US-China Education Review A, July 2026, Vol. 16, No. 7, 491-496
doi: 10.17265/2161-623X/2026.07.004

Research on Teaching Innovation of Basic Chemistry Courses in Universities Empowered by Digital Information Technology

LI Jiahui, YAN Zhichuang, TONG Xudong, YUAN Qingling, YANG Weiwei
University of Shanghai for Science and Technology, Shanghai, China
LI Dandan*
Shanghai Zhongqiao Vocational and Technical University, Shanghai, China

The comprehensive advancement of digital transformation is driving the iterative upgrading of higher education teaching models. The digital transformation of inorganic chemistry experiments and the integration of information technology into the teaching of the history of chemistry have emerged as the two core directions for reforming fundamental chemistry education. Based on a systematic review of relevant studies, this paper analyzes the application advantages of digital technologies in fundamental chemistry courses, examines the practical challenges in teaching practice, and proposes innovative pathways for digital empowerment from four dimensions: teaching resource development, classroom model reform, evaluation system optimization, and enhancement of teachers' digital literacy. The study suggests that digital technologies can effectively overcome long-standing bottlenecks in abstraction, resource constraints, and knowledge fragmentation, while facilitating the deep integration of theoretical instruction, context-based teaching in the history of chemistry, and experimental instruction, thereby providing systematic support for improving the overall quality of fundamental chemistry education in universities.

Keywords: digital information technology, inorganic chemistry, chemistry history, teaching reform

Introduction

Next-generation information technologies—such as AI, big data, and cloud computing—are rapidly reshaping traditional teaching models. *China's Education Modernization 2035* calls for accelerating educational reform in the information age through smart campus development and the integration of intelligent platforms. Against this backdrop, the digital transformation of higher education has become an irreversible trend. As a foundational course for science and engineering majors, fundamental chemistry features strong theoretical foundations, a heavy reliance on experiments, and a rich disciplinary history. Yet traditional instruction faces

---

Acknowledgment: This research is supported by the Natural Science Foundation of Shanghai (22ZR1444200).

LI Jiahui, Bachelor, University of Shanghai for Science and Technology, Shanghai, China.
YAN Zhichuang, Master's candidate, School of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai, China.
TONG Xudong, Master's candidate, School of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai, China.
YUAN Qingling, Bachelor's student, School of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai, China.
YANG Weiwei, Ph.D., School of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai, China.
LI Dandan* (corresponding author), Ph.D., Department of Basic Education, Shanghai Zhongqiao Vocational and Technical University, Shanghai, China.

three persistent challenges: abstract content that hinders macro-micro connections, resource-constrained experiments that limit hands-on practice, and fragmented teaching of the history of chemistry that fails to cultivate scientific thinking. Digital technologies—smart platforms, multimodal resources, virtual labs, and big-data analytics—offer new solutions to these problems (Lopes & Silva, 2026).

Existing research on the digitalization of inorganic chemistry experiments and the informatization of the history of chemistry has proposed strategies, including updates to resources, digital assessment, and interdisciplinary collaboration (Shaforost & Lut, 2026). Most studies remain single-dimensional, lacking an integrated framework that combines experimental digitalization and classroom reform. This paper therefore articulates the core advantages and practical challenges of digital empowerment and proposes a four-dimensional implementation framework—resources, instruction, evaluation, and teacher competencies—to inform the digital transformation of fundamental chemistry courses.

Core Advantages of Digital Information Technology in Empowering Fundamental Chemistry Courses

Expanding the Spatiotemporal Boundaries of Teaching and Promoting Flexible Learning Modalities

Traditional fundamental chemistry instruction relies heavily on classroom lectures and laboratory operations, constraining learning activities within significant spatiotemporal limitations. The introduction of digital technologies has fundamentally altered this situation. On the one hand, smart teaching platforms and online course resources enable students to transcend the 45-minute classroom limitation by engaging in pre-class preparation, post-class review, and independent inquiry at their own pace. On the other hand, virtual simulation technologies allow students to conduct experiments through computer simulations at any time and from any place, effectively compensating for the constraints imposed by insufficient experimental resources on learning opportunities. This “classroom + online + virtual” blended learning ecology not only enhances learning flexibility but also aligns well with the autonomous and personalized learning habits of contemporary college students.

