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Exploring the Application of Generative Artificial Intelligence to Support Pre-Class Preparation in County-Level High School Chemistry

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Abstract: In the pre-class preview stage of chemistry education within county-level high schools, several pedagogical challenges are commonly observed, including insufficient resource support, highly formalized preview activities, and the persistent difficulty teachers face in promptly assessing students' learning statuses. Generative artificial intelligence (AI), which excels in dynamic content creation, offers a promising solution by providing timely feedback, constructing diversified learning scenarios, and organizing a comprehensive educational environment. Consequently, this advanced tool introduces innovative strategies for optimizing the pre-class preview paradigm in chemistry instruction. Grounded in the authentic teaching conditions of county-level high school chemistry courses, this study systematically explores the application value of generative AI in pre-class preparatory activities. Drawing upon AI-TPACK theory, constructivist learning theory, and distributed cognition theory, we propose a practical application model encompassing task release, intelligent preview, learning situation diagnosis, and seamless classroom integration. This comprehensive model diversifies pre-study materials, cultivates students' problem-finding habits, and significantly enhances independent learning capabilities, while simultaneously allowing educators to dynamically adjust classroom instruction based on empirical pre-study data. However, the practical deployment of this intelligent tool presents potential risks, such as students directly copying standard answers, developing an overreliance on AI, and encountering factual errors or informational omissions in AI-generated content. To mitigate these issues, educators must strategically position generative AI as an auxiliary teaching instrument, design preview tasks emphasizing the cognitive learning process, and rigorously verify students' preview outcomes during classroom sessions to provide targeted, effective guidance.

Keywords: generative ai; chemistry education; educational technology; independent learning; instructional design

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1. Introduction

Chemistry is highly abstract, experimental, and logical. During the learning process, students often need a foundational understanding of basic concepts, experimental phenomena, and relevant background knowledge before class. However, in county-level high schools, pre-class preparation often faces challenges such as superficiality, inefficiency, and a lack of depth. Some students struggle with effective pre-study methods, limiting their process to reading textbooks and outlining concepts, which hinders the development of genuine problem awareness [1]. Additionally, due to constraints such as teaching tasks and large class sizes, teachers often find it difficult to monitor each student's preparation and provide personalized guidance tailored to individual differences. Traditional educational models also face limitations, including low knowledge coverage and the absence of quantifiable evaluations for generating personalized learning paths.

Generative artificial intelligence technology is advancing rapidly, with commonly used platforms such as Deepseek, ChatGPT, and Doubao increasingly integrated into school teaching environments. These intelligent tools can generate descriptive reading materials, provide customized learning guidance and exercises, and create scenario-based learning content based on student queries. They enable teachers to design preview assignments, analyze student questions, and enhance classroom activities. In county high schools, where teaching resources are often limited, generative artificial intelligence offers new opportunities for development [2, 3]. It enhances the overall quality of pre-class preparation and accelerates the pace of daily classroom teaching. Research has shown that these tools foster improved learner engagement, creativity, and digital skills, while also streamlining instructional design processes through prompt engineering and real-time feedback.

This article focuses on the pre-class preparation phase of chemistry lessons in county high schools, examining the unique advantages of generative artificial intelligence in educational applications. The theoretical foundations of intelligent technology are analyzed, and feasible application models for teaching are summarized. The research aims to develop practical methods to support the integration of generative artificial intelligence, ultimately enhancing the overall effectiveness of high school chemistry instruction [2, 4].

2. The Application Advantages of Generative Artificial Intelligence in Supporting Pre-Class Preview of Chemistry in County-Level High Schools

Pre-study learning materials can be greatly expanded. This can effectively address the issue of limited teaching resources in county high schools. County high schools play a pivotal role in enhancing the quality of local basic education. These schools are central to improving rural education and supporting regional development. They provide foundational support for rural revitalization and contribute to the advancement of new urbanization. Their operation significantly influences the overall development of local education and ensures the high-quality development of regional human resources.

