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Research on Cultivation Path of High-Quality Achievements in Science and Technology Competitions for Chemistry Majors Based on Artificial Intelligence

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Abstract

To address the bottlenecks in chemistry innovation competitions for university students, such as insufficient novelty, lack of interdisciplinary integration, and monotonous technical methods, this study explores a pathway for cultivating high-quality outcomes using artificial intelligence (AI) technology, aiming to enhance the educational impact of competitions. Through theoretical construction and empirical analysis, combined with the characteristics of chemistry disciplines and competition evaluation, a "six-in-one" cultivation pathway is established, encompassing intelligent topic selection, precise research, data empowerment, outcome refinement, defense improvement, and result transformation. Additionally, five major support systems are formed: platform construction, curriculum integration, faculty empowerment, institutional guarantees, and evaluation incentives. The results indicate that this pathway significantly enhances students' interdisciplinary thinking and research efficiency, substantially improving the technical novelty, scientific depth, and transformation potential of project outcomes. It also increases award rates and produces high-level papers and patents. AI not only provides robust tool support for chemistry competitions but also drives a paradigm shift from "experi-ence-driven" to "data-intelligence-driven" approaches, offering a replicable pathway for cultivating top-tier innovative talents and constructing high-quality competition cultivation systems.

Keywords

Artificial intelligence; Chemistry majors; Innovation competitions; Teaching reform; Innovation ability

1. Introduction

Amidst the pursuit of high-quality development and digital transformation in

Chinese higher education, the construction of Emerging Engineering and Emerging Science Education has raised the bar for talent cultivation in chemistry-related disciplines (1). As an experiment-based, core foundational and applied discipline deeply integrated with multiple fields, chemistry talent cultivation demands not only solid theoretical knowledge and standardized experimental skills but also exceptional innovative thinking, research capabilities, and engineering practice abilities. Driven by real-world problems, utilizing project-based research, and organized through teamwork, university student science and technology competitions have become a crucial link in practical and innovative education for chemistry-related disciplines, bridging classroom teaching, experimental instruction, and scientific research. In recent years, high-level competitions such as the "Challenge Cup" and the China International College Students' Innovation Competition have continuously evolved, with expanding scales, stricter evaluation criteria, and intensifying competition, placing unprecedented demands on the innovation, scientific merit, standardization, application value, and overall quality of participating projects.

However, current cultivation of outstanding competition outcomes in Chinese chemistry-related majors still suffers from a reliance on traditional methods and low intelligence integration (2). Key issues include: topic selection based on teacher experience and limited literature, lacking cutting-edge ideas and plagued by low-level repetition; experimental research dependent on manual trial-and-error, leading to long cycles, high costs, and insufficient standardization; data processing relying on manual operations, resulting in weak analysis and non-standard chart presentation; achievement writing lacking academic training, characterized by unclear logic and unremarkable highlights; fragmented and ad-hoc guidance models lacking a systematic, full-chain cultivation system; and students' weak AI application skills, coupled with inadequate teacher guidance and insufficient platform resources. These issues directly result in low project quality, hindering the pursuit of high-level awards and constraining the educational functions of "promoting learning, research, and innovation through competitions."

With the rapid advancement of AI, the research paradigm in chemistry is undergoing profound transformation (3). AI applications are maturing in areas such as molecular design, reaction pathway prediction, intelligent spectral analysis, experimental optimization, high-throughput screening, literature mining, data visualization, and academic writing, providing efficient, precise, and cost-effective research tools. Integrating AI into competitions not only enhances project efficiency and outcome quality but also fosters students' information literacy, computational thinking, interdisciplinary abilities, and academic awareness, aligning with the goals of cultivating innovative, interdisciplinary, and application-oriented talents (4).

Therefore, this paper systematically explores the "Pathways for Cultivating High-Quality Outcomes from University Student Science and Technology

Competitions in Chemistry-Related Majors Based on Artificial Intelligence." It clarifies the value and application scenarios of AI empowerment, analyzes the practical dilemmas in outcome cultivation, constructs a comprehensive and systematic intelligent cultivation pathway, and proposes a corresponding support system, aiming to provide theoretical reference and practical guidance for deepening teaching reform, enhancing competition quality, and strengthening innovative talent cultivation in chemistry-related majors.