Breaking Through the Bottleneck of Abstract Cognition and Enhancing the Intuitiveness of Knowledge Transfer

Fundamental chemistry encompasses a substantial body of knowledge involving microstructures, dynamic processes, and abstract concepts. Traditional instruction relies predominantly on verbal descriptions and static illustrations, making comprehension difficult for students and limiting their ability to transfer and apply knowledge. Digital technologies, through multimodal means such as animated videos, three-dimensional projections, and molecular simulation software, render the invisible microscopic world visible and complex reaction processes dynamic, enabling students to develop scientific cognition based on intuitive perception. Particularly in the teaching of chemistry history, digital technologies can reconstruct the historical scenes of classic experiments and simulate scientists’ exploratory journeys, allowing students to grasp the scientific spirit and methodology through a sense of “presence” (Olsson et al., 2015).

Enriching Context Creation and Deepening the Educational Function of Chemistry History Teaching

Chemistry history is not merely a chronicle of disciplinary knowledge but also a vehicle for scientific thinking, humanistic values, and innovative spirit. The presentation of chemistry history in traditional teaching is largely textual, making it difficult to evoke students’ emotional resonance and deep reflection. Information technology offers richer means for context creation in chemistry history teaching: video materials recreate historical scenes, interactive animations reproduce experimental processes, and three-dimensional models demonstrate the exquisiteness of ancient chemical implements. Taking ancient artifacts such as Han Dynasty bronze ox lamps and Song Dynasty oil-saving lamps as teaching examples, digital means not only visually display their physical structures and operating principles but also guide students to understand core concepts—such as the energy conversion of fuel combustion and the specific heat capacity of water—from a chemical perspective, achieving an organic integration of historical contexts and disciplinary knowledge.

Supporting Whole-Process Academic Evaluation and Enhancing the Precision of Teaching Decision-Making

Traditional teaching evaluation relies predominantly on final summative examinations, lacking effective monitoring and timely feedback on students' learning processes. Digital teaching platforms and learning analytics systems provide technical support for whole-process evaluation. Through automated collection and analysis of multidimensional data including online quizzes, discussion participation, laboratory report submissions, and virtual experiment operations, instructors can obtain real-time awareness of the learning status of both the class as a whole and individual students, promptly identifying weak areas and implementing targeted interventions (Weber & Stein, 2023). Evaluation is no longer confined to knowledge memorization but can be extended to comprehensive competency assessment that encompasses experimental skills, scientific thinking, collaborative abilities, and other dimensions.

Practical Challenges in Applying Digital Information Technology to Fundamental Chemistry Teaching

Insufficient Reserves of Chemistry History Teaching Resources and the Urgent Need for In-Depth Development

As an important resource for disciplinary education, the history of chemistry has long remained marginalized in existing textbooks and teaching systems. The chemistry history content in textbooks is largely brief and introductory, lacking systematicity and depth, making it difficult to support the implementation of context-based teaching. Instructors also lack convenient channels for accessing high-quality chemistry history materials during lesson preparation, resulting in superficial coverage of related instruction (Ghibaudi et al., 2020). Although digital technologies offer rich means for presenting the history of chemistry, the predicament of "having means but lacking content" remains prominent—the construction of high-quality digital repositories of chemistry history resources is still in its infancy and requires in-depth collaboration among disciplinary educators, historical researchers, and information technology specialists.