County high schools face notable deficiencies in various teaching resources. Digital teaching tools for daily instruction are limited, and experimental teaching resources are scarce. Teachers often lack the means to provide personalized guidance to students. Many abstract chemical concepts require supplementary teaching methods. For instance, teachers may use analogies to explain concepts like effective molecular interactions or employ models to illustrate the structures of different substances. Modern artificial intelligence tools can assist in addressing these challenges. Generative artificial intelligence can produce diverse learning materials on specific chemistry topics, including professional explanations, real-life teaching examples, experimental backgrounds, and graded exercises [5, 6]. This enables students to access more comprehensive resources for pre-class preparation. For example, before introducing chemical bonds, teachers can use generative artificial intelligence to create realistic learning scenarios.

A typical preview scenario can be designed as follows: A student discovers two types of white crystalline substances during weekend cooking—table salt and sugar. Both substances share similar particle shapes and dissolve completely in water, yet they exhibit distinct properties in daily use [7]. This scenario encourages students to investigate the underlying reasons for these differences, helping them grasp abstract academic concepts through relatable, everyday experiences.

This tool supports personalized student learning and caters to the diverse needs of pre-class preparation. Students possess varying levels of understanding of basic chemistry concepts, and standardized preview materials may not address all their needs. Generative artificial intelligence can provide instant answers to students' questions, simplifying complex topics through clear explanations and comparative displays. It breaks down challenging concepts into manageable learning steps, making them more accessible to all learners [8].

Generative learning feedback enhances the precision of classroom teaching. Traditional pre-class previews rely on fixed teacher evaluation methods, such as

reviewing students' notes or posing questions in class [9, 10]. These approaches have limitations, including a lack of timeliness and incomplete coverage of students' learning challenges. In contrast, generative artificial intelligence enables students to document their thought processes and questions systematically. It helps them organize core knowledge and identify difficult areas. Students can submit their completed pre-study tasks, which teachers can analyze using artificial intelligence tools. This analysis reveals common learning challenges and gaps in students' knowledge, allowing teachers to adjust classroom content accordingly. As a result, classroom instruction becomes more targeted and better aligned with students' individual learning needs.

Realistic learning scenarios can ignite students' enthusiasm for chemistry. While chemical knowledge is widely applied in industry and daily life, many students struggle to connect theoretical concepts with real-world applications [11]. This disconnect often arises during pre-class exercises. Generative artificial intelligence can create scenario-based learning tasks that focus on everyday situations, local agricultural practices, environmental protection, food safety, and other practical topics. These scenarios help students appreciate the real-world value of chemistry. For instance, teachers can design preview tasks related to "ionic reactions" by incorporating scenarios such as the formation and removal of scale in tap water. Students can explore the fundamental properties of ionic reactions through these tangible phenomena.

3. The Theoretical Basis for Generative Artificial Intelligence to Empower Pre-Class Preview

3.1. Ai-tpack Theory

AI-TPACK is a theoretical framework introduced by Yan Zhiming et al. in 2020. It extends beyond TPACK by considering technology from a tool-based perspective. New teaching practices are exemplified in "AI + teacher" collaborative teaching, data-driven precision teaching, and on-demand personalized teaching [12]. The AI-TPACK framework outlines specific skill requirements for educators. Teachers are expected to possess expertise in their subject areas, proficiency in traditional teaching methods, and foundational technical application skills. Additionally, they should cultivate a basic awareness of artificial intelligence. Figure 1 illustrates the collaborative dynamics between teachers and generative AI. Generative artificial intelligence does not replace the teaching responsibilities of educators. Teachers are responsible for core teaching preparation, designing appropriate learning tasks, selecting suitable intelligent learning tools, and providing effective guidance on their use. All preparations align with predefined chemistry teaching objectives. Educators must maintain clear boundaries in their teaching practices. While some preview tasks can be supported by artificial intelligence, certain complex topics require in-class explanation and detailed analysis by the teacher.

