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AI-Empowered Reconstruction of Teaching Ecology: A Practical Study on the "One Body, Four Dimensions" Framework in Object-Oriented Programming

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Abstract: Object-Oriented Programming is a core foundational course for computer science majors in universities, serving as a key link between introductory programming and advanced engineering practice. Under traditional teaching models, this course faces four major pain points: de-contextualized teaching content, homogenized teaching methods, black-boxed teaching environment, and one-sided evaluation system, making it difficult to meet students' individualized development needs and the industry's demand for high-quality programming talents. Based on two years of classroom teaching practice, this study proposes a "One Body, Four Dimensions" AI-empowered framework, which takes the "teaching ecology collaborative community" as its core and integrates AI technology into four dimensions: content, method, environment, and evaluation, achieving full-process collaborative empowerment. Practical results show that the understanding rate of core knowledge points increased from 60% to 92%, code accuracy increased from 70% to 95%, after-class exercise completion rate increased from 75% to 98%, and 96% of students believed that AI-empowered teaching helped them understand abstract concepts. The framework effectively reconstructs the teaching ecology and has the value of being promoted to similar programming courses and abstract-concept courses.

Keywords: Teaching Ecology; Artificial Intelligence; Object-Oriented Programming; Teaching Innovation; Personalized Teaching.

1. Introduction

With the advancement of the education digitalization strategy, artificial intelligence technology is profoundly changing the teaching landscape of university classrooms [1]. As a core foundational course for computer science and electronic information majors, Object-Oriented Programming undertakes the important task of cultivating students' object-oriented thinking, including abstract modeling, encapsulation and inheritance, and polymorphic reuse [2]. However, this course has long faced a unique dilemma: although students already possess basic programming knowledge such as C language and data structures, they still commonly exhibit the phenomenon of "knowing syntax but failing at modeling" when facing abstract concepts such as "object" and "polymorphism" [3].

Traditional teaching models are limited by the dual structure of "teacher-led, textbook-centered," making it difficult to meet students' individualized development needs and the industry's demand for high-quality programming talents [4]. In recent years, although studies have explored introducing AI tools into programming teaching , most focus on single tools or single links, lacking a "full-process, multi-dimensional, ecological" systematic framework.

Based on the theme of "digital-intelligence empowerment, teaching innovation, and cultivating first-class talents" of the teaching innovation competition, this study proposes a "One Body, Four Dimensions" full-process AI-empowered framework. It constructs a teaching system with the "teaching ecology collaborative community" as its core and the four dimensions of "content, method, environment, and evaluation" linked together, deeply integrating AI technology into the full process of "pre-class, in-class, and post-class," achieving precise adaptation of teaching content, diversified innovation of teaching methods, intelligent upgrading of the teaching environment, and comprehensive transformation of teaching evaluation. This study aims to answer three questions: first, how to reconstruct the teaching logic of AI empowerment from an ecological perspective; second, what are the specific implementation strategies of the four-dimensional linkage; third, how to verify the practical effectiveness.

2. Literature Review

(1) Research on AI in education

In recent years, research on artificial intelligence in education has mainly focused on intelligent tutoring systems, learning analytics, adaptive learning, and automated assessment. Studies have shown that AI technology can effectively support personalized learning path recommendation, real-time feedback and diagnosis, and learning behavior analysis. However, existing studies mostly regard AI as an auxiliary tool, lacking a perspective of reconstructing the overall ecology of the teaching system .

(2) Research on programming course teaching reform

Research on programming course teaching reform mainly focuses on project-based learning, gamified teaching, blended teaching, and peer collaboration. For Object-Oriented Programming, existing studies have paid attention to the concrete teaching of abstract concepts, code specification training, and engineering thinking cultivation. However, most reforms are still teacher-centered and fail to fully leverage AI technology's advantages in learning diagnosis, resource push, and process tracking [5].

(3) Educational ecology theory

Educational ecology emphasizes the interdependence, dynamic balance, and collaborative evolution among various elements within the educational system. Introducing

educational ecology theory into teaching reform helps break through the limitations of the "teacher-student" dual structure and construct a multi-agent collaborative, multi-dimensional teaching ecosystem. At present, research combining educational ecology theory with AI-empowered teaching is still rare.

(4) Research gap

Looking at existing research, AI education applications mostly focus on single tools or links, programming teaching reform is mostly limited to the method level, and educational ecology theory mostly remains at the macro level. Research integrating these three aspects is still blank. This study attempts to fill this gap by constructing a "One Body, Four Dimensions" AI-empowered framework to achieve systematic reconstruction of the teaching ecology.

