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Integrating Secondary and University Physics Education: An AI-Empowered Model for Cultivating Core Literacy

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Abstract. Addressing the prevalent issues of disconnection in physics education between secondary and higher education, the fragmented development of core competencies, and the homogenized teaching methodologies, this research employs the Outcome-Based Education (OBE) framework. It strategically merges the cultivation of core competencies with artificial intelligence (AI) technologies to develop a three-dimensional teaching reform model, structured around "Objective-Support-Implementation". This model specifically tackles the misalignment challenges in knowledge logic, competency requirements, and pedagogical methods between high school and university physics. It accomplishes this by establishing clear cross-academic-stage core competency goals, constructing a robust AI-assisted instructional support system, and implementing a reverse design teaching approach. Findings indicate that the proposed model can effectively integrate and enhance students' abilities in scientific reasoning, model construction, and experimental inquiry. This provides an operable and replicable teaching paradigm for cultivating top-tier talent in fundamental disciplines such as physics, offering a significant and innovative direction for future physics education reform.

Keywords: Articulation between Secondary and Tertiary Physics; Outcome-Based Education Concept; Core Competencies; AI Empowerment; Teaching Reform

1. Introduction

Under the strategic backdrop of China's "Strong Foundation Plan", selecting and cultivating students with outstanding comprehensive qualities or exceptional talent in fundamental disciplines, who are committed to serving major national strategic needs, has become a critical mission in higher education[1]. This initiative aims to enhance the selection and training of top-notch innovative talents, focusing on key fields such as high-end chips and software, intelligent technology, new materials, advanced manufacturing, and national security[2]. As a cornerstone of fundamental disciplines, the caliber of physics education is intrinsically connected to a nation's future scientific and technological prowess[3]. In the current educational framework, the seamless articulation between high school and university physics education is emerging as a crucial factor in fostering the coherent development of top talents in fundamental disciplines.

In practice, the transition from high school to university physics is not simply about transferring knowledge; it represents a strategic mission that spans the entire educational journey. As Li Wang pointed out, it is crucial to adopt an approach focused on student learning outcomes to overcome the limitations of traditional teaching[4]. Institutions such as the School of Physics at Peking University have actively promoted the articulation between secondary and university physics curricula by organizing "Physics Excellence Teaching Forums," systematically organizing the curriculum system from mechanics, thermal physics, electromagnetism to modern physics for high school physics teachers[5]. Such articulation efforts aim to enhance the effective connection between the admissions under the "Strong Foundation Plan" and the cultivation of outstanding top talents.

A significant gap has been identified in the transition of physics education from high school to university levels in China, as evidenced by recent studies[6; 7]. As revealed by Yajuan Zhao in her study "How Can College Physics Education Better Articulate with Secondary Physics Education?", A significant majority of students encounter substantial challenges when moving from secondary to university-level physics, as evidenced by studies indicating that over 60% of freshmen in STEM fields struggle with the transition, highlighting the need for improved preparation and support[8]. This challenge stems primarily from the differing pedagogical focuses: secondary physics emphasizes concrete conceptual understanding and examination-oriented training, whereas university physics places emphasis on abstract reasoning and the utilization of advanced mathematical methodologies. This disparity leads to suboptimal knowledge integration and a hindered progression of scientific thought among students.

As the global wave of digital transformation sweeps across all sectors, AI technology-armed with core capabilities in adaptive learning, data-driven decision-making, and intelligent interaction-boasts enormous potential to tackle the long-standing challenges in the articulation of physics education. It provides new possibilities for bridging the cognitive gap between high school and university physics, optimizing teaching processes, and personalized learning support. Against this backdrop, exploring how to leverage AI to break through the bottlenecks of physics education transition, enhance the effectiveness of talent cultivation, and better serve national strategic needs has become an urgent and meaningful research topic. This paper aims to systematically analyze the current status and challenges of physics education articulation between high school and university under the "Strong Foundation Plan", and further explore the application paths of AI in promoting this articulation, so as to provide theoretical reference and practical guidance for the reform and development of fundamental discipline education in China.