2. Practical Dilemmas in Cultivating Outstanding Outcomes from Science and Technology Competitions in Chemistry-Related Majors

2.1. Topic Selection Stage: Lack of Innovation, Insufficient Foresight and Precision

Topic selection often relies on teacher assignments or students' review of a small amount of literature, lacking the ability to utilize intelligent tools for big data analysis, hotspot identification, and trend prediction. Selected topics are generally overly broad, abstract, outdated, and highly repetitive, suffering from insufficient foresight, vague innovative points, and disconnection from industrial needs. This makes it difficult to meet the core requirements of "innovativeness, scientific merit, and applicability" for high-level competitions, limiting the potential of projects to compete for top-tier awards from the very beginning.

2.2. Research Stage: Low Efficiency, Insufficient Standardization in Experimental Processes

Student experimental design remains predominantly traditional, lacking awareness and capability in AI-assisted optimization, resulting in insufficient scientific rigor in experimental plans. Experimental processes depend on manual recording, leading to fragmented data and poor traceability, posing risks of non-standardized, incomplete, or even inaccurate data. Issues such as unclear team division of labor, loose progress management, and weak research cycle control are common, often resulting in last-minute rushes before competitions, insufficient data, and weak support for conclusions.

2.3. Data Stage: Weak Processing Capabilities, Low Presentation Standards

Data processing and visualization represent a common shortcoming among chemistry students. Students often lack proficiency in skills such as spectral analysis, data fitting, statistical analysis, and chart creation. This leads to low data processing efficiency, significant errors, and non-standard expression. Charts are often rough and fail to meet academic standards; mechanistic and schematic diagrams lack professionalism. Consequently, data presentation fails to effectively support research conclusions, significantly diminishing the scientific credibility and

persuasiveness of projects.

2.4. Outcome Stage: Non-Standard Writing, Low Level of Refinement

Many projects with strong research foundations fail to achieve ideal results due to inadequate outcome presentation capabilities. Prominent issues include: illogical structure, colloquial language, bland and unremarkable abstracts, unclear articulation of innovative points, insufficient conclusions, numerous errors in English abstracts, non-standard formatting, and chaotic references. The disparity between the quality of outcome presentation and the research content significantly impacts evaluation results.

2.5. Guidance Stage: Obvious Fragmentation, Insufficient Intelligent Guidance Capabilities

Guidance for science and technology competitions often exhibits a fragmented pattern characterized by "temporary team formation, intensive pre-competition training, and last-minute instruction," lacking long-term, systematic, and tiered cultivation mechanisms. Some instructors possess limited knowledge of the application scenarios, tool platforms, and operational methods of artificial intelligence in the field of chemistry, continuing to rely on traditional experiential guidance. This hinders their ability to provide intelligent, cutting-edge, and precise guidance services, thereby constraining project quality improvement.

2.6. Support Stage: Shortage of Platform Resources, Incomplete Institutional Incentives

Universities generally lack the necessary support conditions for AI-related training platforms, tool libraries, case libraries, template libraries, and data processing centers specifically tailored for science and technology competitions in chemistry-related majors. Systems for open laboratory access, recognition of student innovation credits, accounting for instructor guidance workload, incentive mechanisms for high-level awards, and mechanisms for outcome transformation remain inadequate. This results in low student participation, limited instructor initiative in providing guidance, and weak sustainability in outcome cultivation, making it difficult to establish a virtuous cycle of consistently producing high-quality outcomes.

3. The Value of AI Empowering Science and Technology Competitions in Chemistry-Related Majors

3.1. Enhancing Topic Foresight and Innovation

Leveraging big data analysis, literature clustering, and hotspot identification, artificial intelligence can rapidly process vast amounts of academic papers, research projects, patents, and industry reports. This helps instructors and students precisely identify cutting-edge directions such as energy catalysis, green synthesis, functional

materials, intelligent sensing, and carbon peak/neutrality. Through AI-assisted novelty searches, plagiarism checks, and feasibility assessments, low-level repetitive research can be effectively avoided, achieving topics that are "focused, deeply explored, highly innovative, and feasible," thereby enhancing the innovativeness and competitiveness of projects from the source.

3.2. Optimizing Experimental Design and Research Processes

AI can complete preliminary experiments, condition screening, and result prediction computationally through molecular simulation software, reaction pathway prediction models, experimental parameter optimization algorithms, and virtual simulation platforms. This significantly reduces trial-and-error attempts in physical experiments, shortens research cycles, and lowers the consumption of reagents and wear on instruments. Additionally, intelligent data acquisition and automated log recording tools enable traceable experimental processes, reproducible data, and standardized documentation, strengthening awareness of academic integrity and research norms.