3. Teaching Pain Points and Learning Situation Analysis

(1) Teaching pain points

De-contextualized teaching content: the disconnect between abstract modeling and concrete experience. Object-Oriented Programming requires establishing abstract modeling thinking of "object/class," and students find it difficult to transform life logic into class hierarchy structures. This phenomenon of "knowing syntax but failing at modeling" caused by the lack of object thinking is a unique entry barrier for this course .Homogenized teaching methods: the obstruction of transformation from syntax imitation to engineering thinking. Object orientation not only requires "writing correct code" but also "designing architecture." Although traditional teaching can explain syntax clearly, it cannot support students' thinking leap from "coder" to "architect." The lack of this thinking advancement channel causes teaching to remain at the code surface, making it difficult to touch the essence of object-oriented design .Black-boxed teaching environment: the separation of code iteration and cognitive construction. The traditional closed teaching ecology (online-offline separation, lack of tool support) staticizes the dynamic process of object-oriented programming. Teachers find it difficult to perceive the trajectory of students' thinking evolution, resulting in delayed teaching guidance and missing the best opportunity for thinking correction .One-sided evaluation system: result-oriented assessment makes it difficult to measure comprehensive ability growth. The evaluation method is mainly result-oriented, with the core basis being final exam scores and after-class code assignment completion, making it difficult to fully reflect students' learning process and ability growth. It ignores students' performance in pre-class preview, in-class interaction, group collaboration, and problem exploration; evaluation standards are insufficient in considering core competencies such as code standardization and logical rigor, and cannot objectively measure students' comprehensive abilities [6].

(2) Learning situation analysis

The learning situation survey shows that the most urgent need of basic-level students is "intensive explanation of basic knowledge points + personalized error correction guidance," hoping that AI tools can push supplementary learning resources and simple cases in a targeted manner. The needs of advanced-level students focus on "code specification optimization + engineering scenario cases," expecting to improve team collaboration efficiency through AI collaborative tools. Innovative-level students pay more attention to "advanced knowledge expansion + design idea guidance," hoping to obtain AI-assisted design pattern exploration resources. Overall, 85% of students recognize the role of AI tools in improving learning efficiency, and their acceptance of AI-empowered methods such as personalized resource push and real-time code diagnosis is relatively high.

4. Theoretical Construction of the "One Body, Four Dimensions" AI-Empowered Framework

(1) Theoretical basis

This study is based on educational ecology, constructivist learning theory, and personalized learning theory. Educational ecology emphasizes the interdependence and dynamic balance of various elements in the educational system; constructivism emphasizes that learners actively construct knowledge in real situations; personalized learning theory emphasizes providing adaptive learning support according to learner differences [7]. Together, these three provide theoretical support for the "One Body, Four Dimensions" framework.

(2) Core "One Body": Teaching Ecology Collaborative Community

Taking "Object-Oriented Programming teaching" as the bond, a teaching ecology collaborative community of "teacher-student-AI technology-teaching resources" is constructed with four-party dynamic collaboration. Among them, teachers are positioned as guides of the teaching ecology, responsible for teaching design and direction control; students, as active constructors, aim to improve knowledge mastery and ability advancement; AI technology plays the role of collaborative enabler, undertaking core tasks such as learning analysis, resource push, and real-time feedback; teaching resources, as dynamic supporters, achieve layered adaptation and continuous optimization based on AI empowerment. The four parties form an interdependent, dynamically iterative, and virtuous ecological closed loop.

(3) Key "four dimensions": full-dimensional AI collaborative empowerment

Around the teaching ecology collaborative community, AI technology is implanted from the four dimensions of "content, method, environment, and evaluation" to achieve full-dimensional collaborative empowerment. The content dimension addresses "what to teach," the method dimension addresses "how to teach," the environment dimension addresses "where to teach," and the evaluation dimension addresses "how to evaluate." The four dimensions support each other and dynamically link together, jointly constituting the practical path of teaching ecology reconstruction [8].

5. Practical Path and Effectiveness

Based on the "One Body, Four Dimensions" framework, AI technology is integrated throughout the course process, with coordinated reform implemented across four dimensions: content, method, environment, and evaluation. In the content dimension, an AI learning analysis model is constructed to automatically generate student ability labels and push differentiated resources: the basic level focuses on intensive knowledge explanation and simple cases, the advanced level focuses on code specification and engineering scenario cases, and the innovative level focuses on advanced expansion and design pattern exploration. Meanwhile, tools such as

