Article

Strategy Construction and Practice Research of Embodied Teaching Integrated into Chemistry Experiment Teaching in High School

Miaomiao Jia[1], Min Zhang[1], Jinjie Qu[1], Huiya Li[1] and Tianlu Liao[1,*]

[1] School of Chemical Engineering and Technology, Tianshui Normal University, Tianshui, China
* Correspondence: Tianlu Liao, School of Chemical Engineering and Technology, Tianshui Normal University, Tianshui, China

Abstract: Under the guidance of core educational literacy, high school chemistry experiment teaching carries the critically important mission of cultivating students' scientific inquiry abilities, practical skills, and innovative consciousness. However, there is a growing tendency of "separation" and "superficialization" in current experimental teaching methodologies. Frequently, students' physical participation in laboratory settings is entirely disconnected from their underlying cognitive thinking and knowledge construction. Embodied teaching, an emerging pedagogical paradigm, emphasizes that human cognition is deeply rooted in bodily perception, sensorimotor interactions, and active physical experience. This framework provides a highly promising new perspective for comprehensive experimental teaching reform. Based on the foundational theory of embodied cognition, this study systematically analyzes the inherent pedagogical compatibility between embodied teaching principles and chemical experiment instruction. Furthermore, it critically examines the existing structural problems and limitations prevalent in current experimental teaching practices. To address these challenges, this research constructs a comprehensive five-dimensional strategy system designed to seamlessly integrate physical action with cognitive engagement. The implementation of this embodied teaching strategy demonstrates significant pedagogical benefits. It can effectively improve students' hands-on experimental operation abilities, elevate their overall scientific thinking levels, and substantially boost their intrinsic learning interest. Ultimately, this study provides a highly practical and operational path for the systematic reform of high school chemistry experiment teaching, ensuring that students achieve a more holistic and deeply integrated scientific education.

Keywords: embodied cognition; chemistry education; teaching strategies; core literacy; experimental teaching

Received: 09 April 2026
Revised: 02 June 2026
Accepted: 15 June 2026
Published: 18 June 2026

1. Introduction

At present, the ongoing advancements in basic education curriculum in China emphasize the orientation of core literacy as the fundamental guidance for teaching reform and practice across various subjects [1]. Chemistry, as a natural science rooted in experimentation, plays a pivotal role in fostering students' scientific inquiry abilities, innovative consciousness, and scientific attitudes. Experimental teaching serves as a crucial medium for generating and verifying chemical knowledge, while also cultivating practical skills such as hands-on operation, phenomenon observation, evidence reasoning, and reflective communication. Optimizing experimental teaching methods and enhancing their effectiveness are essential to achieving the core literacy objectives of the chemistry discipline.

Nevertheless, significant challenges persist in high school chemistry experimental teaching. In some classrooms, teacher demonstrations dominate, leaving students to passively observe and mechanically record, with limited opportunities for hands-on engagement and immersive experiences. Certain experimental activities remain superficial, focusing solely on verifying textbook conclusions and completing procedural tasks, without providing authentic problem-driven scenarios or spaces for independent inquiry [2]. Additionally, some educators prioritize experimental outcomes and test-oriented goals over the inquiry process, cognitive development, and innovative exploration, leading to situations where students engage in "hands but not brains" and "operation without inquiry." This approach diminishes the educational value of experiments and fails to align with the demands for cultivating innovative talents in the modern era.

Embodied cognition theory offers a novel theoretical perspective and practical approach to address these challenges. This theory posits that cognition is not merely an internal psychological activity but a process shaped through interactions with the environment, practical experiences, and situational contexts. It emphasizes experiential, situational, generative, and subjective characteristics. Chemistry experiments inherently involve cooperative engagement of the hands, eyes, and brain, along with multi-sensory integration, aligning closely with the principles of embodied teaching. Incorporating embodied teaching concepts into high school chemistry experimental instruction—by enhancing physical participation, situational immersion, interactive inquiry, and meaningful construction—can effectively stimulate students' learning initiative. This approach encourages students to "learn by doing, think by exploring, and act by creating," thereby fostering deeper scientific inquiry and innovation consciousness. Consequently, exploring strategies and conducting practical research on integrating embodied teaching into high school chemistry experiments holds substantial theoretical and practical significance [3].