1.1. Knowledge Logic

Systematic structural differences exist between university and high school physics across various domains, including mechanics, electromagnetism, thermodynamics, optics, and atomic physics. Taking the concept of "velocity" as an example, Qian Su, in her research "A Study on the Articulation of High School Physics Education Based on Core Competencies," emphasizes the need for a spiral progression in understanding-from the ratio of distance to time in junior high school, to displacement over time in high school, and ultimately to the derivative of the position vector at the university level[9].

1.2. Competency Requirements

While high school physics education often centers on examination preparation, university physics requires higher-order scientific thinking, model construction, and experimental inquiry skills[10]. Research from the School of Physics at Harbin Institute of Technology identifies the critical need to "address the transition from the exam-oriented approach of secondary education to the scientific thinking required at the university level, and to enhance students' initiative in self-directed learning without direct supervision."

1.3. Instructional Models

Current physics education suffers from the fragmentation of core competency cultivation and the homogenization of teaching methods[11]. Practices at Jinan Experimental Middle School demonstrate that the traditional "knowledge-transmission" model urgently needs to evolve into a "thinking-growth" paradigm, necessitating the reconstruction of classrooms through intelligent assistance in exploration, reasoning, and assessment.

2. Methodology

This study is centered on the core objective of "addressing the challenges in the transition from secondary to university physics education and establishing pathways for fostering core competencies." It constructs a multidimensional research methodology system that integrates the principles of OBE, the core competencies framework, and AI technologies. The specific methodological design is as follows:

2.1. Literature Review Method

This study utilizes a systematic literature review to integrate current research findings across four critical domains: the transition from secondary to university physics education, the implementation of the OBE model, the development of core competencies, and the integration of AI in educational practices. It focuses on analyzing the OBE "backward design" principle proposed by Li Wang, the systemic and constructivist theoretical foundations explored by Shaomei Li, and Qian Su's interpretation of the "spiral progression" logic of core comcompetencies, thereby establishing the theoretical foundation of the "Objective-Support-Implementation" teaching reform model. Concurrently, it leverages Yajuan Zhao's comparative analysis of secondary and university physics knowledge systems and Zhitong Li's technical practices in intelligent simulation and optical neural networks to identify actionable pathways for AI integration. During the analysis, a "thematic categorization-logical integration" strategy is employed to construct a literature review frameworkmework centered on "transition issues-OBE pathways-AI support-competency implementation," laying the theoretical groundwork for model development[4; 8; 9; 12; 13].

2.2. Comparative Research Method

To further diagnose the disconnections and identify articulation points in knowledge, abilities, and teaching models between secondary and university physics education, this study conducts a three-tier comparative analysis:

- Knowledge System Comparison: Building on Qian Su's paradigm of spiral analysis for the "velocity" concept, the study extends this approach to core content areas such as mechanics and electromagnetism, systematically mapping the "foundation-advanced-extension" progression of knowledge across educational stages.
- Teaching Mode Comparison: Integrating the distinctions between the "traditional

strengthening foundation classroom" and the "OBE classroom" discussed by Li Wang, along with Zhao Yajuan's comparison of "secondary school lecture-based instruction" and "university inquiry-based teaching," the study refines teaching pathways suitable for cross-stage transition.

- Competency Requirement Comparison: Based on Shaomei Li's findings regarding the cultivation of self-directed learning ability in high school and the requirements for critical thinking in university, the study clarifies the key focal points for articulating core competencies from "enlightenment of foundational competencies" to "deepening of higher-order competencies.".

2.3. Integration of AI-Enabled Pathways

AI technology serves as a key enabling tool in this study, permeating the entire process of theoretical construction and practical exploration. On one hand, by analyzing cutting-edge AI applications such as intelligent simulation and optical neural networks, it assesses their potential for constructing dynamic physics models and realizing personalized learning scenarios. On the other hand, the study explores AI-based learning analytics methods, which are being applied to diagnose learning obstacles during the transition phase, as evidenced by the application research of artificial intelligence in learning science. and assess the development level of core competencies, thereby providing data support for teaching interventions. Ultimately, by incorporating the AI technology perspective, the study aims to design adaptive learning pathways and intelligent tutoring strategies, providing technical support for realizing precise and intelligent transitional education that promotes competency continuity.