Uneven Digital Literacy Among Teachers and Superficial Integration of Technology and Instruction

Teachers are key agents in implementing digital transformation, and their digital literacy directly affects the effectiveness of technology-empowered instruction. Currently, there are significant disparities in the digital competencies of fundamental chemistry instructors in universities: some instructors can proficiently use smart teaching platforms, simulation software, and data analysis tools, while a considerable proportion remain at the preliminary stage of producing electronic slides. Of greater concern is the insufficient depth of integration between technological application and instructional design—phenomena such as merely transferring offline content to online platforms and using virtual experiments to substitute rather than supplement physical experiments are widespread (Vasquez, 2025). This status quo of "technology embedding" rather than "technology integration" undermines the potential effectiveness of digital transformation.

Lack of Deep Integration Between Technology and Disciplinary Instruction, With Evident Formalistic Tendencies

The deep integration of digital information technology with fundamental chemistry instruction is far more than replacing blackboard writing with PowerPoint or substituting videos for demonstration experiments. In current practice, some information technology-enabled teaching reforms remain at the surface level, lacking profound understanding of the intrinsic logic and pedagogical principles of the chemistry discipline. For example, the introduction of virtual experiments should focus on extreme conditions, microscopic processes, or high-risk reactions that are difficult to realize in physical experiments, rather than simply replacing basic operational training. Similarly, the multimedia presentation of the history of chemistry should serve the goal of cultivating scientific thinking rather than merely functioning as ornamentation to regulate the classroom atmosphere. Without in-depth design tailored to the discipline's characteristics, the integration of technology and instruction may easily fall into the trap of formalism—"technology for technology's sake"—which not only fails to optimize instruction but may also increase the cognitive load on both instructors and students (Miller & Carter, 2024).

Imbalanced Hardware Development and Maintenance Support, Constraining Sustainable Development

The effective implementation of digital teaching depends on a stable network environment, well-established information technology infrastructure, and professional operation and maintenance support. However, the level of digitalization development varies significantly across different universities. Some institutions, due to budget or technical limitations, face challenges such as low smart classroom coverage, unstable virtual simulation platforms, and delayed updates of teaching software. Even when hardware is in place, ongoing routine maintenance, troubleshooting, and version upgrades require sustained technical investment. Weak infrastructure support not only constrains the routine implementation of digital teaching but also undermines instructors' motivation to adopt information technologies.

Innovative Implementation Pathways for Digital-Empowered Fundamental Chemistry Teaching

Developing a Systematic Digital Teaching Resource Repository for Fundamental Chemistry

Teaching resources constitute the foundation of digital transformation. A systematic digital resource repository should be planned and constructed in a coordinated manner, encompassing three major modules: theoretical instruction, experimental teaching, and chemistry history education. At the theoretical instruction level, the focus should be on developing visualization materials for abstract concepts (such as molecular structure animations, reaction mechanism simulations, and energy-level transition illustrations). At the experimental teaching level, priority should be given to establishing virtual simulation experiment projects and remote laboratory platforms, covering not only basic operational training but also the digital transformation of inquiry-based and comprehensive experiments. At the chemistry history education level, classic documents, instrument images, scientists' biographies, and original experimental records from the history of chemistry should be systematically collected, organized, and digitally processed to construct a searchable, recombinable, and interactive digital chemistry history material repository.

Resource repository development should emphasize the cutting-edge nature and applicability of its content, with regular updates to reflect the latest disciplinary advances and continuous optimization of resource organization formats and interactive modes based on feedback from teaching practice. Furthermore, inter-institutional resource sharing should be actively promoted to avoid redundant low-level development and enhance resource utilization efficiency.

Constructing a Blended Teaching Model Integrating Online and Offline Instruction

Building on resource development, systematic restructuring should be undertaken at the instructional-model level. In the pre-class phase, smart teaching platforms are used to deliver preview videos and guided learning tasks, helping students prepare their knowledge. In the in-class phase, lectures, discussions, case analyses, virtual demonstrations, and hands-on experiments are organically combined to deliver three-dimensional, integrated instruction on “theory + context + operation.” In the post-class phase, online discussions, extended reading, and virtual experiment exercises promote knowledge consolidation and transfer.