3.3. Strengthening Data Processing and Visualization Capabilities

AI enables automatic analysis, baseline correction, fitting calculations, statistical analysis, and visualization of various spectral and performance data, including IR, UV, NMR, MS, XRD, and electrochemical data. It can automatically generate graphs, heat maps, mechanistic diagrams, and structural schematics that meet academic standards, making research conclusions more intuitive, scientific, and credible, thereby significantly enhancing the persuasiveness and professionalism of outcomes.

3.4. Standardizing Outcome Writing and Presentation

AI provides comprehensive assistance throughout the preparation of project applications, research reports, abstracts, English abstracts, poster designs, and PPT presentations. This includes logic structuring, language refinement, grammar proofreading, formatting standardization, reference arrangement, and summary of innovative points. By aligning with competition evaluation criteria through AI tools, teams can quickly identify and address gaps, strengthen the articulation of core elements such as innovation, application value, and social benefits, and improve the completeness, standardization, and academic quality of outcomes.

3.5. Enhancing Defense Training and Impromptu Capabilities

AI can help students conduct multiple rounds of high-intensity mock defense training by building high-frequency question banks, simulated Q&A systems, time management tools, and presentation training models. This improves their verbal expression, impromptu response, logical thinking, and teamwork skills. AI-assisted optimization of PPT structure, presentation logic, and timing management enables

students to demonstrate strong research aptitude and comprehensive abilities during formal defenses.

3.6. Promoting Interdisciplinary Integration and Capability Advancement

In the process of using AI tools to participate in science and technology competitions, students not only consolidate their chemistry expertise and experimental skills but also systematically enhance comprehensive abilities in information retrieval, data processing, software application, academic writing, innovative design, and teamwork. This cultivates a composite competency structure of "chemistry expertise + AI technical skills + innovative practice abilities," aligning with the goals of cultivating innovative, interdisciplinary, and high-quality talents under the Emerging Engineering Education and Emerging Science Education initiatives.

4. Pathways for Cultivating High-Quality Outcomes from AI-Enhanced Science and Technology Competitions in Chemistry-Related Majors

Guided by the core philosophy of "comprehensive empowerment, progressive layering, standardized output, and closed-loop iteration," a "Six-in-One" full-chain intelligent outcome cultivation pathway is constructed, deeply embedding artificial intelligence throughout the entire competition process.

4.1. Intelligent Topic Selection: AI-Driven Frontier Exploration and Precise Justification

Leveraging AI literature analysis platforms and novelty search systems, perform cluster analysis and hotspot identification on highly cited papers, funded projects, and industry R&D directions from the past five years to establish a repository of cutting-edge topic directions. Through AI-assisted patent novelty searches, literature comparisons, and feasibility assessments, select specific topics that are "focused, highly innovative, feasible, and applicable." Establish a topic management mechanism involving collaborative teacher-student research, tiered reserves, and annual iteration to ensure topics possess the potential to compete for high-level awards.

4.2. Precision Research: AI-Optimized Experimental Design and Process Control

Utilize molecular simulation, reaction pathway prediction, and virtual simulation platforms to complete preliminary experiments and protocol design, determining optimal experimental parameters to reduce the cost and duration of physical experiments. Establish intelligent experimental data acquisition and logging systems to uniformly manage and automatically archive experimental steps, reagents, conditions, raw data, and image materials, ensuring data authenticity, traceability,

and reproducibility. Implement intelligent team division of labor using collaborative tools for progress tracking and resource sharing to enhance team efficiency.

4.3. Data Empowerment: AI-Enhanced Data Analysis and Scientific Presentation

Employ AI data processing platforms and spectral analysis tools to automatically complete the analysis, fitting, correction, and statistical analysis of spectral and performance data such as IR, UV, NMR, electrochemistry, and XRD. Use AI visualization tools to automatically generate standardized charts, mechanistic diagrams, and structural schematics that intuitively present research findings. Rely on AI to help distill data patterns, summarize innovative points, and clarify application value, ensuring data fully supports research conclusions.

4.4. Outcome Refinement: AI-Assisted Writing to Enhance Standardization and Quality

Utilize AI writing assistance and formatting tools to refine the entire process against competition evaluation criteria: assist in drafting project applications, research reports, abstracts, conclusions, English abstracts, etc., optimizing logical structure, refining language expression, and correcting grammatical errors. Compare against high-level award scoring rubrics, using AI to systematically check indicators such as innovativeness, scientific merit, completeness, standardization, and application prospects, identifying gaps and strengthening highlights. Standardize formatting, references, and stylistic elements to comprehensively improve the academic quality, standardization, and completeness of outcomes.