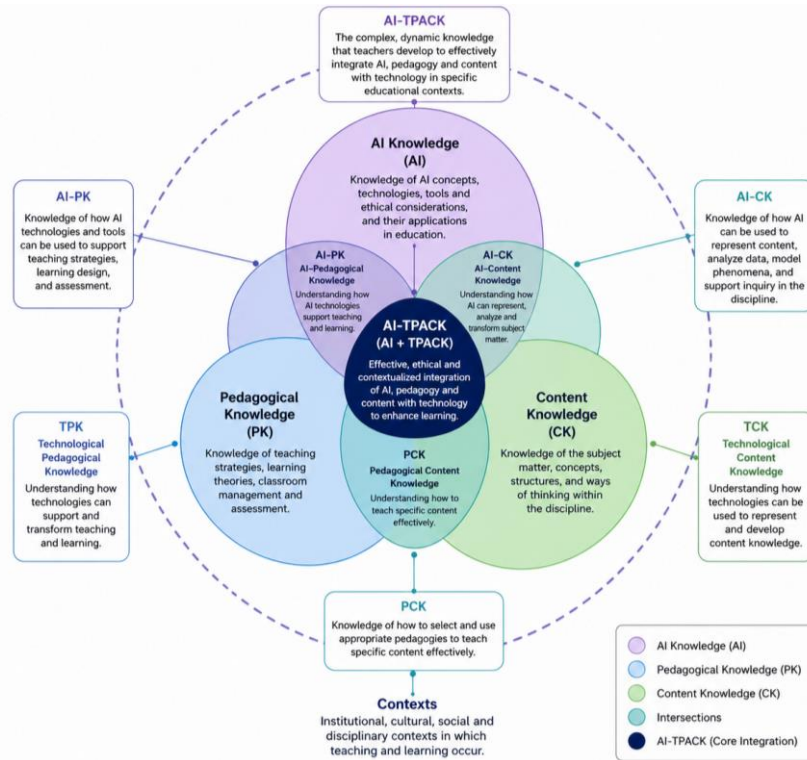


Figure 1. The Ai-tpack Theory

3.2. Constructivist Learning Theory

Constructivist learning theory emphasizes the active role of learners in the educational process. It posits that students should not passively receive knowledge but instead construct their own understanding. This construction occurs within a specific learning environment, utilizing available materials and external support. Generative artificial intelligence can create situational content for teachers prior to formal instruction, offering realistic scenarios for classroom previews. It facilitates a problem-oriented learning environment, providing diverse materials and immediate feedback. This approach encourages students to identify learning challenges, formulate their own questions, and independently resolve them. These activities primarily take place during the pre-class learning phase, where students engage with intelligent AI tools to continuously refine and optimize their existing knowledge base [13]. This process helps establish a foundational understanding of professional chemical concepts.

3.3. Distributed Cognition Theory

Distributed cognition theory offers a distinctive perspective on human cognitive behavior, emphasizing that cognitive tasks cannot be accomplished solely through individual effort. Instead, cognitive processes encompass learners, learning tools, the environment, and various tasks. The integration of generative artificial intelligence into pre-class learning has significantly transformed traditional learning methods. Previously, learning primarily involved interactions between students and textbooks. Modern approaches, however, have evolved into a multi-dimensional interactive model that includes students, textbooks, artificial intelligence, and teacher-assigned tasks. Artificial intelligence serves as a critical external support in students' cognitive processes, enhancing their learning activities by broadening access to diverse resources and methods. Teachers assign specific pre-class learning tasks, guiding students to complete preparatory work using both textbooks and AI tools. All interactions between students and generative artificial intelligence are systematically recorded, enabling the creation of comprehensive datasets for teachers. These datasets allow educators to analyze students' learning challenges, adapt classroom content, adjust the complexity of instructional material, and refine teaching methodologies to optimize the overall learning experience.

