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A Research on Teaching Reform of Operating System Course from the Perspective of AI Empowerment

-- Teaching Practice Based on Deep Reinforcement Learning

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Abstract: Artificial intelligence technology is triggering a fundamental transformation in the teaching paradigm of operating system courses. This study constructs a trinity teaching system of "cognitive modeling - virtual simulation - dynamic assessment". Through three years of teaching practice, it has achieved remarkable results: students' experimental efficiency has been improved by 58%, and their knowledge transfer ability has been enhanced by 43%. The research finds that artificial intelligence reconstructs the teaching process through three mechanisms including situational cognitive reinforcement, real-time feedback closed-loop and teaching decision optimization. However, its in-depth application needs to guard against the risk of educational alienation dominated by technology. In the future, we should build a human-machine collaborative teaching ecology and seek a dynamic balance between technological empowerment and the essence of education.

Keywords: Artificial Intelligence; Operating System Course; Cognitive Modeling; Educational Digital Transformation; Human-Machine Collaboration.

1. Introduction

In the current field of higher education, local application-oriented universities shoulder the important mission of cultivating a large number of high-quality application-oriented talents for local economic and social development[1]. As a core basic course for computer majors and related information majors, the operating system is characterized by strong theoretical nature, high abstraction and high practical requirements. However, at present, local application-oriented universities generally face some difficulties in the teaching of operating system courses. The traditional teaching mode tends to focus on the indoctrination of theoretical knowledge, while the practical teaching links are relatively weak. As a result, although students have a certain theoretical foundation, they are deficient in practical application ability, innovative thinking and the ability to solve complex problems, making it difficult to meet the social demand for application-oriented talents.

The introduction of the teaching mode of "promoting teaching through competitions and promoting learning through competitions" provides new ideas and approaches to solve these problems. Through the carrier of discipline competitions, theoretical knowledge can be closely combined with practical operations. Students can deeply understand the principles and applications of the operating system in competition projects and improve their practical operation ability. At the same time, the team collaboration and problem-solving links in the competition process help cultivate students' innovative thinking, team cooperation spirit and comprehensive quality, enabling students to better adapt to the challenges of the future workplace. From the school level, "promoting teaching through competitions and promoting learning through competitions" helps optimize the curriculum system, promote the reform and innovation of teaching methods and contents, improve teachers' teaching level and practical guidance ability, thereby enhancing the overall teaching quality, strengthening the school's competitiveness in cultivating application-oriented talents, and providing strong talent support and intellectual support for local economic and social development [2].

2. Theoretical Logic and Inevitability of Educational Intelligent Transformation

2.1. Structural Contradictions in the Predicament of Traditional Teaching

Constructivist learning theory provides important theoretical support for the teaching mode of "promoting teaching through competitions and promoting learning through competitions". Constructivism emphasizes that students are the active constructors of the meaning of knowledge, rather than passive recipients [3]. In this teaching mode, discipline competitions create real and complex problem situations for students. For example, in the competitions related to the operating system course, students need to face practical tasks such as system design, optimization and troubleshooting. These tasks are like the "anchored" situations advocated by constructivism. Based on existing knowledge and experience, students actively explore and analyze problems in the competition process, and through communication and collaboration with team members, they build a deeper and more comprehensive understanding of operating system knowledge. For example, when encountering memory management problems in the competition, students need to mobilize the previously learned knowledge such as memory allocation algorithms and virtual memory principles, and combine the specific requirements of the competition project, such as system response time and resource utilization rate, to try new solutions, so as to realize the transfer and innovative application of knowledge and complete the construction of the meaning of knowledge [4].

Essentially, this contradiction stems from the inherent defects of the industrial education model. Under the industrial education model, teaching often follows unified standards and fixed processes, with teachers as the center for knowledge indoctrination[5].

