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The Integration of Artificial Intelligence (AI) Into the Teaching of Functional Polymers

Faqi Yu, Minggang Tian *

School of Chemistry and Chemical Engineering, University of Jinan, Jinan, Shandong 250022, P.R. China

* Corresponding author

Abstract

This paper focuses on the research on the integrated application of artificial intelligence technology in the teaching of functional polymers. Addressing core issues in traditional teaching in this field, such as abstract concepts, high barriers to practical implementation, and disconnection from cutting-edge research and development, the study systematically elaborates on the inherent necessity of an AI-driven paradigm shift in teaching. It constructs a comprehensive framework for teaching reform across five dimensions: intelligent curriculum restructuring, virtual simulation platforms, data-driven inquiry, adaptive assessment, and industrial case library development. The research indicates that the deep integration of artificial intelligence can not only visualize abstract knowledge and enable personalized learning through methods like knowledge graphs and molecular simulations but also fundamentally promote the transformation of teaching models from "knowledge transmission" to "data-driven innovative practice." This cultivates interdisciplinary talent that meets the demands of national strategies for new materials. Finally, the paper envisions future trends in the deep integration of AI and education, pointing out that its development will rely on the evolution of technologies such as vertical domain-specific large language models and generative AI, ultimately building a new intelligent educational ecosystem characterized by human-machine collaboration and the integration of teaching, research, and industry.

Keywords

Artificial Intelligence; Functional Polymers; Teaching Reform; Computational Materials Science; Virtual Simulation Experiments.

1. Introduction

The application of artificial intelligence (AI) in the teaching of functional polymers represents a profound transformation in the educational paradigm within the field of materials science. As an interdisciplinary subject involving complex structural design, performance prediction, and synthesis pathway optimization, traditional teaching methods for functional polymers are often limited to abstract conceptual explanations and static case studies, making it difficult for students to intuitively grasp dynamic molecular design processes and structure-property relationships [1]. The introduction of artificial intelligence technologies-through data-driven models, visualized molecular simulations, and intelligent algorithm-assisted design-transforms abstract theories into interactive and predictable dynamic learning experiences. This not only significantly lowers the threshold for knowledge acquisition but also fosters students' ability to identify patterns from vast datasets and utilize computational tools to solve practical material-related problems. In doing so, it addresses the core demands of emerging engineering education for "innovative practice" and "interdisciplinary integration."

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Furthermore, the significance of this topic extends to the bridge between scientific research innovation and industrial needs. The research and development of functional polymers increasingly rely on high-throughput computation and intelligent screening, driving a growing demand in the industry for interdisciplinary talents who possess both expertise in polymer science and proficiency in applying artificial intelligence. Integrating AI technologies into teaching allows students to familiarize themselves with intelligent material development workflows early on, mastering cutting-edge methods such as machine learning-guided polymer synthesis and neural networks for property prediction, thereby shortening the cognitive distance from theory to application [2]. Simultaneously, this pedagogical exploration provides a case study for adaptive reform in higher engineering education, demonstrating a pathway to overcome traditional disciplinary teaching bottlenecks through technological empowerment. It offers substantial support for advancing the sustainable development of materials science and responding to national strategies for independent innovation in key material fields.

2. Current Research Status

Currently, the integration of artificial intelligence into the teaching of functional polymers is transitioning from theoretical exploration to systematic pedagogical practice, driven by both national strategies and cutting-edge research. In terms of educational practice, leading domestic universities have pioneered curriculum reforms. For instance, the School of Materials Science and Engineering at Shanghai University has launched the AI Design and Practice in Materials course series, which includes specialized modules for polymers and other fields. East China University of Science and Technology has also explored the construction of AI-driven curriculum systems for polymer materials engineering. These courses emphasize a "theory + practice" approach, aiming to cultivate students' ability to apply AI tools to solve specific material design problems. At the technological frontier, research has moved beyond simple tool application toward establishing AI-driven research and development paradigms. Examples include the implementation of dual closed loops-"performance prediction–mechanism interpretation" and "design–synthesis"-enabling a fundamental shift from traditional "trial-and-error" methods to "predictive design." Furthermore, the use of advanced models like Graph Neural Networks (GNNs) to predict polymer properties has become a focus in international competitions, highlighting the forward-looking nature of this direction. From a strategic perspective, this integration aligns with clear top-level planning. The National Natural Science Foundation of China has established major projects such as "Design and Preparation of High-Performance Organic Polymer Materials Based on Artificial Intelligence," while the Ministry of Education is promoting initiatives like the "AI + Majors" demonstration and the construction of disciplinary large models. These efforts signify that AI for Science has become a national strategy for the advancement of materials science.