2. Overview of Embodied Cognition Theory

Embodied cognition is an important theory that emerged in the field of cognitive science in the 1980s, and its formation does not depend on the contribution of a single scholar. The American philosopher George Lakoff and the linguist Mark Johnson constructed the core framework of this theory in the book The Metaphor We Live By, which has been continuously enriched and developed through various academic studies [3, 4]. Ye Haosheng, a Chinese scholar, carried out a systematic study on the theoretical connotation, experimental basis, and educational application of embodied cognition. He pointed out that embodied cognition fundamentally subverted the concept of "off-body cognition" held by traditional cognitivism, and believed that cognition is not limited to abstract symbol processing inside the brain, but the product of the interaction between brain, body, and environment. In his view, the body is not only the carrier of cognition but also an indispensable component of cognition. Its physical attributes, sensorimotor system, and interaction with the environment directly determine the nature and form of cognition. On this basis, Ye Haosheng introduced the theory of embodied cognition into the field of education, put forward the concept of "embodied education," and advocated that education should return to the real interaction between body and environment: on the one hand, he emphasized the participation of the body in learning, advocated the promotion of cognitive development through hands-on operation and personal experience, and regarded physical experience as an important foundation of knowledge generation. For example, children form basic cognition of things by touching and fiddling with physical objects; on the other hand, it attaches importance to situational learning and thinks that knowledge itself is embedded in specific situations. Education should abandon the mechanical indoctrination of abstract symbols, closely combine life reality with real scenes, and guide learners to actively construct knowledge systems in the interaction between body and environment.

3. Analysis of the Compatibility between Embodied Teaching and Chemical Experiment

Embodied teaching emphasizes physical experience, situational interaction, and the integration of action and thought, highlighting the situational, experiential, and generative aspects of cognition [5]. High school chemistry experiment teaching, centered on practical operations, exploration, and literacy cultivation, aligns naturally with these principles. The theoretical framework, practical approach, and educational objectives of both are inherently compatible, providing a robust foundation for integrating embodied teaching into high school chemistry experiment instruction.

3.1. High Compatibility of Cognitive Generative Logic

Embodied cognition theory challenges the traditional notion of isolated cognition, proposing instead that cognition arises from the interaction between the brain, body, and environment. It emphasizes that bodily perception and practical experience are fundamental prerequisites for constructing knowledge meaning. High school chemistry encompasses numerous abstract concepts, such as microscopic particle motion and the principles of chemical reactions [6, 7]. Purely theoretical instruction often fails to foster deep understanding, whereas chemistry experiments provide students with a tangible cognitive bridge. By operating instruments, observing experimental phenomena, and perceiving material transformations, students engage in the coordinated integration of hands, eyes, and brain. This process transforms abstract chemical knowledge into intuitive physical experiences, aligning seamlessly with the embodied teaching logic of "physical participation-experience perception-knowledge construction."

3.2. Natural Adaptation of Teaching Practice Forms

The core practical paths of embodied teaching are situational immersion, hands-on experience, and interactive inquiry learning, emphasizing students' active participation [8, 9]. High school chemistry experiment teaching itself represents a typical embodied practical activity. Whether it involves verifying substance properties, exploring chemical reactions, or conducting organic matter preparation experiments, students are required to actively engage in experimental operations and utilize multi-sensory perception throughout the process. This entire process integrates physical actions and cognitive thinking simultaneously, aligning seamlessly with the practical principles of embodied teaching, which emphasize the "symbiosis of doing and thinking and interaction of situations." Together, these elements enable the natural integration of theoretical concepts and practical application.

