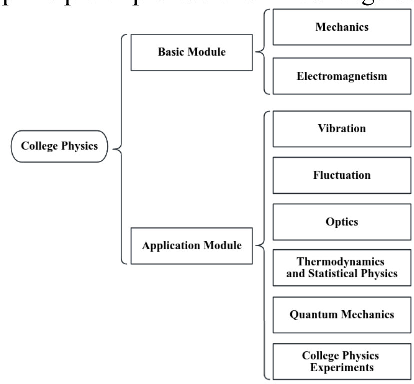

Fig. 1. The modular teaching reform of the college physics

At the same time, a "student-centred" innovative teaching model of "hierarchical tasks, three-dimensions and six-segments" was constructed. In accordance with the requirements of the core qualities of the discipline of physics, graded tasks are set up to form a hierarchical task chain, which not only mobilises students' motivation to construct knowledge on their own, but also progresses step by step to meet the developmental needs of students at different levels. By means of task level refinement, the objective is to attain a strong foundation, enhance abilities, and create unique designs. By using the "three-dimensions and six-segments" teaching design, reconfiguring the teaching links, creating supplementary teaching materials, the curriculum of the new engineering and the physics teaching content are deeply integrated.

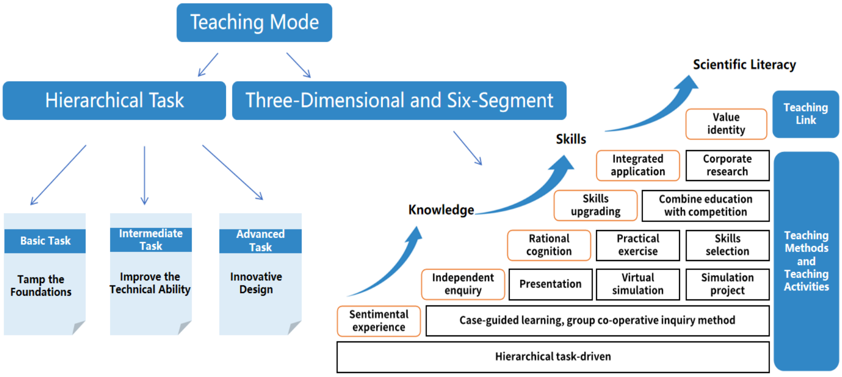

Fig. 2. "Hierarchical task, three-dimensional and six-segment" innovative teaching model

The "hierarchical task, three-dimensional and six-segment" innovative teaching model is shown in Fig.2. In the "three-dimensional and six-segment" teaching practice process, the six stages are shown in the following:

1) Stage 1-Sentimental experience: Students complete pre-study assignments through self-study micro-learning before class and graded tasks to complete relatively simple knowledge, so that students can have initial sentimental experience of the teaching content. Simultaneously, before to the lesson, the instructor compiles a summary in order to comprehend the typical challenges faced by the students.

2) Stage 2-Independent enquiry: Teachers communicate the challenging issues that students are reflecting to the class through the case introduction. At the same time, students change their position as teachers and organise group reports to develop students' self-learning, expression and thinking skills.

3) Stage 3-Rational cognition: The theoretical content is transformed into reality, for example, students use Matlab or other simulation software to simulate the three-dimensional diagram of the electric dipole equipotential line. This will cultivate students' hands-on practical ability and lay the foundation for their subsequent scientific research studies.

4) Stage 4-Skills upgrading: Students choose the topic for practical exercises, after the group review, the teacher scores, which can cultivate the best talent into the best.

5) Stage 5-Integrated application: Teachers provide customized guidance to exceptional students and emphasis the significance of the course ideology.

6) Stage 6-Value identity: Cultivate students' sense of acquisition and identification with the profession through major competitions such as corporate studies and physics innovation.

3.2 SPOC+BOPPPS Blended Teaching

In the traditional teaching scenario of college physics courses, it is only "teachers speak, students listen", students' participation and motivation to learn is not high, the theoretical part of the course can not be effectively absorbed and understood. Thus, resulting in a poor grasp of professional knowledge, which can not be effectively guided by the practice, and can not ensure the effectiveness of the course.

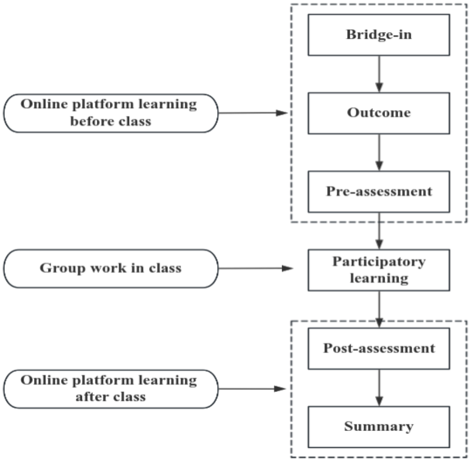

Fig. 3. The chart of BOPPPS blended teaching

To achieve the learning effect of being "task driven and problem oriented", online and offline blended teaching is adopted, and the learning task list is utilized to develop the entire process independent learning framework for students before, during, and after class. A hybrid teaching model based on SPOC+BOPPPS can effectively improve teaching quality. The chart of BOPPS blended teaching is shown in Fig.3.