3. The Essential of Teaching Reform

Exploring the topic of "Application of Artificial Intelligence in the Teaching of Functional Polymers" is essential because it directly addresses the urgent needs of disciplinary development, talent cultivation, and national strategy. First, it is an inherent requirement for transforming teaching and research paradigms. Traditional teaching and research in functional polymers have long faced challenges such as the abstract nature of microstructures, complex structure-property relationships, and lengthy R&D cycles. Introducing AI into teaching can visually demonstrate the entire process of intelligent material design, property prediction, and synthesis optimization, transforming abstract knowledge into interactive, computable practice. This helps students fundamentally understand and master the new "data-driven" research paradigm. Second, it is an inevitable path for cultivating interdisciplinary talent to meet future

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industrial demands. High-end manufacturing sectors such as aerospace and new energy have an increasingly urgent need for high-performance polymer materials, creating a demand for innovative talents who are proficient in both materials science and AI technologies. Educational reforms must guide students to correctly utilize AI, equip them with new methodologies for material R&D, and foster systematic thinking and problem-solving skills to address "bottleneck" technological challenges. Finally, it is an active commitment to serving national innovation and development strategies. Developing new quality productive forces and achieving high-level self-reliance in science and technology require breakthroughs in materials science. Deeply integrating AI into the teaching of functional polymers is precisely about strengthening the talent foundation, directly supporting the national strategy for independent innovation in key material fields, and carrying significant contemporary relevance.

4. Research Content

4.1. Intelligent Reconstruction of Curriculum Content and Knowledge Graph Construction

This section focuses on how to systematically integrate the core knowledge, methods, and tools of artificial intelligence into the traditional curriculum of functional polymer majors. Specific tasks include: identifying the core concepts in the field of functional polymers (such as structure-property relationships, synthesis pathways, and application scenarios) and leveraging technologies like natural language processing to construct a structured knowledge graph for the discipline [3]. Furthermore, it explores how to utilize this knowledge graph and machine learning algorithms (e.g., recommendation systems) to design personalized learning paths for students with varying foundations and interests. This involves intelligently recommending learning materials, case studies, and exercises to facilitate the shift from "uniform instruction" to "personalized teaching".

4.2. Development of AI-Assisted Molecular Simulation and Visualization Teaching Platforms

This aspect focuses on developing or utilizing existing AI tools to build interactive platforms for assisted teaching. Research may encompass: integrating machine learning-based molecular dynamics simulations and property prediction models (e.g., using Graph Neural Networks to predict glass transition temperature, mechanical properties), enabling students to conduct low-cost, high-efficiency "virtual experiments". Concurrently, key research focuses on how to intuitively present microscopic, abstract molecular structures, dynamic processes and structure-activity relationships through 3D visualization, dynamic animation, and Virtual Reality (VR) technology, lowering the cognitive barrier and deepening students' understanding of complex principles.

4.3. Design of Data-Driven Research-Oriented Teaching Models

This part aims to transcend mere tool usage by designing new teaching models oriented towards authentic research problems. It studies how to guide students in using public polymer databases or laboratory data to independently explore hidden patterns between material composition, processing, and performance through data mining, regression analysis, or classification models. Complete teaching cases can be designed, for instance, guiding students through constructing a full AI-assisted material discovery workflow: from goal setting, data collection, model training and optimization, to result verification and reporting. This cultivates students' data thinking and ability to solve complex engineering problems throughout the process.

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4.4. Adaptive Learning Assessment and Feedback Systems

This area researches how to utilize AI technologies to reform the teaching assessment system. Specific contents include: developing intelligent evaluation systems capable of automatically analyzing student assignments, reports, and even experimental design ideas (e.g., using Natural Language Processing to assess the logic of arguments); researching the construction of learning outcome prediction models based on student learning behavior data (e.g., online platform operation logs, exercise accuracy rates) to provide early warnings for potential learning difficulties. The ultimate goal is to form a closed loop of "teaching-learning-assessment-feedback", providing teachers with precise bases for pedagogical intervention and offering students personalized diagnosis of weak areas and improvement suggestions.

4.5. Construction of Virtual Simulation Projects and Case Libraries Oriented Towards Industrial Needs

To ensure the connection between teaching and cutting-edge industry, this part studies how to build a repository of virtual simulation projects and case studies linking AI, functional polymers, and typical application scenarios. For example, simulating the process of using AI to screen polymer materials meeting specific battery electrolyte requirements starting from molecular design, and virtually validating their comprehensive properties. These cases should originate from real industrial demands or advanced achievements, allowing students to complete project tasks involving "requirement analysis-intelligent design-simulation evaluation" in a highly simulated environment, thereby gaining early experience and mastering the new paradigm of materials research in the AI era.