4. Developing an Application Model for Generative AI to Support Pre-Class Preparation in High School Chemistry in Rural Counties

4.1. Teachers Design Pre-Class Assignments

Teachers need to formulate specific standards for pre-class learning content. They must establish clear rules for students' pre-study tasks and clarify the appropriate use of generative artificial intelligence tools. All work should align with the objectives of classroom teaching and the actual learning levels of students. Certain complex chemistry concepts are unsuitable for independent AI-based previews, such as organic structure deduction, redox reactions, and electrochemical analysis. Generative AI tools have inherent limitations in content generation, which may lead to the omission of essential conditional information in chemical knowledge or the production of inaccurate analysis results. Such flawed outputs can disrupt students' logical reasoning and hinder their understanding of standard chemical concepts. Preview tasks should not be confined to simple information searches using artificial intelligence. Teachers need to design systematic preview task tables that emphasize practical problems and the learning process. For instance, before teaching "chemical reaction rate," teachers can assign targeted tasks requiring students to first read the textbook and identify all factors influencing reaction speed. Students can then pose specific questions to generative AI tools, such as the principle behind temperature increases accelerating chemical reactions. They should document all AI-generated content, highlighting any confusing or unclear parts [14]. Subsequently, students can formulate new questions about reaction rates, integrating real-life examples to deepen their understanding.

4.2. Students Engage in Smart Previewing

Students independently engage in preview learning with the assistance of generative artificial intelligence, completing pre-study tasks assigned by the classroom teacher. During the preview process, students focus on gaining a foundational understanding of new learning content rather than merely copying standard answers. They utilize smart tools to address duplicate questions and review various versions of explanatory content. This approach enables them to independently organize and clarify confusing knowledge points. Teachers have established fixed submission requirements for pre-study assignments, which include three distinct components. The first component documents the entire interaction process with generative AI. The second component reflects the student's personal understanding of the learning material [15]. The third component lists unresolved questions and outstanding issues. This structured writing format discourages the direct replication of AI-generated content and encourages critical thinking among students.

4.3. Systematically Organize Student Academic Information

Students independently complete all assigned pre-study tasks, and teachers collect the submitted materials. These materials encompass students' doubts, learning errors, and diverse opinions on the subject matter. Teachers systematically organize and classify this information to evaluate students' academic performance. Common challenges during the preview phase include difficulties in fully understanding core concepts, accurately describing experimental phenomena, and executing clear operational steps for calculations. Additionally, students often struggle to apply learned knowledge flexibly to solve practical problems. Generative artificial intelligence serves as a valuable tool for educators, facilitating the preliminary sorting of student issues [6]. This process creates favorable conditions for designing classroom instruction that aligns closely with students' actual learning needs and status.

4.4. Seamless Transition from Classroom Instruction

The ultimate goal of pre-class preparation is to complement classroom instruction rather than replace it. Instructional design forms the foundation of classroom teaching, clarifying learning objectives and ensuring structured delivery. Teachers can utilize generative artificial intelligence to explore diverse teaching design ideas. Based on

students' pre-study learning data, teachers can adapt classroom teaching plans accordingly. Classroom content can be arranged flexibly, allowing students who have already grasped the material to make simple adjustments during class. Teachers can concentrate on addressing challenging knowledge points that confuse the majority of students. Detailed analyses of students' misconceptions enable teachers to provide targeted guidance for correcting these errors. Traditional classroom teaching often follows a uniform model, whereas modern approaches can achieve greater relevance and precision by tailoring instruction to students' actual learning situations (As shown in Figure 2).