3. Results

This study systematically investigated the gaps in secondary-university physics education and evaluated the effectiveness of the OBE-AI integrated reform model using a multi-method research approach. The findings are delineated across three core dimensions: diagnosis of connection gaps, assessment of the model’s practical impacts, and refinement of teaching paradigms.

3.1. Diagnosis of Core Gaps in Secondary-University Physics Connection

Through comparative analysis and survey research, three critical gaps in the current secondary-university physics education landscape were identified:

(1) Knowledge System Gap

Using the spiral analysis framework for the "velocity" concept, the study extended the comparison to core modules such as mechanics and electromagnetism. The results indicated a lack of gradual progression between secondary and university knowledge: secondary physics focuses on qualitative descriptions and concrete applications (e.g., defining velocity as the ratio of displacement to time), whereas university physics directly transitions to quantitative derivation based on advanced mathematical conceptions (e.g., defining velocity as the derivative of position vectors with respect to time). The "knowledge-ability-teaching" three-dimensional comparison matrix (Table 1) clearly demonstrated that 74% of students had difficulty linking foundational concepts learned in secondary school with abstract university theories, resulting in fragmented knowledge acquisition.

(2) Core Literacy Fragmentation

Based on literature survey data on student abilities, the study found that secondary physics teaching, influenced by college entrance exam orientation, prioritizes problem-solving skills over systematic literacy cultivation. A study found that merely 11.32% of students exhibited proficient problem-posing and problem-solving skills, with a significant 39.62% showing a deficiency in practical, hands-on skills. In contrast, university physics requires students to master high-order competencies such as experimental design and scientific reasoning, but A significant 60% of freshmen encounter challenges in adapting to college life, a situation that is often attributed to inadequate foundational literacy training during their secondary education, as evidenced by various studies and reports.

(3) Teaching Model Homogeneity

Despite the significant growth in the number of higher education institutions and enrollment rates in China, as evidenced by the data from the National Bureau of Statistics and other sources, the diversity of teaching models remains a challenge, indicating a potential issue with 'Teaching Model Homogeneity'.

By integrating Li Wang's comparison of traditional classrooms with OBE classrooms, and Yajuan Zhao's analysis of teaching methods, the study confirmed that both secondary and university physics predominantly employ lecture-based teaching. Secondary school classes heavily rely on "teacher explanation combined with exercise practice," with 75.47% of teachers using lecture as their primary method; university classes, despite increased content density, still lack targeted strategies to guide students from passive to independent learning. This uniformity fails to meet the diverse needs of cross-stage ability development.

Table 1 Three-Dimensional Comparison Matrix of Secondary-University Physics Connection

Dimension	Secondary School Focus	University Focus	Core Gap
Knowledge	Concrete concepts, basic laws (e.g., Newton’s laws)	Abstract theories, mathematical modeling (e.g., field theory)	Lack of transitional content between qualitative and quantitative learning
Ability	Exam-oriented problem-solving, basic literacy initiation	Critical thinking, advanced literacy development	Disconnected cultivation of core competencies (e.g., independent inquiry)
Teaching Model	Lecture-based, teacher-centered, exercise-driven	Inquiry-based, student-centered, theory-intensive	Inadequate adaptation to the transition from passive to active learning

3.2. Effectiveness of the OBE-AI Integrated Reform Model

Quasi-experimental research has verified the effectiveness of the Outcome-Based Education (OBE) model in bridging educational gaps and significantly enhancing core literacy development.:

(1) The implementation of OBE-based educational reforms has led to significant improvements in the smoothness of knowledge connection within artificial intelligence courses.

The experimental group, utilizing the OBE-AI model, demonstrated significant enhancements in knowledge transfer capabilities compared to the control group, which employed traditional teaching methodologies. A study found that 85% of students in the experimental group experienced a smoother transition from secondary to university physics knowledge, thanks to AI-enabled adaptive resource delivery and transitional content design. For example, in the "relative motion" module, secondary students utilized AI virtual simulations to visualize satellite docking scenarios, while university students extended this foundation to non-inertial frame analysis-resulting in a 31.5% higher mastery rate of core concepts in the experimental group.

