ISSN: 2424-8460(O)
2251-2608(P)

Original Research Article

PBL experimental teaching of operating systems empowered by intelligent technology

Long Zhao[1], **Yuanyuan Wang**[2]
[1] *Department of Computer Science, Inner Mongolia Honder College of Arts and Sciences, Hohhot, Inner Mongolia, 010070, China*
[2] *Big Data Application and Information Monitoring Center of Hohhot Public Security Bureau, Hohhot, Inner Mongolia, 010070, China*

Abstract: Against the backdrop of digital transformation, the experimental teaching of operating systems is confronted with problems such as the disconnection between traditional models and industrial demands, insufficient student participation, and a single evaluation method. This paper proposes a PBL experimental teaching model empowered by intelligent technology. By integrating three major platforms, namely Tencent Digital Human (dynamic scene construction), VMware Virtualization (hierarchical experimental environment), and Feishu -DeepSeek (intelligent evaluation and feedback), a teaching closed loop of "life-like scene introduction - hierarchical experiment implementation - intelligent evaluation and feedback" is constructed. This model is based on the theoretical framework of "one core, dual drivers, three stages, and four dimensions", with the cultivation of students' systematic abilities as the core. It deeply integrates PBL problem-driven approaches with intelligent technology empowerment, providing a replicable practical paradigm for the teaching reform of operating system courses and having reference value for promoting the digital transformation and upgrading of engineering education.
Keywords: intelligent technology empowerment; operating system PBL mode; experimental teaching reform; digital teaching closed loop

1. Introduction

Against the backdrop of the deep integration of digital transformation and the new round of technological revolution, higher education is undergoing profound changes centered on intelligence and personalization. The rapid development of intelligent technologies such as cloud computing and artificial intelligence has not only reshaped the ecosystem of the information technology industry, but also put forward higher requirements for the systematic capabilities and innovative qualities of computer professionals in the context of new engineering disciplines. As a core course that integrates the knowledge system of computer software and hardware, "Operating System" is a key carrier for cultivating students' systematic thinking, engineering practice and ability to solve complex problems. Its teaching quality is directly related to the core competitiveness of talent cultivation. However, the traditional experimental teaching of this course has long been confronted with structural predicaments: On the one hand, the teaching content mostly remains at the verification of classic theories such as process management and memory allocation, which is seriously disconnected from the cutting-edge practices in the industry such as container orchestration and performance tuning; On the other hand, in the teaching process, there is a widespread problem of students' fear of difficulties and insufficient participation due to the abstraction of core principles and the complexity of concurrent debugging. Especially for the student group with relatively weak professional foundations, cognitive gaps are more likely to occur. Furthermore, the teaching evaluation methods are monotonous, overly relying on experimental reports and final written tests, making it difficult to conduct a scientific and comprehensive assessment of students' system design capabilities, engineering thinking, and innovation processes. To solve the above-mentioned problems, scholars at home and abroad have made beneficial explorations, such as building simulation environments based on virtual laboratories or using online platforms to support project-based learning (PBL). These studies have provided

ISSN: 2424-8460(O)
2251-2608(P)

important references for curriculum reform. However, the current practices are still insufficient in the deep integration and application level of intelligent technologies. Especially in terms of using intelligent technologies to dynamically construct teaching scenarios, precisely diagnose the learning process and provide personalized feedback, there is still room for in-depth exploration. In view of this, this paper aims to deeply couple the PBL teaching model with intelligent technology and construct a new experimental teaching paradigm for "Operating System" supported by multiple platforms such as Tencent Digital Human, VMware virtualization, and Feishu -DeepSeek intelligent evaluation. By designing a teaching closed loop of "life-like scenario introduction - hierarchical experiment implementation - intelligent evaluation feedback", a leap in ability from knowledge verification to innovative design is achieved, with the aim of effectively enhancing teaching effectiveness and providing a replicable and scalable practical solution for the intelligent teaching reform of similar courses.

2. Theoretical framework design of the "intelligent technology - PBL" integrated teaching model

The "Intelligent Technology - PBL" integrated teaching model constructed in this paper is based on constructivism and personalized learning theories, aiming to systematically reshape the experimental teaching of operating systems through the deep coupling of intelligent technology and problem-oriented learning. The core of this model lies in achieving a fundamental transformation of intelligent technology from an auxiliary tool to a teaching enabler, thereby building a teaching ecosystem centered on students' ability development and self-optimizing.