The following is an example of the teaching link analysis's law of conservation of angular momentum for a rigid body rotating on a fixed axis.

- Pre-assessment: The lesson's pre-assessment gives the teacher the opportunity to monitor the progress of each student. Through self-study microteaching, the instructor provides learning resources, and students gain a basic comprehension of the law of conservation of angular momentum of a rigid body spinning on a fixed axis. In order to assess the students' grasp of moment and moment of inertia, the teacher assigns two questions via learning pass. During the official session, the teacher goes over and responds to the answers to the two exercises.
- Outcome: The knowledge objectives is to understand the law of conservation of angular momentum for fixed axis rotation, and learn to use conservation of angular momentum to solve practical problems. The capability objectives is to develop students' ability to use their knowledge of the law of turning, compare the newton's second law in physical thinking and calculate practical problems in physics. The Quality objectives is to enable students to establish the pattern of development of things, thus building the ability to identify problems and solve them.
- Bridge-in: This session mainly introduces the learning content through phenomena in life, pictures and videos. The content of this section is introduced

by a video, playing a clip of Chinese competitors participating in the Winter Olympics figure skating, so that students can think about what makes the speed of rotation speed up when the arms are closed? When the arms are open, the rotation speed slows down?

- Political elements: Students will be inspired with a sense of national pride and enhance their cultural confidence through teaching the story of Shen Xue/Zhao Hongbo winning China's first gold medal in the Winter Olympics, which is full of positive energy.
- Participatory learning: This session focuses on student-centredness and guides students to engage with the content of the class. By reviewing the previous discussion on the angular momentum of a mass, students are guided to deduce the angular momentum of a rigid body against an axis; by analogy, newton's second law is compared with the law of constant-axis rotation of a rigid body to help students understand and differentiate; by creating scenarios, posing questions, and discussing in groups, students are guided to derive the law of conservation of angular momentum of a rigid body.
- Summary: This part is to guide students to summarise what they have learnt in this lesson about the angular momentum of a rigid body against an axis, the angular momentum theorem of a rigid body rotating on a fixed axis, and the law of conservation of angular momentum; to guide students to use the habit of mind of learning physical knowledge by analogy; and to understand the cognitive method of going from a simple system of plasmas to a complex system of rigid bodies.
- Post-assessment: This session is conducted in order to grasp the students' mastery of this lesson. Teachers release homework and expand learning resources with the help of the teaching platform, students explore independently, consolidate and expand their knowledge, and communicate with the help of Xuexitong to answer questions and solve problems.

3.3 Exploration of Curriculum Ideological and Political Education into College Physics

1) Revise the syllabus with ideological and political elements: To carry out course ideology in college physics teaching, the first step is to revise the existing syllabus, start from the purpose and mission of the course, take the knowledge point as the medium, take the formation of scientific knowledge as the basis, take the thinking ability with the characteristics of the discipline as the goal, extract the elements of moral education from the logic of science to the discipline, and look for the combination point of ideology education and university physics. Secondly, in terms of the basic objectives of course teaching, it is necessary to integrate the background of the emergence of the laws of physics, the process and method of understanding and the unremitting efforts made by human beings into the teaching, to cultivate students' pursuit of truth, to explore the spirit of science, to learn the methods of understanding, analysing and solving problems, and to form a materialistic worldview.

2) Enhance teachers' awareness and competence in political thinking: Improve the teachers' ability to educate students, to ensure the implementation of the ideological and political education course from the teachers. Raise awareness of the importance and necessity, so as to achieve full participation in ideological and political education.

3) Discuss collectively and Explore the ideological and political elements of college physics: Integrate professional knowledge with courses, deeply explore the timing and methods of ideological and political education in the class, carefully organize classroom teaching, ensure the effectiveness of ideological and political education in courses, and improve the quality of talent cultivation.

4) Choose appropriate teaching methods and modes to carry out ideological and political education courses: Emphasize the diversification of ideological and political teaching methods in the curriculum. The popular teaching methods in current teaching include lectures, discussions, analogies, experiments, reading guidance. These teaching methods are very helpful in teaching course concepts, stimulating students' interest in learning, and cultivating their creative thinking.