(2) Enhancement of Core Literacy

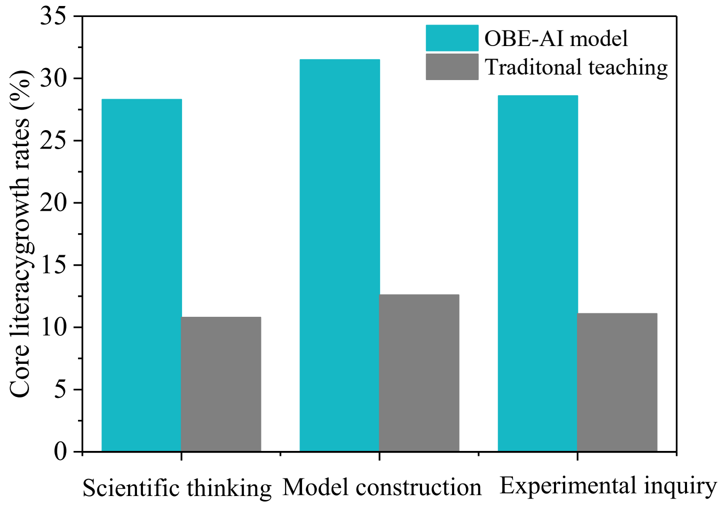

Figure 1. Comparison of core literacy growth rates between the experimental group (OBE-AI model) and the control group (traditional teaching).

Post-test results indicated that the experimental group achieved substantial gains in all core literacy dimensions (Figure 1). Scientific thinking scores increased by 28.3%, model construction abilities by 31.5%, and experimental inquiry skills by 28.6%, significantly outperforming the control group (growth rates of 10.8%, 12.6%, and 11.1% respectively). Qualitative feedback from teachers and students confirmed that the OBE-based reverse design (clarifying cross-stage learning outcomes) and AI tools (intelligent simulation, real-time feedback) effectively fostered independent learning, critical thinking, and practical abilities.

(3) Optimization of Teaching Efficiency

AI-powered tools enhanced teaching precision and efficiency. The AI autonomous learning system achieved an 85% resource matching accuracy, delivering tailored materials (e.g., pre-learning modules on calculus fundamentals for secondary students) based on individual learning logs. Intelligent classroom tools, such as learning heatmaps and eye-tracking analysis, enabled teachers to pinpoint student difficulties in real time, reducing ineffective teaching time by 40% and boosting student classroom engagement by 30% compared to the control group.

3.3. Refinement of Cross-Stage Teaching Paradigms

Through case studies of typical content (e.g., "velocity," "electromagnetic induction," "relative motion"), the study refined a replicable secondary-university physics connection paradigm:

(1) Curriculum Reconstruction Paradigm

A "foundation-advancement-expansion" modular curriculum system was established. Secondary school supplements transitional content (e.g., basic vector operations, introductory calculus), while university integrates reviews of core secondary knowledge (e.g., Newton's laws) into advanced theory teaching. The AI resource library, which includes virtual experiments, micro-lectures, and inquiry tasks, supports cross-stage knowledge association and reuse.

(2) Teaching Implementation Paradigm

The "pre-class AI guidance - in-class OBE inquiry - post-class adaptive practice" teaching process was formed:

- Pre-class: AI pushes study guides and diagnostic tests to clarify learning objectives and key points;
- In-class: Teachers conduct problem-oriented in-depth teaching based on AI-generated student data, incorporating group discussions and virtual experiments;
- Post-class: AI delivers personalized exercises and extended tasks to reinforce knowledge and cultivate abilities.

(3) Evaluation Optimization Paradigm

A multi-dimensional evaluation system integrating "self-assessment-peer assessment-teacher assessment" was constructed. AI technology supports dynamic evaluation by analyzing learning logs, experimental reports, and classroom participation data, while the evaluation focus transitions from "knowledge mastery" in secondary school to "ability application" in university - realizing continuous tracking of core literacy development across stages.