2.1. Core concept: Achieve a paradigm shift from tool assistance to teaching empowerment

The core concept of this model is to promote the role elevation of intelligent technology in teaching, making it the creator of teaching scenarios, the scaffold of cognitive processes, and the enabler of personalized learning. Tencent's digital human platform, through dynamic visualization technology, transforms abstract principles such as process scheduling and memory management into vivid life scenarios like "cafeteria window scheduling", effectively reducing students' cognitive load. The VMware virtualization environment provides a secure and trial-and-error experimental sandbox, supporting students to actively construct knowledge in practice. Feishu -DeepSeek intelligent assessment system, through real-time data analysis of the learning process, plays the role of a "cognitive coach", providing each student with precise feedback and resource push, achieving a transformation from unified teaching to personalized customization.

2.2. Framework construction: Form a collaborative model of "one core, dual drivers, three stages, and four dimensions"

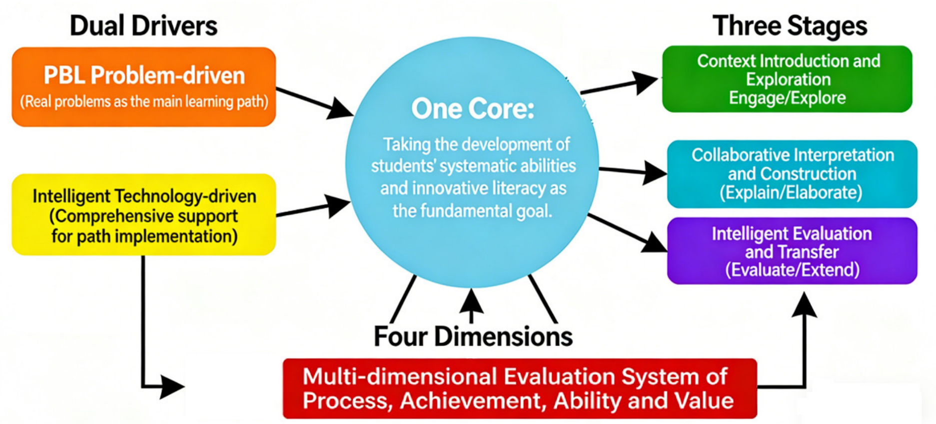

Figure 1. Shows the framework diagram of the "One core · Dual drive · Three order · Four Dimensions" theoretical framework.

This paper designs a theoretical framework of "one core, dual drivers, three stages, and four dimensions" to clearly expound the collaborative relationship among various elements. The "One Core" refers to taking the all-round development of students' systematic abilities and innovative qualities as the fundamental goal. The "dual drive" clearly defines PBL problem-driven and intelligent technology-

ISSN: 2424-8460(O)
2251-2608(P)

driven as the two major engines for the operation of the model. Among them, PBL provides a learning path centered on real problems, while intelligent technology offers all-round support for the implementation of this path. The "Third stage" integrates the 5E inquiry-based teaching model into the PBL process and plans out a progressive teaching phase of "Engage/Explore", "Explain/Elaborate", and "Evaluate/Extend". The "Four Dimensions" refer to the establishment of a multi-dimensional evaluation system covering process, outcome, ability and value, aiming to conduct a comprehensive assessment of learning outcomes. The overall structure of this framework is shown in **Figure 1**.

2.3. Integration logic: Achieve deep synergy among technology, teaching methods and evaluation

The underlying logic of this model lies in achieving a deep synergy and closed-loop optimization among technology, Pedagogy and evaluation. The PBL teaching method establishes the learning goals and paths. Intelligent technology provides a powerful engine and support platform for the smoothness of this path, while the data-driven evaluation system is like a navigation system, monitoring the learning status in real time and providing feedback. Specifically, in the "three-stage" teaching process, PBL guides the direction of inquiry, the technical platform empowers the depth and breadth of inquiry, and intelligent evaluation runs through the entire process. The data it generates is not only used to assess students but also optimizes teachers' teaching decisions and the precise push of resources in reverse. This synergy effect together constitutes a dynamic, adaptive and student-centered teaching organism, and the operation mechanism of its evaluation system is shown in **Figure 2**.