5) Integrate ideological and political content into course assessment: Based on the characteristics of college physics, ideological and political elements are fully integrated into the knowledge, abilities, and qualities covered by process assessment and result assessment, stimulating students' learning enthusiasm and motivation, and improving teaching quality. Based on the actual situation of students, select a certain proportion of questions from the question bank that cover ideological and political elements for the final exam, and effectively combine theme discussions, quizzes, questionnaires, group tasks, practical operations and other forms of college physics ideological and political assessment to diversify the exam format and play a subtle and nurturing role.

3.4 Establishment of a Diversified Assessment and Evaluation System

Build a three-dimensional curriculum assessment system, with a whole process, multi-dimensional, and multi subject process assessment and final assessment. Based on the analysis of learning process data, quantify the behavioral performance during the learning process into indicators, dynamically improve teaching strategies, provide timely feedback to students, thereby stimulating their learning enthusiasm and motivation, enhancing their confidence, improving the quality of course teaching, and motivating students to develop comprehensively. The chart of three-dimensional evaluation system is shown in Fig.4.

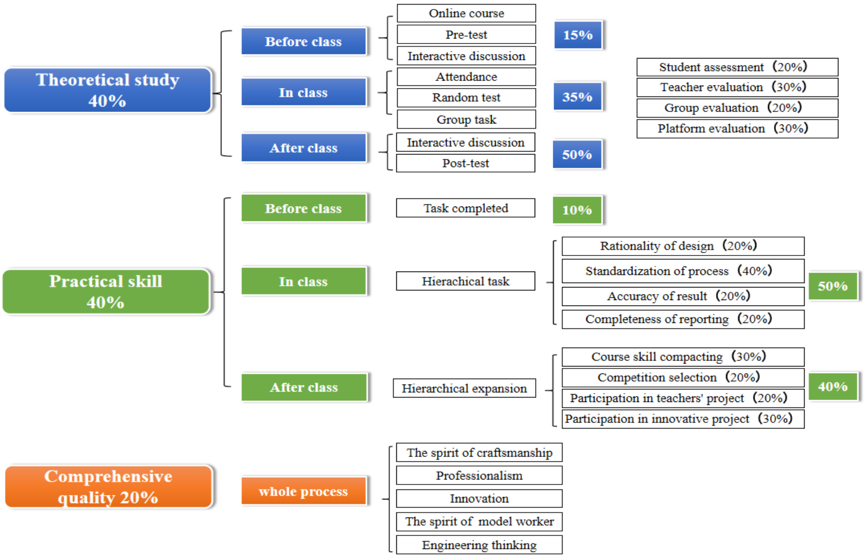

Fig. 4. Three-dimensional evaluation system

4 Analysis of the Effectiveness of Teaching Reform

After implementing teaching reform, 78.1% of students believe that combining modular and hierarchical teaching in college physics majors can stimulate students' interest in learning. Most students believe that using inquiry based teaching methods such as videos and pictures to create real-life physics scenarios can vividly and easily explain dull and difficult physics knowledge. The statistics chart of student score based on the Learning App is shown in Fig.5. According to the scores of 59 students from the class of 2022 majoring in microelectronics science and engineering at Wuhan technology and business university, the score basically follows a normal distribution, with 18.6% of students scoring lower 0-39 points due to less participation in online platform discussions and casual answering of questions; 32 students scored above 60 points, accounting for 54.2% of the total number of students. The reason for the overall low score of students is that they are given points based on their first answer to a question. A considerable number of students, guided by the teacher and self-learning, have replied to questions multiple times without receiving extra points. In response to this situation, students will be given extra points for each reply in the future, in order to encourage them to search for information, learn independently, and gradually cultivate their habit of self-directed learning.

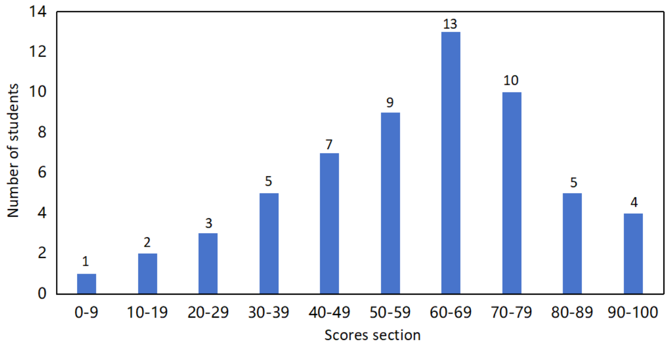

Fig. 5. The statistics chart of student score based on the learning App

The achievement degree was calculated based on the actual academic performance of 228 students in the 2022 Artificial Intelligence College of Wuhan technology and business university in the compulsory module of college physics experiments. The results are shown in Table 1.

- Objective 1: Master the basic knowledge of physics experiments, commonly used experimental operation techniques, usage methods of basic instruments, and measurement methods of basic physical quantities.
- Objective 2: Analyze and process experimental data, and obtain reasonable and effective conclusions through information synthesis. Improve the ability to identify, analyze, and solve problems.