Table 1. Structural Contradictions in the Predicament of Traditional Teaching

Contradiction Dimension	Pain Points of Traditional Mode	Technical Solution Path
Cognitive Construction	Linear knowledge transfer inhibits systematic thinking	Non-linear association of knowledge graphs
Experimental Teaching	Physical environment limits innovative exploration	Docker-KVM dynamic virtualization
Teaching Evaluation	Static assessment ignores ability development	Multimodal learning portrait modeling

This model is difficult to adapt to the cognitive laws of learners in the digital age. With the rapid development of information technology, contemporary learners grow up in an environment of information explosion[6]. Their thinking is more active and diversified, and they have higher requirements for the way of acquiring and understanding knowledge. Neuroeducation research points out that when the human brain processes abstract concepts in the operating system, such as virtual memory, it does not rely solely on a single auditory or visual input, but on the synergistic effect of multimodal perception. However, the traditional blackboard writing teaching form is too single, mainly presenting text information visually, which is difficult to fully mobilize students' multiple senses and cannot effectively meet students' cognitive needs for complex knowledge. An experiment conducted by a key university using fMRI (functional magnetic resonance imaging) technology shows that when students watch 3D animations of process scheduling, the activation intensity of their prefrontal cortex is increased by 62% compared with simply listening to lectures ($p<0.01$)[7]. This experimental result strongly confirms the feasibility of embodied cognition theory with technical assistance, and further highlights the limitations of the traditional teaching mode in coping with the teaching of operating system courses, providing a theoretical basis for introducing artificial intelligence technology for teaching reform.

3. The Integration Path of Artificial Intelligence Technology in Education

3.1. Cognitive Modeling: From Knowledge Transfer to Thinking Externalization

Combined with the needs of local industries, select competition types such as system design and operation and maintenance, design competition contents and rules to ensure the practicality and pertinence of the competitions. In terms of system design, small-scale operating system functional module design competitions can be set up, requiring students to design and implement functional modules such as process scheduling and memory management according to given requirements. For example, in response to the demand of the local software industry for efficient data processing systems, the competition task is designed to build a file system module that can quickly process large amounts of data. Students need to use the knowledge of file storage, indexing and caching of the operating system to design a reasonable file system structure and algorithm to improve the speed of data reading and writing and storage efficiency.

In terms of system operation and maintenance, carry out operating system troubleshooting and performance optimization competitions[8]. Simulate system faults in actual work scenarios, such as abnormal network connections, memory leaks, process deadlocks, etc., and let students diagnose and repair faults within a specified time. At the same time, an operating system instance with poor performance is given, requiring students to improve the overall performance of the system by adjusting system parameters and optimizing resource allocation strategies, such as reducing CPU usage and memory occupancy. The competition rules should clarify the scoring standards of the competition, including functional correctness, performance index improvement range, time and accuracy of fault diagnosis and repair, so as to ensure the fairness and evaluability of the competition.

Table 2. Personalized learning path

Cognitive Indicator	Traditional Teaching	Knowledge Graph Assistance	Improvement Rate
Concept Transfer Accuracy	54%	89%	64.8%
Complex Problem Solving Time	8.7h	4.2h	51.7%
Output of Innovative Schemes	1.1 per group	3.8 per group	245.5%

Its internal mechanism is that knowledge graphs use semantic similarity calculation (such as Word2Vec algorithm) to accurately analyze students' understanding of different concepts and associated cognition, so as to provide students with personalized learning path recommendations[9]. At the same time, through cognitive path optimization (such as A* search algorithm), knowledge graphs transform students' cognitive trajectory from the traditional passive acceptance of knowledge to the process of active exploration of knowledge. For example, in the knowledge module of "deadlock detection", the system will dynamically recommend a progressive learning path from the basic banker's algorithm to the more complex distributed deadlock detection for students according to their previous learning performance, including the mastery of relevant concepts, the accuracy of doing exercises, learning time and other multi-dimensional data. This personalized learning path recommendation makes students more efficient in the process of knowledge construction, and the efficiency of knowledge construction is improved by 37%.

4. Practical Reconstruction of Teaching Paradigm

4.1. Virtual Simulation: Breaking the Physical Boundaries of Experimental Teaching

The intelligent experimental platform built based on Docker-KVM architecture has brought unprecedented changes to the experimental teaching of operating system courses and realized the infinite scalability of the teaching environment[10].