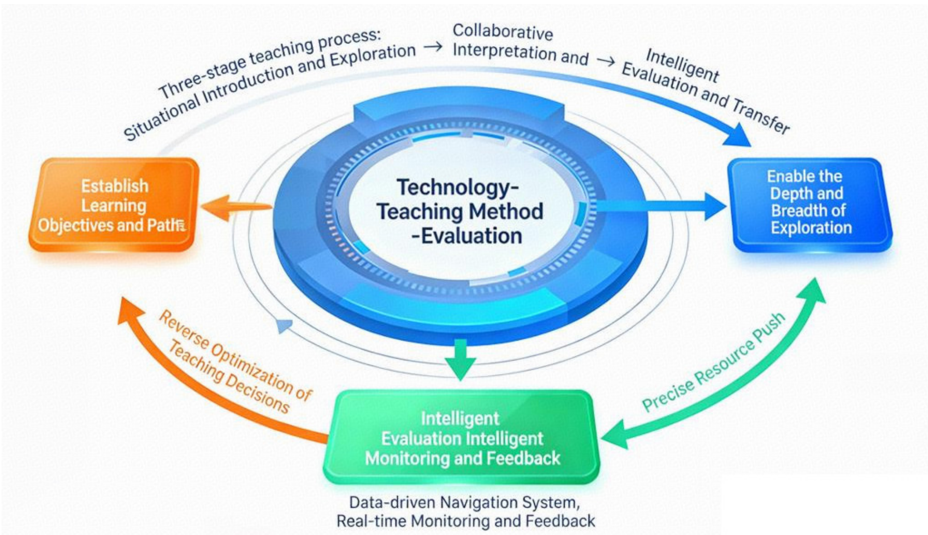

Figure 2. Shows the deep synergy and closed-loop diagram of technology, teaching methods and evaluation.

3. Teaching practice: The implementation path of PBL teaching empowered by intelligent technology

This chapter will elaborate in detail on the specific implementation path of the PBL teaching model empowered by intelligent technology in the operating system experiment course. By integrating Tencent digital humans, VMware virtualization platform and Feishu - DeepSeek intelligent assessment system, a full-chain digital teaching closed loop covering before, during and after class is constructed, achieving precise adaptation of teaching content, intelligent reconstruction of teaching processes and dynamic optimization of teaching evaluation.

3.1. Reconstruction of teaching content empowered by intelligent technologies

At the level of teaching content design, this paper realizes the deep integration of theoretical knowledge and practical scenarios through intelligent technology. Tencent's digital human platform takes on the core function of creating teaching scenarios. Teachers utilize its dynamic visualization capabilities to transform real-life cases such as "cafeteria window scheduling" and "parking lot management" into concrete teaching scenarios, helping students intuitively understand abstract concepts like process scheduling and deadlock prevention. For instance, when explaining process synchronization, digital humans can simulate the phenomenon of resource competition in a multi-threaded concurrent scenario, enabling students to naturally form an understanding of the demand for semaphores by observing the animation effects. The VMware virtualization environment supports the implementation of the hierarchical experimental system. The platform provides a three-level experimental task package of "observation - modification - design": The basic layer experiments guide students to use preset commands to observe the changes in system status; The progressive experiment requires students to modify the code to fix memory leaks or logical errors. The elevated layer experiment encourages students to independently design simple scheduling algorithms. This hierarchical design not only meets the entry-level needs of students with weak foundations but also provides an innovative space for those with outstanding abilities.

3.2. Classroom teaching process reengineering driven by intelligent technology

At the teaching process level, intelligent technology is deeply integrated into every link of PBL teaching, forming a virtuous cycle of "problem guidance - technical support - data feedback". Before class, students preview the experimental background through digital human animations and submit their preview questions on the Feishu platform. Teachers accurately identify teaching difficulties and dynamically adjust the focus of their lessons based on the heat map of students' learning conditions generated by the system. During the class stage, students conducted collaborative research in groups in the VMware sandbox. For instance, they triggered file concurrent conflicts by modifying the number of threads and then attempted to solve the problem by adding mutex locks. Teachers monitor the code submission status of each group in real time through the Feishu - DeepSeek system, provide concentrated explanations for common problems, and offer targeted guidance for individual issues. After class, the platform automatically evaluates the experimental reports and generates personalized improvement suggestions, such as pushing relevant micro-lesson resources for incorrect use of semaphores. Meanwhile, the system visually presents students' growth trajectories in dimensions such as system programming and debugging capabilities through ability radar charts, providing data support for subsequent learning planning. The specific process is as follows:

3.2.1. Pre-class stage: Rely on an intelligent platform to introduce scenarios and analyze students' learning situations

In the pre-class stage, the core objective of teaching implementation is to stimulate students' interest and accurately diagnose their prior knowledge. Teachers first use the Tencent Digital human platform to generate dynamic teaching videos with life-like cases such as "cafeteria window scheduling" and "parking lot management" as the background, transforming abstract concepts like process scheduling and semaphores into intuitive and visual animated scenarios, thereby effectively attracting students to Engage in the problem situations. Students watch videos through the Learning Pass platform and conduct independent exploration on the core issues preset by teachers, initially forming their own solutions or raising questions. Subsequently, students selected their preview questions and difficulties in the shared table on the Feishu -DeepSeek platform. The system automatically classifies and conducts a preliminary analysis of these issues, generating a visual student situation dashboard. By analyzing this board, teachers can accurately grasp the common confusions and individual differences of all students in the class, providing a scientific basis for differentiated teaching and key point explanation in class, and achieving the transformation from "preparing lessons based on experience" to "preparing lessons based on data".

3.2.2. In-class stage: Conduct collaborative exploration and real-time feedback in a virtual environment

The in-class stage is a crucial link for students to internalize knowledge and build their abilities. The teacher first provides a concise explanation of the core principles and experimental tasks based on the students' learning situation data, highlighting the key points of knowledge. Subsequently, students worked in groups of 4 to 5 to conduct collaborative research in the standardized Ubuntu experimental sandbox built by VMware. Each group, centering on the questions raised before class, put into practice the hierarchical experimental tasks of "observation - modification - design", for instance, from observing the changes in process state to modifying the code to fix deadlocks, and then attempting to design simple scheduling algorithms, thereby elaborating in depth on their understanding of the principles. During this process, teachers go around providing guidance and offer concentrated guidance on common problems. The Feishu -DeepSeek system plays the role of an "intelligent teaching assistant". Students submit their experimental logs and phased codes in real time. The system can perform immediate compilation and

ISSN: 2424-8460(O)
2251-2608(P)

logical analysis, quickly identify common problems such as semaphores usage errors and memory leaks, and provide targeted prompt information and links to related learning resources instead of directly giving answers. This guides students to think independently and adjust, greatly enhancing the efficiency and depth of exploration.

3.2.3. After-school stage: Promote knowledge consolidation and ability transfer through intelligent evaluation

The after-school stage focuses on the evaluation of learning outcomes and the transfer and expansion of knowledge. Students are required to submit a complete experiment report and code to the Feishu - DeepSeek platform. The system uses intelligent algorithms to automatically review reports, not only checking the correctness of the code, but also evaluating its logical structure, annotation norms and innovation points, and generating personalized evaluation reports containing detailed improvement suggestions. Meanwhile, the system will integrate the performance data of students throughout the PBL process, generate personal ability radar charts, and visually display their ability levels in dimensions such as command operation, synchronization mechanism, and system design. Students revise their reports and consolidate their knowledge based on the feedback, and conduct online group reviews in the discussion area of the platform, sharing their experiences in problem-solving. Teachers, based on the class-wide learning data and evaluation reports provided by the platform, conduct teaching reflections and dynamically adjust subsequent teaching strategies. Finally, the platform will push extended challenge tasks that combine with the cutting-edge of the industry to students who have spare capacity for learning, encouraging students to transfer and apply the knowledge they have learned to more complex situations, achieving a leap from knowledge mastery to ability innovation.

3.3. Reconstruction of the data-driven teaching evaluation system

At the level of teaching evaluation, intelligent technology has achieved a transformation from result-oriented evaluation to process-oriented and value-added evaluation. The Feishu - DeepSeek system builds a comprehensive evaluation model through multi-dimensional data collection: The process evaluation module records behavioral data such as students' previewing duration and classroom interaction frequency; The capability evaluation module quantifies programming capabilities through indicators such as static code analysis and test case pass rates. The value evaluation module assesses team collaboration and innovation literacy through dimensions such as group mutual evaluation and innovation points in experimental reports. The final visual assessment report generated by the system not only includes score conclusions but also reveals learning weaknesses through patterns such as error distribution graphs and ability trend lines, enabling students to clearly understand the direction for improvement. Teachers can also dynamically adjust teaching strategies based on the overall class data, such as adding special training modules for common memory management issues, to continuously optimize the teaching closed loop.