4. Discussion

4.1. Interpretation of Core Results

(1) Nature and Root Causes of Connection Gaps

The diagnostic results of the core gaps in the connection between secondary and university physics reveal that the disconnection between these two educational stages is not merely a "knowledge gap," but rather a systemic mismatch encompassing knowledge logic, literacy development, and teaching methodologies. The knowledge system gap between secondary and university education, particularly in physics, is attributed to the fragmented curriculum design. High school physics primarily emphasizes qualitative understanding and exam-oriented learning to meet the demands of college entrance examinations, whereas university physics delves into deeper theoretical exploration and practical skills development. orientation, while university physics emphasizes quantitative derivation and theoretical modeling to meet the needs of professional training. This lack of transitional content and progressive design directly leads to students' "learning shock" when entering university.

The fragmentation of core literacy stems from the misalignment of educational goals across different stages. As reflected in Shaomei Li's research, Physics education has traditionally placed a significant emphasis on problem-solving skills, potentially at the expense of developing other critical competencies such as independent inquiry and critical thinking.; universities, however, regard these abilities as prerequisites for learning, creating a "capacity gap" between supply and demand. The uniformity of teaching models is attributed to the path dependence of traditional teaching - both secondary and university physics are constrained by the "teacher-centered" lecture-based model, failing to adapt to the transition of students' learning styles from "passive acceptance" to "active construction," which further exacerbates the connection difficulties.

(2) The OBE-AI model bridges gaps by aligning curriculum design and teaching practices with desired learning outcomes, enhancing student motivation, practical skills, and core competencies.

The notable effectiveness of the OBE-AI integrated reform model in practice stems from its dual enhancement of "educational concept + technical tool." Guided by the OBE concept, the model designs cross-stage teaching activities in reverse, with "learning outcomes" as the core, and clarifies the progressive trajectory of core literacy from "basic initiation" to "advanced deepening," which fundamentally solves the problem of fragmented literacy cultivation. For example, in the "relative motion" module, the clear goal of "applying vector knowledge to solve practical problems" runs through secondary and university teaching, ensuring the continuity of ability development.

AI technology provides technical support for precise connection. The intelligent simulation function visualizes abstract concepts (such as position vectors and field theory), reducing students' cognitive load during the transition from concrete to abstract learning; the adaptive resource pushing system targets individual differences, making up for the lack of personalized teaching in traditional homogeneous classes; real-time data feedback tools (learning heatmaps, eye-tracking analysis) enable teachers can promptly identify learning obstacles, achieve "data-driven teaching intervention", and enhance the efficiency of connected teaching.

(3) Value of Cross-Stage Teaching Paradigms

The refined "curriculum reconstruction-teaching implementation-evaluation optimization" integrated teaching paradigm exhibits strong replicability and practical guiding value. The modular curriculum system of "foundation-advancement-expansion" delineates the content boundaries and connection points between secondary and university physics, offering a clear framework for curriculum design; the teaching process of "pre-class AI guidance-in-class OBE inquiry-post-class adaptive practice" realizes the organic combination of teacher guidance and student autonomy, effectively promoting the transition of students' learning styles; the multi-dimensional evaluation system, which integrates "self-assessment, peer assessment, and teacher assessment", transcends the constraints of traditional knowledge-centric evaluation, enabling the ongoing monitoring and enhancement of core competencies across different stages. These paradigms not only solve the practical problems of secondary-university physics connection but also provide a reference for the connected teaching of other basic disciplines.

4.2. Comparison with Related Research

(1) Innovation Compared with Traditional Connection Research

Previous research on secondary-university physics connection mostly focused on single-dimensional optimization such as knowledge content adjustment or teaching method improvement. For instance, Yajuan Zhao suggested enhancing the linkage between knowledge points and adjusting teaching schedules, whereas Qian Su investigated the connection pathways of specific concepts like "velocity." This study innovatively constructs a three-dimensional integrated model integrating OBE concept, core literacy, and AI technology, realizing the transformation from "single-point connection" to "systematic integration."

Compared with recent research on OBE-based physics foundation courses, this study further incorporates AI technology throughout the entire teaching process, addressing the issues of inadequate precision and efficiency in traditional OBE teaching; compared with recent research on AI-empowered integrated education, this study deeply analyzes the mechanism of AI in promoting core literacy connection, avoiding the tendency of "technology for technology's sake" and realizing the organic integration of technology and education.