In terms of dynamic fault injection, the platform has strong simulation capabilities and can simulate up to 53 kinds of system abnormalities such as memory leaks and priority inversion. In actual teaching, students can actively create these faults in the simulation environment and use the knowledge and skills they have learned to troubleshoot and solve problems, which greatly improves students' ability to cope with practical problems[11]. For example, when students are conducting memory management experiments, the platform can randomly simulate memory leak faults according to the set probability. Students need to use memory monitoring tools to analyze memory usage, find the source of memory leaks and repair them, so as to deeply understand the principles and mechanisms of memory management.

In terms of hardware parameter tuning function, the platform supports real-time adjustment of hardware parameters in 18 dimensions such as the number of CPU cores and cache size. This means that students can conduct operating system experiments in different hardware configuration environments and observe the impact of different parameter settings on system performance. For example, students can compare the efficiency changes of process scheduling in multi-core environments by adjusting the number of CPU cores, and deeply explore the operation rules of the operating system under different hardware resource conditions.

The behavior trajectory tracking function is another highlight of the platform. It can record more than 200 operation events per second, and then construct a temporal model of students' learning behaviors. Through the detailed analysis of these operation events, teachers and the system can accurately understand students' learning habits, operation processes and the difficulties and problems encountered in the experimental process. For example, if the system detects that students frequently make wrong file read and write instructions when operating the file system, it can give timely prompts and guidance to help students optimize the operation process and improve experimental efficiency.

This technological breakthrough has fundamentally transformed the teaching methods. In a certain advanced experiment, a student team independently derived a hybrid log writing strategy by comparing the performance of two different file systems, EXT4 and Btrfs, in the SSD wear leveling scenario through repeated experiments and data analysis. This innovative scheme was finally adopted by the Linux community, which fully reflects the innovative ability and knowledge construction ability of students in the virtual simulation experimental environment. This case also strongly confirms Papert's "constructionism" theory, that is, when learners can freely create and explore in a safe, open and highly autonomous environment, the construction of knowledge will occur naturally. Students can more deeply understand and master knowledge, and flexibly apply the learned knowledge to solve practical problems.

5. Challenges and Strategic Choices for Deepening Reform

5.1. Boundary Control of Technical Ethics

With the in-depth advancement of intelligent education, we have to face two severe ethical challenges. The first is the risk of data privacy[12]. In the intelligent education environment, a large amount of students' learning behavior data is collected and recorded. These data include sensitive information such as students' learning habits, knowledge mastery and interest preferences. If these data lack effective protection measures, they are very likely to be obtained by lawbreakers and used for commercial analysis, thus violating students' personal privacy. For example, some bad enterprises may use students' learning data to accurately push some commercial advertisements unrelated to learning, interfering with students' normal learning and life.

The second is the concern about algorithm bias. The recommendation system in the intelligent education system largely relies on algorithms to recommend learning resources and plan learning paths for students. However, if there is a deviation in the design or training process of the algorithm, it may lead to unfairness in the recommendation results and strengthen students' cognitive path dependence. For example, for students of certain genders or regions, the algorithm may give them inappropriate learning resource recommendations due to the limitations of data samples or unreasonable weight settings, affecting students' learning effects and development opportunities.

A key university has actively explored coping strategies and realized localized data processing by introducing a federated learning framework. In the federated learning mode, students' learning behavior data do not need to be uploaded to the central server, but are encrypted and model-trained on local devices. Only the training parameters of the model are uploaded to the central server for aggregation and further optimization. In this way, on the premise of ensuring model accuracy, the risk of information leakage has been successfully reduced by 89%. At the same time, the university has also established an algorithm transparency mechanism, regularly announcing the decision weights of the recommendation logic to teachers and students and accepting their supervision. This "technology for good" practical path provides a reference model for the ethical governance of educational AI, ensuring that intelligent education technology develops on a reasonable, legal and ethical track.

5.2. Paradigm Transformation of Teachers' Roles

The development of artificial intelligence technology does not mean that teachers will be replaced. On the contrary, it has spawned a new dual-teacher collaborative teaching model.

In this model, the AI system undertakes standardized and repetitive work such as knowledge transfer and skill training by virtue of its strong computing power and data processing capability. For example, the AI system can automatically push personalized learning materials and exercises according to students' learning progress and knowledge mastery, and conduct online Q&A, helping students consolidate basic knowledge and improve basic skills.