From Table 1, it can be seen that both course objective 1 and course objective 2 have achieved the preset 0.7 course objective achievement standard. In addition, compared to course objective 2, the achievement of course objective 1 is better, indicating that students have completed online platform learning, experimental operations, and data measurement better. However, the writing of experimental reports, especially experimental data processing and result analysis, still needs further improvement.

Table 1. Achievement of Objectives in Compulsory Module College Physics Experiment

Course Objectives	**Preview before class**		**Performance in class**		**Experiment report**		**Objective Achievement value**
	Scores	***Achieved value***	***Scores***	***Achieved value***	***Scores***	***Achieved value***	
Objective 1	20	0.91	30	0.815	—	—	0.853
Objective 2	—	—	—	—	50	0.731	0.731

Meanwhile, this article evaluates the achievement of course objectives by investigating the satisfaction of students with their own course objectives through a questionnaire survey. The questionnaire mainly involves the evaluation of the achievement of the course objectives. Each course objective is divided into five levels, corresponding to the achievement of the course objectives from high to low, which are very satisfied, satisfied, basically satisfied, dissatisfied, and very dissatisfied. The assigned scores are 1 point, 0.75 point, 0.5 point, 0.25 point, and 0 point, respectively. Based on the questionnaire statistics and assigned scores for each course objective, calculate the weighted achievement value of that course objective. The expected achievement value of the questionnaire survey is set to 0.8. A questionnaire survey was conducted on 228 students from the Artificial Intelligence College of Wuhan technology and business university in 2022, and the results are shown in Table 2. It can be seen that the achievement of both course objectives is higher than the expected value of the achievement survey questionnaire. This indicates that students themselves recognize the teaching objectives of the college physics experiment.

Table 2. Questionnaire survey results on the achievement of course objectives

Course Objectives	Very satisfied (1 point)	Satisfied (0.75 point)	Basically satisfied (0.5 point)	Dissatisfied (0.25 point)	Very dissatisfied (0 point)	Achieved value
Objective 1	159	50	18	1	0	0.902
Objective 2	148	56	21	2	1	0.882

5 Conclusions

Under the background of the construction of new engineering courses, in response to the pain points and problems in current college physics course teaching, the teaching of traditional engineering majors in college physics courses seems outdated. In order to meet the requirements of cultivating application-oriented talents in the new engineering field, combined with the construction goals of the new engineering major, this paper focuses on the teaching philosophy, content, mode, and evaluation methods of college physics, promoting the reform of college physics teaching, improving the quality of college physics teaching, and laying a solid foundation for the cultivation of new engineering talents.

Acknowledgment

This work was supported by the Teaching Reform Research Project of Wuhan Technology and Business University (Project No. 2023Z01 "Research and Practice on the Teaching Reform of College Physics under the Background of New Engineering").

References

1. M. Ye, H. Kong, and W. Zhang, “New engineering: from concept to action,” Research on Higher Engineering Education, vol. 01, pp. 24–31, 2018.

2. D. Hua, "The connotation and action of new engineering construction," Research on Higher Engineering Education, vol. 03, pp. 1–6, 2017.
3. T. Shang, X. Yang, "Reflection and practice on the reform of college physics curriculum under the OBE concept," Education and Teaching Forum, vol. 10, pp. 83–86, 2022.
4. C. Pang, L. Wang, "An Analysis of Attempts to Reform the Teaching Content and Methods of College Physics Courses," Curriculum Education Research, vol. 38, pp. 189–190, 2019.
5. Y. Dai, L. Bai, M. Zhang and Y. Zhang, "Exploration and practice of "curriculum ideology and politics" in college physics teaching," College Education, vol. 8, pp. 84-86, 2019.
6. X. Wang, "Reform measures and practice of physics curriculum teaching in new engineering universities," Journal of Chuzhou University, vol. 20, pp. 120–122, 2018.
7. X. Jin, Y. Wang, X. Mao, C. Ning and T. Chen, "Some thoughts on ideological and political construction of college physics course", Physics and Engineering, vol. 32(04), pp. 74-83, 2022.
8. X. Zhang, F. Qu, M. Qiu and Y. Pi, "Research and discussion on mixed teaching mode of college physics course," Heilongjiang Science, vol. 11(09), pp. 44-45, 2020.
9. W. Zhang, D. Xu, L. Duan and J. Zhang, "Research on the effect and influencing factors of blended learning of collge physics," Physics and Engineering, vol. 31(6), pp. 163-168, 2021.
10. Y. He, "Thoughts on developing ideological and political education in college physics," Educational Informatization Forum, pp. 58-59, 2021.
11. H. Mu, X. Pan, J. Ta and J. Xin, "How to implement ideological and political education in college physics teaching," The Guide of Science & Education, vol. 21, pp. 126-128, 2021.