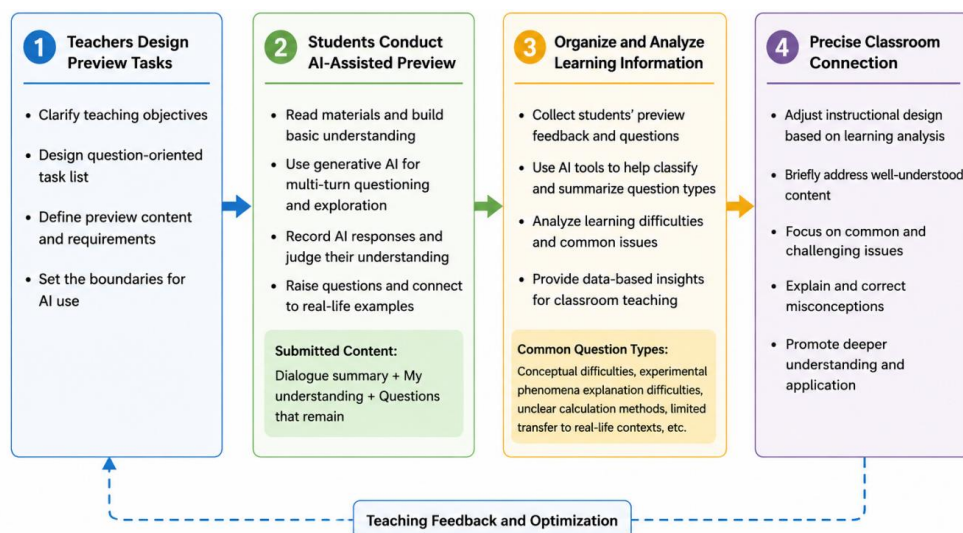


Figure 2. Building an Application Model for Generative AI to Support Pre-Class Preparation in Chemistry

5. The Practical Significance of Generative AI in Supporting Pre-Class Preparation for Chemistry

5.1. Encouraging Students to Take the Initiative in Preparing for Class

Generative artificial intelligence tools can alleviate students' learning pressure during pre-class tasks by providing timely and personalized responses to their questions. These tools enable students to receive effective assistance before formal classroom instruction. Traditional preview methods often place students in a passive role, merely reading textbook content. In contrast, generative artificial intelligence fosters a more active learning approach, allowing students to pose individual questions during their preparation, explore challenging topics further, and enhance their understanding through self-verification. This active engagement promotes a higher level of participation in daily chemistry learning. While students may occasionally make errors when addressing learning challenges, these misunderstandings can offer valuable insights for teachers in refining their instructional design. The solutions generated by AI should be viewed as tools to encourage deeper thinking and reflection, rather than as definitive measures of problem-solving ability.

5.2. Improving Teachers' Classroom Teaching Efficiency

Teachers review the questions raised by students prior to class and assess the completion of students' preparatory tasks [5]. This enables teachers to identify students' genuine learning challenges in advance, thereby minimizing uncertainties during classroom instruction. As a result, more class time can be allocated to addressing complex learning content. Teachers also encourage students to develop independent thinking skills, enabling them to apply previously acquired knowledge to unfamiliar academic scenarios. This approach enhances the overall effectiveness of classroom teaching. Additionally, content-generating AI introduces innovative teaching methods, allowing educators to

experiment with new lesson delivery techniques. Teachers can create customized open learning materials for use before formal class sessions and produce video demonstrations for classroom experiments. These videos may incorporate interdisciplinary knowledge, fostering connections across multiple subjects. By reducing the time and effort required for daily lesson preparation, teachers can focus on improving key aspects of classroom instruction, ultimately enhancing the quality of education.

5.3. Promoting the Digital Transformation of High School Chemistry Education in County Areas

Artificial intelligence tools are increasingly utilized for pre-class lesson preparation, addressing a significant challenge faced by county high schools: the lack of sufficient teaching resources. This approach is cost-effective and aligns with the goals of the National Digital Education Strategy Initiative. Digital education serves as a core driving force, enabling schools to explore innovative development paths for high school education in county areas. Teachers can leverage intelligent tools to create diverse learning resources, enhance the design of student learning tasks, and analyze student performance. This allows chemistry teaching in county-level high schools to move beyond traditional experiential models. Teaching practices can be informed by real student data, enabling more precise and effective instructional arrangements. This approach supports the holistic growth and development of students while fostering steady improvements in teachers' professional awareness and overall classroom teaching quality.