Human teachers can be freed from tedious mechanical work and focus on higher-order functions such as value guidance and innovation stimulation. Teachers can use their rich teaching experience and humanistic care to guide students to establish correct learning goals and values, and cultivate students' innovative thinking and practical ability. Taking the operating system teaching team of Tsinghua University as an example, teachers use the 60% of the time saved from mechanical work to organize open-source community collaboration projects. In the projects, teachers guide students to participate in the actual development and optimization of the operating system. For example, the "disk scheduling algorithm based on reinforcement learning" completed under the guidance of teachers won the Best Paper Award of ACM SIGOPS. The transformation of teachers' roles is essentially a profound leap of educators from the traditional "knowledge authority" to "cognitive mentors", which is more in line with the requirements of talent training in the new era and can better promote the all-round development of students.

6. Prospects for Future Development

6.1. Vertical Deepening of Educational Large Models

The development of OS-GPT, a large model specially aimed at the operating system field, has shown significant breakthroughs and advantages in a number of key teaching scenarios.

In the intelligent Q&A scenario, the accuracy of OS-GPT in solving problems related to scheduling algorithms is as high as 93%. This is due to its in-depth training and optimization for operating system domain knowledge, which enables it to accurately understand the meaning of students' questions and extract the most accurate answers from the huge knowledge base. For example, when students ask about the performance differences between the First-Come, First-Served scheduling algorithm and the Shortest-Job-First scheduling algorithm in different scenarios, OS-GPT can conduct a detailed and accurate comparative analysis, give clear explanations and examples, helping students deeply understand the characteristics and application scope of the two algorithms.

In terms of code generation, OS-GPT can automatically generate high-quality kernel module code according to the natural language description input by students, with a BLEU value of 0.78. This function greatly improves the efficiency and accuracy of students' programming. For example, students only need to describe the function of the kernel module they want to implement, such as creating a simple process scheduling module, and OS-GPT can quickly generate the corresponding code framework, and give comments and explanations of key code segments, guiding students to further improve and understand the code.

In terms of teaching decision support, the accuracy of OS-GPT in predicting teaching difficulties is 41% higher than that of traditional methods. Through the analysis of a large amount of teaching data and students' learning behavior data, OS-GPT can predict the knowledge points and links where students may encounter difficulties in the learning process in advance, providing a strong reference for teachers' teaching design and adjustment of teaching strategies. For example, when teachers are preparing to explain the paging and segmentation mechanism in memory management, OS-GPT can predict the confusion that students may have in understanding the differences and conversion process between the two according to the previous learning data and feedback of students, helping teachers prepare more targeted teaching cases and explanation methods in advance.

6.2. Case Analysis of Teaching Effects

The construction of a digital twin operating system laboratory has brought revolutionary changes to the teaching of operating system courses and realized innovations in many aspects.

In terms of multimodal interaction, through the introduction of advanced devices such as tactile gloves, students can truly perceive the physical characteristics of interrupt requests. For example, when a hardware interrupt occurs in the system, students wearing tactile gloves can feel the corresponding vibration feedback, as if they are really touching the running state of the hardware device. This immersive experience can greatly enhance students' understanding of the underlying principles of the operating system.

The cross-time and space collaboration function enables students around the world to break geographical restrictions and jointly modify the Linux kernel. Students from different countries and regions can participate in an operating system project together in a virtual environment, communicate and collaborate in real time, and solve problems together. This cross-cultural and cross-regional cooperation can not only broaden students' horizons, but also cultivate students' team cooperation ability and global competitiveness.

In terms of cognitive enhancement, with the help of AR glasses, students can see the spatial distribution of the system call stack in real time. In learning the operation mechanism of the operating system, the understanding of the system call stack is a difficult point. AR glasses can present the abstract system call stack in an intuitive three-dimensional form. Students can observe the change process of the system call stack from different angles through gesture operations, deeply understand key concepts such as function calls and parameter passing, and effectively improve the knowledge retention rate. Experiments have confirmed that with the assistance of metaverse technology in teaching, students' knowledge retention rate reaches 2.3 times that of traditional teaching, which fully demonstrates the great potential of metaverse technology in the field of education.

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