3.3. Working in the Same Direction as the Core Education Goal

Under the new curriculum standard, the core educational goal of high school chemistry experiment teaching is to guide students to experience the process of scientific inquiry, cultivate scientific inquiry ability and innovative consciousness, and implement the requirements of cultivating the core literacy of the chemistry subject. Embodied teaching abandons traditional indoctrination methods, prioritizes the development of students' subjectivity, and emphasizes enhancing students' thinking ability, practical skills, and innovative spirit through hands-on experience and reflective inquiry. The educational value orientation and literacy cultivation goals of both approaches are closely aligned, focusing on the holistic development of students and the implementation of core literacy, thereby achieving deep compatibility between teaching philosophy and educational objectives [10].

3.4. Deep Integration of Essential Attributes of Disciplines

Chemistry is a natural science grounded in experimentation. Experimentation serves as the core characteristic of chemistry and is the fundamental method for students to comprehend chemical laws and the essence of the subject. The discipline itself is highly practical and exploratory. Embodied teaching, which emphasizes the integration of learning, real-world scenarios, and hands-on practice, aligns closely with the experimental nature of chemistry. This approach effectively addresses the limitations of traditional experimental teaching, such as prioritizing observation over hands-on practice and focusing on outcomes rather than processes. By engaging students in embodied experiences, it facilitates a deeper understanding of chemistry and achieves a cohesive alignment between teaching methodologies and the intrinsic attributes of the discipline.

4. The Strategy Construction of Incorporating Embodied Teaching into High School Chemistry Experiment Teaching

The Five-Dimensional Embodied Teaching Strategy System integrates the core principles of embodied cognition theory with the specific requirements of high school chemistry experiment teaching. Centered on fostering students' embodied experiences, knowledge construction, and literacy development, this system outlines five targeted implementation strategies. These strategies aim to achieve a seamless integration of embodied teaching methods within the context of chemistry experiments, enhancing both educational depth and practical engagement (As shown in Figure 1).

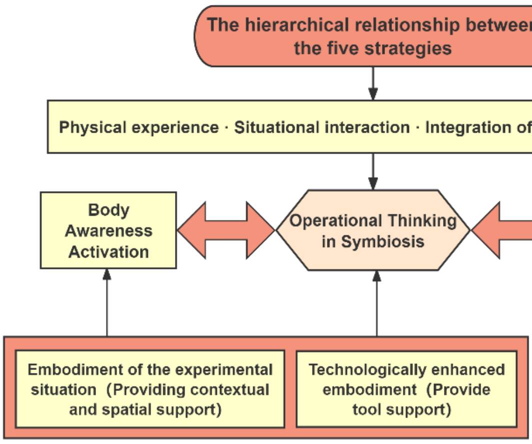

Figure 1. Logical Hierarchical Relationship of Embodied Teaching Strategies

4.1. Body Perception Activation Strategy

Body perception serves as the foundation of embodied cognition and is essential for students' comprehension of chemical knowledge. This strategy emphasizes activating students' multi-sensory perception, moving beyond the traditional teaching approach of merely "listening to experiments and observing experiments." In experimental teaching, students are encouraged to engage multiple senses, such as vision, touch, and smell, to perceive the states of experimental substances, observe changes in experimental phenomena, and understand reaction processes comprehensively. By doing so, the body becomes a central medium for cognition. For instance, students can be guided to handle experimental instruments, feel temperature changes in substances, observe variations in color and state, and detect gas odors (ensuring adherence to standard safety protocols). Through this multi-sensory engagement, abstract chemical principles are transformed into tangible bodily experiences. Additionally, by linking body movements with experimental operations, students can begin to form chemical concepts through perception, strengthen the connection between theoretical knowledge and physical experience, address the challenges of abstract chemical concepts, and solidify the cognitive foundation necessary for experimental learning.