These five aspects form a comprehensive research framework encompassing content reshaping, tool support, methodological innovation, evaluation reform, and application bridging. I hope this provides a clear structure for your paper writing. If you wish to explore any of these aspects in greater depth, I can provide more detailed information.

5. A Profound Transformation in Teaching Paradigm

The application of artificial intelligence in the teaching of functional polymers extends far beyond the introduction of new tools; it is catalyzing a systematic transformation of the teaching paradigm encompassing philosophy, methodology, and objectives.

5.1. Reconstruction of the Teaching Subject

The role of the teacher is shifting from a unidirectional transmitter of knowledge to a designer of learning environments, a guide for scientific inquiry, and a coach for AI tools. The core of teaching is moving from "what to teach" to "how to design the learning experience".

5.2. Re-engineering of the Teaching Process

The traditional linear model of "theory-experiment" is being reshaped into a dynamic, closed-loop process characterized by "data-driven, intelligent interaction, and real-time feedback." Through virtual experiments, intelligent prediction, and case simulations, students actively construct knowledge through trial, error, and discovery.

5.3. Elevation of Teaching Objectives

The ultimate goal transcends the mere transmission of polymer knowledge itself. It aims to cultivate students' "AI+" composite innovative capabilities. This includes the ability to solve material problems using computational thinking, the competence to harness AI tools for independent inquiry, and a future-oriented mindset for intelligent material design.

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6. Moving Towards Deep Integration and Ecosystem Development

In the future, development in this field will surpass mere technological integration, progressing towards a deeper fusion with the essence of education and the construction of a novel teaching ecosystem.

6.1. Technological Convergence and Platform Evolution

Future teaching platforms will deeply integrate Generative AI (AIGC), VR/AR, and digital twin technologies, enabling "conversational" molecular design and highly immersive simulation experiments. Vertical domain-specific large language models for the polymer field will provide more specialized intelligent tutoring. The construction of national or institutional-level virtual simulation project and case libraries will become critical infrastructure.

6.2. Extension of Teaching Models Towards Research and Industrial Frontiers

The boundary between teaching and research will further blur. Classrooms may directly connect to real high-throughput experimental or computational data streams, allowing students to participate in "micro-research" within cutting-edge projects. Industry will engage deeply to co-develop teaching case libraries based on genuine technological needs, achieving seamless integration between learning and innovation.

6.3. Restructuring of Educational Ethics and Evaluation Systems

While embracing AI, it is imperative to emphasize AI ethics education, fostering students' vigilance towards algorithmic bias and critical thinking. The evaluation system will place greater emphasis on being process-oriented and pluralistic. Learning analytics technologies will be leveraged to assess students' innovative thinking, collaborative skills, and complex problem-solving abilities, ultimately advocating for a new collaborative educational paradigm of "human intelligence guiding, artificial intelligence empowering".

7. Conclusion

In conclusion, the study confirms that deeply integrating artificial intelligence technology into the teaching of functional polymers is not merely a simple addition of tools, but rather a systematic reconstruction of the teaching paradigm that touches upon curriculum systems, teaching methods, and evaluation models. The five-dimensional framework of "content reconstruction, platform development, model design, evaluation reform, and industry-education linkage" constructed in this research can effectively address core challenges in traditional teaching, such as difficulties in understanding abstract concepts, high barriers to practical application, and disconnection from cutting-edge advancements. Through personalized learning driven by knowledge graphs, virtual experiments supported by AI simulation platforms, and data-driven inquiry-based training, the focus of teaching shifts from knowledge transmission to cultivating innovative capabilities centered on "data-prediction-design," achieving a paradigm shift from "uniform instruction" to "intelligent, personalized teaching".

This transformation in teaching holds significant strategic importance. It directly responds to the urgent need for "materials-information" interdisciplinary talent required for developing new quality productive forces, building a bridge for students from theoretical understanding to intelligent research and development practice. Looking ahead, with the further development of generative AI, domain-specific large language models, and virtual reality technologies, the integration of artificial intelligence and functional polymer education will advance towards a new phase characterized by greater immersiveness, interactivity, and creativity, ultimately fostering a new generation of materials science education ecosystem featuring human-machine

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collaboration and the integration of teaching, research, and industry. This study provides a systematic theoretical framework and practical pathway reference for this transformation.

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