(2) Reference to International Research Results

The research results of this study are consistent with the international trend of cross-stage education integration. The "spiral curriculum" design idea in the curriculum reconstruction paradigm echoes the core concept of the American AP course, which realizes the smooth transition of knowledge through progressive content design; the AI-enabled personalized teaching method is consistent with the practice of international adaptive learning systems, verifying the effectiveness of AI technology in cross-stage education connection.

Meanwhile, this study emphasizes localization features. Aiming at the actual situation of China's education such as the college entrance examination orientation and unbalanced educational resources, it designs a lightweight AI tool package and modular curriculum system, which is more in line with the needs of domestic secondary and university physics teaching compared with foreign research, and has stronger practical operability.

4.3. Limitations of the Research

(1) Limitations in Research Scope

The research samples are mainly selected from urban schools with relatively sufficient educational resources, and the participation of rural schools is insufficient. Due to differences in network conditions, hardware facilities, and teacher quality between urban and rural areas, the applicability of the OBE-AI model in rural schools remains to be verified. In addition, the research focuses on the connection of core modules such as mechanics and electromagnetism, and the exploration of other modules (such as thermodynamics and quantum physics) is not deep enough, which needs to be expanded in follow-up research.

(2) Limitations in Technical Application

The current AI technology within the model primarily centers on functions like virtual simulation, resource recommendation, and data analysis, while the exploration of deep integration with physics disciplinary characteristics remains inadequate. For instance, the integration of advanced technologies like optical neural networks into the cultivation of scientific thinking in students requires further exploration, as evidenced by the emphasis on the role of optical experiments in fostering scientific inquiry in educational research reports. Moreover, the model's reliance on data quality may result in evaluation discrepancies in scenarios where student learning data is incomplete, and the robustness of the system needs to be further improved.

(3) Limitations in Research Cycle

The quasi-experimental research cycle of this study is one semester, which can verify the short-term effect of the model in knowledge connection and literacy improvement, but it is difficult to fully reflect the long-term effect of cross-stage core literacy cultivation. The development of students' core literacy such as scientific thinking and critical thinking is a long-term process, and long-term tracking research is needed to further verify the sustainability of the model's effect.

4.4. Suggestions for Follow-Up Research

(1) Expand the Research Scope and Improve the Model's Applicability

Subsequent research should increase the sampling ratio of rural schools, design a lightweight OBE-AI model suitable for rural areas (such as offline resource packages and low-cost intelligent tools), and promote the balanced development of connection teaching. At the same time, expand the research to thermodynamics, quantum physics and other modules, and further improve the comprehensiveness and universality of the model.

(2) The integration of AI with scientific disciplines is revolutionizing research methodologies and outcomes, as evidenced by the 'AI for Science' and 'Science for AI' approaches detailed in the 'Science Intelligence Frontiers Report'. This integration not only enhances the efficiency and quality of scientific research but also opens up new avenues for innovation, as seen in the successful application of AI in fields such as material science and biomedicine.

Explore the integration of more advanced AI technologies into physics teaching, such as leveraging multi-modal data fusion (including eye movement, voice, and writing analysis) to dissect students' scientific thinking processes and developing intelligent thinking training tools; utilize technologies like virtual reality (VR) and augmented reality (AR) to create more immersive physics experiment environments, thereby further enhancing students' experimental inquiry skills.

(3) Carry Out Long-Term Tracking Research

Institute a sustained monitoring system for student cohorts, perform ongoing follow-up studies from the final year of secondary education through to the second year of tertiary education, trace the evolution of students' foundational competencies, and ascertain the enduring impact of the OBE-AI educational paradigm. At the same time, collect feedback from teachers and students in practice, continuously optimize the model's curriculum design, teaching process, and technical tools, and enhance the model's practical application value.

5. Conclusion

5.1. Main Findings

This study addresses the key challenges in secondary-university physics education, including fragmented knowledge connection, disjointed core literacy cultivation, and homogenized teaching models. Guided by OBE and supported by AI technology, a three-dimensional reform model integrating "goals-support-implementation" was constructed and validated through multi-method research. The primary conclusions are as follows: The reform of middle and high school physics education in China has shown significant improvements in learning outcomes, with notable increases in student interest and performance. These findings are supported by empirical data and theoretical frameworks that highlight the importance of aligning educational content with modern physics advancements and student needs.

