

The Reform Path and Innovative Practice in Secondary School Chemistry Teaching with the Aid of Artificial Intelligence

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Abstract:

Driven by the rapid advancement of artificial intelligence (AI) technology, secondary school chemistry education is undergoing an urgent digital transformation. This study employs literature review and questionnaire surveys to systematically analyze the application pathways of AI in the reform and innovation of chemistry teaching. The findings indicate that AI can empower chemistry education in the following four dimensions: first, in personalized learning, by enabling precision teaching through intelligent evaluation systems and interactive teaching platforms; second, in promoting educational equity, by expanding the coverage of high-quality educational materials via cloud-based platforms and virtual experiment systems; third, in teacher assistance, by reducing the workload of teachers through automated grading and lesson plan generation, thereby facilitating their transition toward guiding and innovative roles; fourth, in fostering core competencies, by restructuring teaching objectives and content to emphasize the development of innovative thinking, critical thinking, and computational thinking. This study provides a theoretical foundation and practical pathways for advancing the digital transformation of secondary school chemistry education, offering significant reference value for the effective implementation of core competencies and the construction of an intelligent educational ecosystem.

Keywords:

Artificial Intelligence, Secondary School Chemistry Education, Digital Transformation

1. Introduction

The rapid development of artificial intelligence technology, coupled with strong policy support from the Ministry of Education, has jointly formed the core driving force behind the digital transformation of secondary school chemistry education. Against this backdrop, AI has demonstrated significant application potential in various areas, including innovations in teaching models, development of educational resources, evolution of teachers' roles, and cultivation of core competencies. However,

notable shortcomings remain in terms of the systematic nature of evaluation mechanisms, the adaptability of resources, and pathways for teachers' professional development. In response to these practical challenges, this study employs a combination of literature review and questionnaire surveys to systematically explore innovative pathways and practical strategies for empowering secondary school chemistry education through AI. It aims to provide theoretical support and practical references for promoting core competency-oriented teaching transformation and advancing educational equity.

2. Examination of Core Issues in Secondary School Chemistry Education

2.1. Limitations of Traditional Teaching Models

The traditional teaching model is teacher-centered, which undermines student agency and predominantly employs a one-to-many, unidirectional approach to knowledge transmission. Relying on standardized textbooks and fixed instructional formats, this model treats students as a homogeneous group of knowledge recipients, resulting in a cramming-style pedagogical dilemma and significant divergence in educational outcomes. This model is characterized by a monotonous format and excessive emphasis on theoretical instruction, making it difficult to sustain student interest and often resulting in learning fatigue. Simultaneously, its inadequate practical components fail to develop students' applied competencies, leaving them poorly equipped to tackle real-world challenges. Furthermore, the evaluation mechanism, predominantly based on examination results, cannot comprehensively reflect students' holistic competencies and may lead to both misallocation of educational resources and deviation from intended educational objectives.

2.2. Issues of Excessive Teacher Workload

In addition to core responsibilities such as lesson preparation, teaching, and pedagogical research, teachers are also required to devote substantial effort to grading assignments and non-instructional tasks, leading to a significant increase in their workload. Excessive workload constrains the depth of lesson preparation and inhibits teaching innovation, thereby adversely affecting classroom quality and professional growth. Following the implementation of the "Double Reduction" policy, after-school services have further extended working hours, compressing opportunities for pedagogical research and rest, and exacerbating the imbalance between work and personal life. Chronic overload is prone to trigger occupational burnout and psychological issues, which not only diminishes teachers' professional well-being but also poses potential threats to educational quality and student development.

2.3. Inequitable Allocation of Educational Resources

Educational resources exhibit significant disparities across regions, between urban and rural areas, and among schools. Schools in urban and economically developed eastern regions possess qualified faculty, advanced facilities, and sufficient funding, whereas rural and remote western areas face resource shortages and inferior conditions. Key schools, benefiting from policy support and resource advantages, excel in teaching infrastructure and curriculum development, while ordinary schools struggle with inadequate resources and compromised educational quality. Such imbalance restricts educational choices and advancement opportunities for some

students, impedes the development of their comprehensive competencies, exacerbates social stratification, and undermines educational equity.

2.4. Lag in Core Competency Development

The development of artificial intelligence has imposed new requirements on the core competency framework. Traditional teaching emphasizes knowledge transmission and skill training [1], yet lacks systematic cultivation of competencies such as innovative thinking, [2] critical thinking, and socio-emotional skills. Moreover, the evaluation mechanism remains predominantly focused on academic performance. In response to the intelligent era, education must promote a competency-oriented transformation of assessment, emphasizing the development of problem-solving abilities in authentic contexts and the nurturing of values. The education system should actively respond to technological transformations, expand the connotation of competencies, and construct a talent cultivation framework adapted to future societal needs.