5.4. Fostering Students' Information Literacy and Independent Learning Skills

Under the guidance of teachers, students use generative artificial intelligence to complete pre-class learning tasks. Students develop a foundational understanding of new chemistry knowledge. They acquire effective learning strategies during the preview exercises. They learn to formulate meaningful academic questions and refine their ability to filter relevant learning information. They evaluate the authenticity and applicability of content generated by artificial intelligence tools. Traditional pre-study models offer limited learning support for students. Generative artificial intelligence, however, provides immediate feedback tailored to each student [16, 17]. It offers knowledge explanations from diverse perspectives. Over time, students cultivate constructive learning habits, such as proactively asking questions, exploring independently, comparing content, and engaging in iterative learning and reflection.

Students utilize content-generating digital tools in their studies, exercising caution with all outputs produced. They avoid directly copying these outputs into their work. Instead, students cross-check each piece of AI-generated content against textbook knowledge, classroom learning, and their prior study experiences. They document key insights from interactions with AI tools and organize their thoughts formed during these engagements. They highlight areas of confusion that remain unresolved. Through these practices, students enhance their ability to gather and evaluate useful information. They develop the capacity to assess the value of such information and integrate diverse pieces of knowledge. This process encourages critical thinking, enabling students to construct their own understanding incrementally. Over time, students become more adept at completing study tasks independently. They monitor their learning progress and continuously seek ways to improve their academic outcomes [18]. These daily practices help students adapt to new learning paradigms centered around intelligent technology.

6. Application Risks and Recommendations for Improvement

Generative artificial intelligence provides valuable support for pre-class chemistry study but carries inherent risks in practical application. Students may develop passive learning habits during preparatory sessions, relying on pre-generated answers from intelligent tools. This dependency can reduce pre-class learning to a superficial exercise for many students. Additionally, content generated by such tools often contains inaccuracies, fails to align with real-world scenarios, or does not adhere to strict academic standards. Some generated material may also exceed the comprehension level of high school students. Prolonged reliance on artificial intelligence explanations can negatively

impact learning outcomes, diminishing students' ability to engage in independent critical thinking and reducing their capacity to understand and assimilate textbook content autonomously.

Teachers must address these challenges by implementing targeted improvements in three key areas of teaching.

Educators should thoroughly understand the potential benefits of AI tools and guide students to use them as supplementary aids rather than as sources of complete answers [16]. Pre-class activities should focus on exploring foundational concepts, with teachers fostering environments that encourage active engagement rather than simple fact retrieval.

Teachers should design diverse learning tasks that enable them to monitor students' progress effectively. These tasks should encourage students to remain engaged throughout the learning process. Students should document their questions, highlight areas of difficulty, articulate their thoughts, and provide personal evaluations as they progress through their studies.

Educators can assign tailored learning tasks to students, including activities that involve analyzing AI-generated answers. Teachers should identify and address common misconceptions found in these outputs, using them as teaching opportunities. Students should critically evaluate and refine AI-generated content, fostering a meticulous approach to technology use. Through these practices, students can develop the ability to review their learning processes and cultivate a more thoughtful and independent mindset [15].

7. Summary and Outlook

This study proposes a practical application framework composed of four parts: task distribution, AI-assisted preparation, learning assessment, and class integration. The framework enriches pre-class learning resources and supports the learning needs of individual students. It also provides teachers with clear data on each student's learning status, making classroom instruction more targeted and efficient. Future studies may further examine this matching model, particularly its integration of AI generators with virtual laboratories and interactive exercises.

Through this approach, students can develop a deeper understanding of abstract chemical theories. At the same time, teachers need to strengthen their professional competencies, especially in integrating AI tools into routine instruction. These competencies include designing appropriate learning tasks and evaluating student performance effectively. Generative AI can function as a central learning support in rural chemistry education, helping improve teaching quality, foster student autonomy, and enhance information evaluation skills. Overall, this model provides a practical pathway for digital transformation in education.

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