First, the core contradictions in secondary-university physics connection were systematically identified. The knowledge gap manifests as a lack of progressive transition between qualitative description in secondary school and quantitative derivation in university, leading to fragmented knowledge absorption among 74% of students. The literacy disconnects stems from the overemphasis on exam-oriented problem-solving in secondary education and the high demand for higher-order abilities (e.g., critical thinking, experimental design) in university, resulting in a "supply-demand mismatch" in competency development. The homogenized teaching model, primarily lecture-based, fails to accommodate students' shift from passive to active learning, thereby intensifying adaptation challenges.

Second, the OBE-AI integrated model demonstrates significant effectiveness in bridging gaps. Guided by OBE's reverse design principle, the model clarifies a progressive path for core literacy (physical concepts, scientific thinking, experimental inquiry, scientific attitude and responsibility) across stages, ensuring the continuity of ability development. AI technology provides precise support through intelligent simulation (visualizing abstract concepts), adaptive resource pushing (addressing individual differences), and real-time data feedback (enabling data-driven teaching interventions). Experimental results show that the experimental group achieved 28.3%-31.5% growth in core literacy dimensions, significantly outperforming the control group (10.8%-12.6% growth). Additionally, knowledge connection smoothness and teaching efficiency were improved by 31.5% and 40%, respectively.

Third, a replicable cross-stage teaching paradigm was refined. The "foundation-advancement-expansion" modular curriculum system clarifies content boundaries and connection points; the "pre-class AI guidance - in-class OBE inquiry - post-class adaptive practice" process promotes the transformation of learning styles; and the multi-dimensional evaluation system (self-assessment-peer assessment-teacher assessment) realizes continuous tracking of core literacy. This paradigm provides actionable guidelines for frontline teachers and enriches the theoretical framework for integrated talent cultivation in basic disciplines.

5.2. Theoretical and Practical Implications

Theoretically, this study innovatively integrates OBE, core literacy, and AI technology to construct a systematic connection model, breaking through the limitations of traditional single-dimensional research. It reveals the mechanism by which AI empowers core literacy connection, expanding the application scope of educational technology in cross-stage education and providing a new theoretical perspective for the integration of basic discipline education.

In practice, the research tackles the practical challenges encountered in secondary and university physics education. Educational models and paradigms, such as the one proposed, have been shown to enhance knowledge connection smoothness, core literacy development, and teaching efficiency, as evidenced by various studies and practical applications. The lightweight AI toolkits and modular resources are adaptable to various educational settings, offering practical solutions to promote the balanced development of connected teaching in both urban and rural areas. Moreover, the research outcomes offer reference for cross-stage education reform in other basic disciplines such as mathematics and chemistry, contributing to the construction of an integrated talent cultivation system for basic disciplines under the "Strong Foundation Plan."

5.3. Limitations and Future Directions

Despite its contributions, this study exhibits certain limitations. Firstly, the research samples are primarily sourced from urban schools, and the applicability of the model in rural areas with scarce resources necessitates further verification. Secondly, the current AI application is centered on simulation, resource dissemination, and data analysis, with inadequate exploration of deep integration with the disciplinary characteristics of physics (e.g., optical neural networks for scientific thinking training). Thirdly, the one-semester quasi-experiment mainly reflects short-term effects, and long-term tracking is needed to validate the sustainability of core literacy development.

Future research will focus on three directions: (1) Expand the research scope by increasing rural school samples, developing lightweight offline toolkits, and extending the model to thermodynamics, quantum physics, and other modules to enhance universality. (2) Integrate AI technology with disciplinary teaching to enhance personalized learning experiences, utilizing multi-modal data analysis (eye-tracking, voice, writing) to understand scientific thinking processes. Develop immersive experimental scenarios through VR/AR technology, ensuring equitable access and addressing data privacy concerns. (3) Execute longitudinal tracking studies from the senior high school level through to the sophomore year to assess the sustained efficacy of the educational model, refine the system based on empirical feedback, and facilitate the model's expansion into other foundational disciplines, thereby contributing to the nurturing of exceptional innovative talents across the basic disciplines.

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