CodeGeeX and VisuAlgo are used to dynamically visualize abstract concepts, displaying in real time the memory allocation of classes and objects and the call chain of inheritance and polymorphism . In the method dimension, a "problem-driven, AI-assisted, independent inquiry" process is designed, in which students use AI for code exploration and scheme design, completing knowledge internalization through "trial and error, feedback, and correction" [9]. Based on data such as ability labels and learning styles, AI grouping algorithms are used to achieve "ability complementary, advantage collaborative" group division. An AI Q&A system is constructed to respond to questions 24 hours a day, achieving "instant Q&A and precise push". In the environment dimension, offline classrooms are equipped with smart screens, interactive responders, and AI learning monitoring devices, integrating software such as CodeGeeX and iFlytek Hearing, allowing teachers to view code progress, error distribution, and classroom participation in real time. Online, an AI learning module is integrated into the school platform to achieve full-process support of "pre-class, in-class, and post-class". In the evaluation dimension, indicators are divided into four categories: "knowledge mastery," "practical ability," "team collaboration," and "professional quality." A "student personal learning profile" is established, and the AI system automatically collects learning behavior data and generates personalized reports. Differentiated standards are set for different levels: the basic level focuses on knowledge mastery and code specification, the advanced level focuses on engineering thinking and collaboration ability, and the innovative level focuses on design innovation and problem-solving ability.

The practical results are remarkable. The understanding rate of core knowledge points increased from 60% to 92%, and code accuracy increased from 70% to 95%. In the first semester of the 2024–2025 academic year, no student in a certain teaching class scored below 70 in the overall evaluation. The score distribution was as follows: 2 students (3.45%) scored above 90; 48 students (82.76%) scored 80–89; 8 students (13.79%) scored 70–79; 0 students scored 60–69; 0 students failed; total 58 students. The after-class exercise completion rate increased from 75% to 98%, and the average daily interaction frequency on the online platform increased by 60%. 96% of students believed that AI-empowered teaching helped them understand abstract concepts, and 92% were satisfied with the course teaching model. The course team guided students to win the third prize in the Java Software Development University Group B of the 16th Blue Bridge Cup Anhui Division, the first prize in the East China Division of the 2024 6th National College Computer Ability Challenge Programming Challenge (Java subject), and the bronze prize in the industrial proposition track of the 9th Anhui Province "Internet+" College Students Innovation and Entrepreneurship Competition. AI undertook more than 60% of repetitive work, allowing teachers to invest more energy in teaching design, thinking guidance, and innovation ability cultivation. The course team teachers won the excellence award in the science and engineering group of the school's "16th Teaching Plan and Lecture Draft Competition" and the third prize in the school selection competition of the 5th Yangtze River Delta Private University Teacher Teaching Skills Competition. The four-party collaboration mechanism of "teacher-student-AI-resources" is becoming increasingly mature, forming a virtuous closed loop of "data collection, analysis and diagnosis, precise empowerment, and optimization iteration".

6. Innovation Highlights and Promotion Value

There are three innovation highlights. First, conceptual innovation: breaking through the traditional "teacher-student" dual structure, proposing the core concept of "teaching ecology collaborative community," and clarifying the role positioning and collaboration mechanism of the four parties. Second, method innovation: constructing a diversified teaching model of "layered content + inquiry learning + collaborative learning + personalized tutoring," solving the contradiction between "standardization" and "personalization". Third, technical innovation: integrating multiple AI tools and platforms, connecting multi-source data, and constructing a full-process intelligent teaching environment. There are two aspects of promotion value. First, wide adaptation scenarios: the model can be promoted to all programming courses and abstract concept courses. Second, controllable implementation cost: the AI tools used are mostly open-source or free-adapted resources for universities, and hardware can be transformed based on existing smart classrooms.

7. Value Reflection and Outlook

Some problems remain in this practice: some students are overly dependent on AI error correction, and their ability to independently troubleshoot and think independently needs further cultivation; the adaptability of AI grouping algorithms and learning analysis models to students of different majors and learning styles is insufficient. Future optimization will be carried out from two aspects. First, establish a guidance mechanism of "independent thinking first, AI assistance as a fallback," and cultivate students' ability to solve problems independently through methods such as setting "AI-disabled" phased exercises and carrying out special error troubleshooting training. Second, iterate AI technical tools, optimize grouping algorithms and learning analysis models, enrich cross-major and cross-scenario teaching case libraries, and improve teaching adaptability.

8. Conclusion

Aiming at the teaching pain points of Object-Oriented Programming, this study proposes a "One Body, Four Dimensions" AI-empowered framework, constructs a teaching ecology collaborative community of "teacher-student-AI-resources," and implements coordinated reform from the four dimensions of content, method, environment, and evaluation. Practical results show that the framework effectively improves students' learning efficiency and optimizes the teaching ecology. It has three highlights: conceptual innovation, method innovation, and technical innovation, and has wide adaptation scenarios and controllable implementation costs. Future research will further optimize the AI empowerment strategy, improve technical adaptability, and explore the application effect of this framework in more courses.

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