4. Teaching effectiveness analysis: Model validation based on empirical data

To scientifically verify the effectiveness of the "PBL experimental Teaching model empowered by intelligent Technology", this paper adopts a hybrid research method, combining quantitative data with qualitative materials to conduct a multi-dimensional empirical analysis of the teaching effect.

4.1. Research design

This article takes the students of the 2024 grade majoring in Computer Science and Technology at Inner Mongolia Hongde College of Science who have been promoted from junior college to undergraduate as the practical objects and conducts a teaching practice lasting for one semester (18 weeks). Two parallel classes (with a total of 124 students) were selected as the research objects. Among them, the experimental class (62 students) implemented the PBL experimental teaching mode empowered by intelligent technology, while the control class (62 students) adopted the traditional teaching mode of "theoretical lecture + verification experiment". The research adopted a mixed research method and conducted a before-and-after comparative analysis of students' knowledge mastery and ability improvement through questionnaire surveys. Gain a deep understanding of students' learning experiences through semi-structured interview methods; Record students' experimental operation behaviors through the observation method; The quantitative indicators such as course grades and project completion rates were analyzed through experimental comparison methods to ensure the scientificity and credibility of the research conclusions.

4.2. Quantitative analysis

By comparing the final exam results, project completion degree and ability questionnaire data of the experimental class and the control class, the quantitative analysis results show that the teaching effect of the new model is remarkable. The final exam results show that the average score of the experimental class was 78.6 points, with a pass rate of 93.5% and an excellent rate of 27.4%. All indicators were significantly higher than those of the control class (with an average score of 65.3 points, a pass rate of 75.8%, and an excellent rate of 11.3%). In terms of project completion, the proportion of students in the experimental class who completed comprehensive projects such as "Multi-threaded File Synchronous Access" and "Simple Process Scheduler Design" with high quality reached 89.3%, significantly better than the 62.1% of the control class. The comparison of the pre - and post-tests of the ability questionnaire shows that the improvement rates of students in the experimental class in dimensions such as system programming ability, problem-solving ability and autonomous learning willingness all exceed 30%, fully verifying the effectiveness of the teaching mode reform.

4.3. Qualitative analysis

Through stratified interviews with 20 students, rich qualitative feedback was collected, further confirming the results of the quantitative analysis. Students generally reflect that "Tencent Digital humans have transformed the abstract process state changes into queuing animations at cafeteria Windows, significantly lowering the threshold for understanding." Another student said, "The Feishu -DeepSeek system can point out in real time the usage errors of semaphores in the code and push relevant case videos, which is more efficient than waiting for teachers to correct them." These feedbacks indicate that the application of intelligent technologies has significantly enhanced the intuitiveness of learning and the timeliness of feedback. Furthermore, the student mentioned that "the complete process from observing phenomena to proposing hypotheses and then to experimental verification has helped form a systematic problem-solving approach", indicating that the PBL teaching model has effectively cultivated students' engineering thinking ability.

4.4. Exhibition of achievements

Teaching reform has effectively promoted the improvement of students' innovative practical abilities and achieved fruitful practical results. Students from the experimental class, relying on the knowledge they have learned in the courses, won one first prize and two third prizes in the 2024 Computer Application Competition for College Students in the Five Provinces (Municipalities and Autonomous Regions) of North China and Hong Kong, Macao and Taiwan in the undergraduate group. Their award-winning projects, "Health Card Recorder" and "Smart Internet of Things New Agricultural Assistant", both deeply integrated the core knowledge of the courses such as process scheduling and concurrent control. In addition, many students have applied for and obtained three computer software Copyrights, fully demonstrating their ability to transform theoretical knowledge into practical achievements. These competitions and innovative achievements not only demonstrate the effectiveness of teaching reforms but also lay a solid foundation for students' subsequent career development, achieving the educational goal of "promoting learning through competitions and fostering innovation through application".