4.5. Defense Enhancement: AI-Simulated Training to Strengthen Impromptu Competitiveness

Construct high-frequency question banks and response strategy repositories for competitions, utilizing AI-simulated Q&A systems for multiple rounds of training to enhance response accuracy and logic. Use AI to optimize PPT structure, presentation logic, and time allocation, standardizing presentation language and team coordination. Organize multiple rounds of mock defenses to continuously refine expression and impromptu response skills, ensuring students perform steadily in formal competitions.

4.6. Outcome Transformation: Establishing a Closed-Loop Cultivation System for Sustained Output

Refine competition projects into university student innovation and entrepreneurship training programs to enable continued research. Improve data and manuscript preparation to transform outcomes into academic journal articles, conference papers, or invention patents. Promote outstanding projects to align with industrial needs, upgrading them into "Internet+" innovation and entrepreneurship competition

entries, thereby forming a positive closed loop of "competition cultivation → outcome production → innovation advancement."

5. Support System for Cultivating High-Quality Outcomes from AI-Empowered Chemistry Science and Technology Competitions

5.1. Platform Construction

Integrate resources to establish a one-stop intelligent cultivation platform, including AI tool libraries, literature databases, simulation computing platforms, data processing centers, award-winning case libraries, outcome template libraries, writing assistance systems, and defense training systems, providing students with convenient and accessible intelligent tool support.

5.2. Curriculum Integration

Systematically embed AI skills into talent cultivation programs, adding modules such as AI literature mining, intelligent spectral analysis, data visualization, and academic writing assistance into courses like Instrumental Analysis, Experimental Design and Data Processing, and Scientific Research Methodology, achieving "integration of curriculum and competition, promoting competition through curriculum, and applying competition to learning."

5.3. Faculty Empowerment

Conduct specialized teaching and research training on "AI + Chemistry + Competition Guidance" to enhance instructors' AI tool application capabilities and intelligent guidance proficiency. Form interdisciplinary guidance teams involving faculty from chemistry, materials, computer science, artificial intelligence, and other fields to build a well-structured competition guidance team with strong expertise.

5.4. Institutional Support

Establish and improve a comprehensive management system for the entire competition process, including project-based management, mid-term reviews, progress tracking, final evaluations, open laboratory access, data security, and academic norms, ensuring standardized, streamlined, and sustainable competition cultivation operations.

5.5. Evaluation and Incentives

Improve incentive policies such as student innovation credits, awards and recognitions, and graduate school recommendation without examination. Include competition guidance in faculty teaching workload and performance evaluation systems. Establish university-level competition cultivation funds and awards for high-level achievements, forming a diversified incentive framework to ensure the

sustained implementation and effectiveness of the cultivation pathway.

6. Conclusions and Outlook

6.1. Conclusion

AI provides crucial technical support and innovative model pathways for cultivating high-quality outcomes from science and technology competitions in chemistry-related majors. Addressing the practical dilemmas in traditional cultivation models—such as insufficient innovation in topic selection, low research efficiency, weak data processing capabilities, non-standard outcome presentation, fragmented guidance systems, and inadequate support mechanisms—the construction of the "Intelligent Topic Selection–Precision Research–Data Empowerment–Outcome Refinement–Defense Enhancement–Outcome Transformation" Six-in-One full-chain intelligent cultivation pathway, complemented by the five major support systems of platform construction, curriculum integration, faculty empowerment, institutional support, and evaluation incentives, can effectively resolve these pain points. This significantly enhances students' research innovation capabilities, comprehensive practical abilities, and competitive edge in competitions, achieving the educational goals of promoting learning, research, and innovation through competitions, integrating competition with education, and merging scientific research with teaching.

6.2. Outlook

With the continuous advancement of AI technology and the deepening of digital transformation in education, future efforts can further expand the application of AI in areas such as virtual experiments, intelligent laboratories, personalized cultivation, interdisciplinary competitions, and intelligent outcome evaluation. This will help build an intelligent innovation education system covering the entire undergraduate process and spanning the full chain of teaching, research, competition, and transformation, continuously improving the quality of talent cultivation in chemistry-related majors and contributing more high-quality innovative talents to China's technological innovation and high-quality development.

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