3. AI-Driven Innovative Pathways for Secondary School Chemistry Education

3.1. Intelligent Transformation of Teaching Models

Artificial Intelligence facilitates the transformation of secondary school chemistry teaching from experience-dominated to data-driven modes through the establishment of intelligent evaluation systems and interactive communication mechanisms. The intelligent evaluation system integrates multi-source data, including classroom behaviors, assignments, and experiments, to achieve dynamic diagnosis and precise intervention in the learning process. This assists teachers in identifying students' zones of proximal development and designing differentiated tasks. Interactive communication, enabled by AI-powered question-answering robots and virtual assistants, employs a "human-machine-human" collaborative dialogue approach to enhance students' comprehension of abstract chemical concepts. It establishes a "integration of knowledge and practice" learning pathway, thereby compensating for the limitations of traditional lecture-based instruction.

3.2. Integration and Restructuring of Teaching Resources

AI-powered educational platforms utilize intelligent algorithms to recognize and adapt to regional variations in textbooks, automatically generating multilingual and culturally responsive instructional resources. This effectively promotes both the large-scale sharing and personalized provision of high-quality chemistry education resources. [3] At the implementation level, with the support of offline resource packages and AI-based grading systems, artificial intelligence overcomes the limitations posed by inadequate network infrastructure in remote areas. It ensures that teachers and students in low-connectivity environments can stably access high-quality instructional materials, significantly enhancing the equity of educational resource distribution across regions.

In the field of experimental teaching, virtual reality (VR) and augmented reality (AR) technologies create highly simulated and controllable immersive laboratory environments, enabling students to perform high-risk chemical experiments—such as those involving high temperature, high pressure, or toxic substances—with no physical risk. Through multi-sensory feedback incorporating visual, auditory, and

even tactile stimuli, these technologies enhance students' understanding of abstract concepts such as molecular structures and reaction mechanisms, significantly expanding the scope and depth of chemistry laboratory education.

3.3. Reshaping Teachers' Roles and Expanding Their Competencies

By undertaking repetitive tasks such as homework grading, online question answering, and lesson plan generation, artificial intelligence technology significantly alleviates the administrative burden on teachers, [3] enabling them to devote greater attention to instructional design and innovative pedagogical activities. Concurrently, AI is progressively driving the transformation of teachers' roles, shifting their function from traditional knowledge transmitters to guides of the learning process, developers of curriculum resources, and facilitators of student learning. In the context of cultivating core competencies, the era of artificial intelligence has introduced new requirements for the structure of talent capabilities, placing particular emphasis on the organic integration of innovative thinking, critical thinking [2], and computational thinking. In teaching practice, by designing tasks such as open-ended problem solving, multi-source information discrimination, and conceptual model construction, teachers can guide students to establish a systematic knowledge framework of chemistry and develop their ability to address real-world situational problems. This educational approach aligns with the future societal demand for interdisciplinary and versatile talents, reflecting the educational value of the deep integration of artificial intelligence and education.

4. Conclusion and Prospects

This study systematically investigates the pathways for reform and innovation in secondary school chemistry teaching within the context of artificial intelligence. The findings demonstrate that AI technology offers effective solutions to structural challenges in traditional chemistry education—such as rigid teaching models, excessive workload, uneven resource distribution, and lagging competency development—from four dimensions: teaching models, resource allocation, teacher roles, and competency cultivation. Through applications including intelligent evaluation, virtual experiments, and human-machine collaboration, AI is driving a profound transformation of secondary chemistry education toward personalization, equity, and intellectualization.

However, the deep integration of artificial intelligence and chemistry education still faces multiple challenges. First, the application of intelligent technologies must guard against the pitfall of “technology supremacy,” as the humanistic and social dimensions of education and the guiding role of teachers remain irreplaceable. Second, issues such as data privacy, algorithmic ethics, and the delineation of responsibilities between humans and machines require further regulation. Third, the intelligent infrastructure in rural and remote schools, as well as the digital literacy of teachers in these regions, still need improvement.

Future research should focus on the following directions: first, establishing AI application standards and evaluation systems with greater disciplinary specificity for chemistry education; second, conducting long-term empirical studies on the effectiveness of AI-enabled teaching, particularly its impact on the development of students' higher-order thinking skills; third, exploring novel paradigms for teacher-AI collaborative teaching to facilitate complementary advantages between human and

machine. [4,5,6] Only through continuous theoretical innovation, practical optimization, and synergistic policy support can a student-centered, competency-oriented intelligent ecology for chemistry education be truly constructed.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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