This paper verifies the remarkable effectiveness of intelligent technology empowering the PBL model in the experimental teaching of operating systems through teaching practice. However, several problems that need to be optimized urgently have also been exposed in the practice process, providing a clear direction for improvement and development space for future teaching reform. Firstly, in terms of the group collaboration mechanism, although the stratified experimental design takes into account the differences among students, some students with weak foundations still have insufficient participation and overly rely on the core members within the group, reflecting that the "heterogeneous grouping" strategy still needs to refine role division and strengthen process supervision in its specific implementation. Secondly, at the level of intelligent technology application, some students have developed a dependence on the immediate feedback from platforms like DeepSeek, preferring to directly adopt system prompts rather

ISSN: 2424-8460(O)
2251-2608(P)

than delving into the root causes of errors. This suggests that we need to strike a better balance between technical convenience and the cultivation of thinking depth. For instance, by designing a step-by-step prompt strategy or adding an error analysis report section, students can be guided to think independently. In addition, in terms of the cutting-edge nature of teaching content, although life-related cases have effectively lowered the learning threshold, the depth of connection with industry-leading technologies such as cloud-native and distributed systems is still insufficient. In the future, it is necessary to further deepen the integration of industry and education and introduce real project cases from enterprises to enhance the industrial adaptability of the courses. Looking ahead, this article will continue to deepen teaching reform from three dimensions: First, deepen the empowerment level of intelligent technology. It is planned to develop a more forward-looking intelligent tutoring system based on large model technology to achieve personalized dynamic recommendations of learning paths and adaptive adjustments of teaching strategies, further enhancing the accuracy and scientific nature of teaching. Secondly, promote the open sharing of teaching resources, and strive to build a cross-school collaborative digital teaching resource library. Open up the effective practical cases, stratified experimental project packages and intelligent assessment tools of this model to more sister institutions, so as to expand the scope of beneficiaries and the radiation influence of teaching reform. Thirdly, a long-term follow-up study will be carried out. It is planned to conduct a long-term follow-up on the career development of the students participating in the experiment after graduation. By analyzing key indicators such as their job competence and technological innovation ability, a more comprehensive assessment will be made of the long-term value and deep impact of the teaching reform. Through the above efforts, we expect to continuously improve this teaching model and make greater contributions to cultivating high-quality computer professionals who can adapt to the demands of digital transformation.

Fundings

Inner Mongolia Honder College of Arts and Sciences institutional re-search project "Application Research on Digital Experimental Teaching of 'Operating Systems' under the PBL Model" (HD2024034), and Inner Mongolia Autonomous Region Educational Science Research '14th Five-Year Plan' project "Research on the Application of Digital Experimental Teaching for University Computer Science Majors under the PBL Model in the Context of Digital Empowerment" (NGJGH2024090).

About the author

Long Zhao (1987.01–), male, Hohhot, Inner Mongolia; Master's candidate; Lecturer at Inner Mongolia Honder College of Arts and Sciences, majoring in computer education.

Yuanyuan Wang (1980.04–), female, Hohhot, Inner Mongolia, Master's degree, Police Officer at Big Data Application and Information Monitoring Center of Hohhot Public Security Bureau.

References

[1] Yuan Y. A Study of Artificial Intelligence-Driven Change in Higher Education in the Age of Digital Intelligence[J]. Contemporary Education & Teaching Research, 2024, 5(3).

[2] Inoue M, Tsunoda K, Nagahara Y, et al. Digital Transformation of Higher Education[J]. Journal of JSEE, 2022.

[3] Gkrimpizi T, Peristeras V, Magnisalis I. Classification of Barriers to Digital Transformation in Higher Education Institutions: Systematic Literature Review[J]. Education Sciences, 2023, 13(7).

[4] Zhang Jianxun, Wu Zhifeng, Shi Lianshuan. Construction of Computer-related Majors in Local Universities Based on Industry Colleges[J]. Research in Higher Engineering Education, 2023(01): 85-91.

[5] Yun Yue, Dai Huan, Zhang Yupei, et al. A Survey on Personalized Learning Path Recommendation [J]. Journal of Software, 2022, 33(12): 4590-4615.

[6] Xie Danyan, Ren Xiangmin. Exploration and Practice of Teaching Model Reform for Computer Courses Based on the "Three Abilities Orientation" [J]. Software Guide, 2023, 22(06): 114-118.

[7] Wang Ying. Exploration of the PBL+5E Innovative Teaching Model in College Fundamentals of Computer Applications Instruction [J]. Information & Computer (Theoretical Edition). 2024, 36(19): 215-217.