It is noteworthy that blended teaching is not a simple superposition of “online + offline,” but should pursue the intrinsic linkage of theoretical instruction and experimental teaching through the thread of chemistry history contextual clues. For example, the historical discovery process of a particular chemical concept can serve as the main instructional thread: first, the historical context is presented through information technology means; next, students are guided to verify key phenomena through virtual or physical experiments; and finally, theoretical explanation is revisited—enabling students to achieve deep learning within the complete chain of “problem origin—inquiry process—knowledge generation.” This integrated teaching model, with historical contexts as the link and information technology as the support, is expected to genuinely realize the organic integration of theoretical instruction, chemistry history education, and experimental teaching.

Enhancing Teachers’ Digital Literacy and Interdisciplinary Collaborative Competencies

Teachers are the key agents in the implementation of all reform initiatives. The digital literacy of the teaching workforce should be continuously enhanced through both institutional safeguards and capacity building. In terms of institutional development, digital teaching competencies should be incorporated into teacher training systems and teaching evaluation indicators, with regular organization of information technology-themed training sessions and teaching observations, and encouragement for instructors to participate in digital teaching reform projects and competitions. Regarding training content, both the technical operational level and the instructional design level should be addressed: covering practical skills such as smart teaching platform usage, multimedia production, and data analysis, while also delving into the concepts, strategies, and cases of deep integration between information technology and the instruction of the chemistry discipline.

Meanwhile, interdisciplinary collaboration mechanisms should be actively promoted. The development of digital teaching resources often requires the collaborative efforts of chemistry educators, information technology specialists, instructional designers, and even historians. Through the establishment of interdisciplinary teaching and research teams, the setup of joint research projects, and the construction of experience-sharing platforms, the complementary integration of knowledge and skills across different fields can be facilitated, providing sustained intellectual support for digital transformation.

Conclusion

Digital information technology is reshaping fundamental chemistry education in universities with unprecedented depth. Based on existing research on the digitalization of inorganic chemistry experiments and the informatization of the history of chemistry, this paper analyzes the core advantages and practical challenges of digital empowerment and proposes an innovative implementation framework encompassing teaching resources, instructional models, evaluation systems, and teacher digital literacy.

The study suggests that digital transformation offers a systematic remedy to the long-standing issues of abstraction, resource constraints, and fragmentation in fundamental chemistry instruction. However, the empowering effects of technology are not automatic; the key lies in adhering to the principle that "technology serves educational objectives" and achieving deep integration informed by the distinctive characteristics and pedagogical logic of chemistry. Future empirical research is needed to validate the applicability and effectiveness of these pathways across diverse institutional contexts, thereby providing a more solid practical foundation for the digital transformation of fundamental chemistry courses.

References

Ghibaudi, E., Regis, A., & Roletto, E. (2020). Historical reconstruction of chemical concepts for university teaching supported by digital multimodal resources. *Journal of Chemical Education, 97*(10), 2789-2796.

Lopes, R., & Silva, C. (2026). Bridging the STEM divide: AI-assisted digital experiment design for resource-limited chemistry teaching. *Journal of Chemical Education, 103*(6), 2145-2152.

Miller, J., & Carter, P. (2024). Digital transformation of undergraduate fundamental chemistry: Avoiding technological formalism in instructional design. *Chemistry Education Research and Practice, 25*(3), 987-1001.

Olsson, M., Balgopal, M., & Levinger, N. (2015). Addressing students' misconceptions via digitized history of chemistry contextual teaching. *Science & Education, 24*(9), 1127-1148.

Shaforost, Y., Lut, O., & Shpak, V. (2026). Implementation of edutainment elements in blended chemistry learning using the chemcollective virtual laboratory. *Information Technologies and Learning Tools, 112*(2), 134-153.

Vasquez, A. (2025). Digital literacy training framework for university chemistry instructors in smart campus contexts. *Journal of University Teaching & Learning Practice, 22*(1), 1-18.

Weber, M., & Stein, A. (2023). Results of a three-year survey on electronic laboratory notebooks in advanced inorganic chemistry lab courses. *Journal of Chemical Education, 100*(8), 3210-3217.