4.2. Embodiment Strategy of Experimental Situation

Situations serve as a crucial medium for embodied teaching. The strategy of experimental situational embodiment focuses on creating authentic, immersive, and contextually relevant experimental inquiry scenarios that align with students' real-life experiences. This approach moves beyond the monotonous and isolated experimental contexts found in traditional teaching materials by integrating elements such as real-life applications, societal issues, historical developments in chemistry, and industrial production processes. For instance, inquiry experiments can be designed around scenarios like scale removal or food preservation, leveraging the experimental discovery process in chemical history to replicate inquiry methods, or simulating simplified chemical production processes for hands-on experimentation. By constructing embodied situations, students' interest in experimental inquiry is heightened, enabling them to formulate questions within these contexts, define clear experimental objectives, and actively engage in the entire experimental process. This fosters a deep interaction between the situation and learning, as well as between the body and the environment, ultimately making experimental learning more focused and effective.

4.3. Operational Thinking Symbiosis Strategy

This strategy represents the core approach to integrating embodied teaching into chemical experiments, emphasizing the combination of practical operation and rational thinking. It addresses the traditional issue of prioritizing operation over cognitive engagement, aiming to achieve synchronized advancement and balanced development of experimental skills and analytical reasoning. In experimental teaching, mechanical step-by-step procedures are replaced with a guided process that encourages students to think critically, analyze, reason, and reflect while engaging in hands-on activities. Prior to the experiment, students are encouraged to independently consider the experimental principles and design their own experimental plans based on situational problems. During the experiment, they observe phenomena, record data, and analyze the causes of experimental changes concurrently with their operations. After the experiment, students engage in deeper reflection, logical reasoning, and summarization based on the results and any anomalies observed. By implementing the closed loop of "operation-observation-thinking-correction," students integrate physical actions with cognitive processes, fostering logical, inquiry-based, and innovative thinking [11]. This approach enables students to truly "think while doing and do while thinking," thereby cultivating core competencies in scientific inquiry and innovative consciousness.

4.4. Technology-Enhanced Embodied Strategies

Modern educational technology enables the overcoming of limitations inherent in traditional chemistry experiments, enhancing both the scope and depth of embodied learning experiences while optimizing teaching outcomes. By leveraging tools such as virtual simulation platforms, micro-visualization technologies, and digital sensors, complex, abstract, or high-risk experiments can be transformed into accessible, interactive, and visualized learning activities. For instance, virtual simulations allow students to safely conduct high-risk experiments, while microscopic animations illustrate the movement of particles during chemical reactions. Additionally, pH and temperature sensors provide real-time data visualization, enriching the experimental process. These technological advancements address the challenges of limited hands-on practice and the invisibility of microscopic phenomena in traditional methods. They extend the boundaries of students' experiential learning, enabling a more comprehensive understanding of experimental principles. This seamless integration of tangible experiences with abstract concepts enhances the innovation and effectiveness of experimental teaching.

4.5. Embodied Evaluation Strategy

To align with the principles of embodied teaching, a pluralistic evaluation system should be established, moving beyond the traditional single evaluation model that prioritizes results over processes in experimental teaching [12, 13]. This approach emphasizes process-oriented, developmental, and diverse embodied evaluations. The evaluation framework considers various aspects, including the standardization of students' experimental operations, physical engagement, situational inquiry performance, cognitive development, innovative practical skills, and collaborative interaction. Evaluation subjects encompass teacher assessments, student self-evaluations, and group peer evaluations, ensuring a comprehensive reflection of students' experimental learning journey. The evaluation methodology spans the entire experimental process—before, during, and after—focusing on students' performance in embodied experiences, inquiry operations, cognitive development, reflection, and improvement. By implementing embodied evaluation, educators can provide holistic and objective feedback on students' learning outcomes, encouraging active reflection and continuous improvement. Simultaneously, it offers teachers valuable insights to refine teaching strategies, achieving the dual goals of "promoting learning through evaluation and enhancing teaching through evaluation," thereby fostering the sustainable development of embodied experimental teaching (As shown in Figure 2).

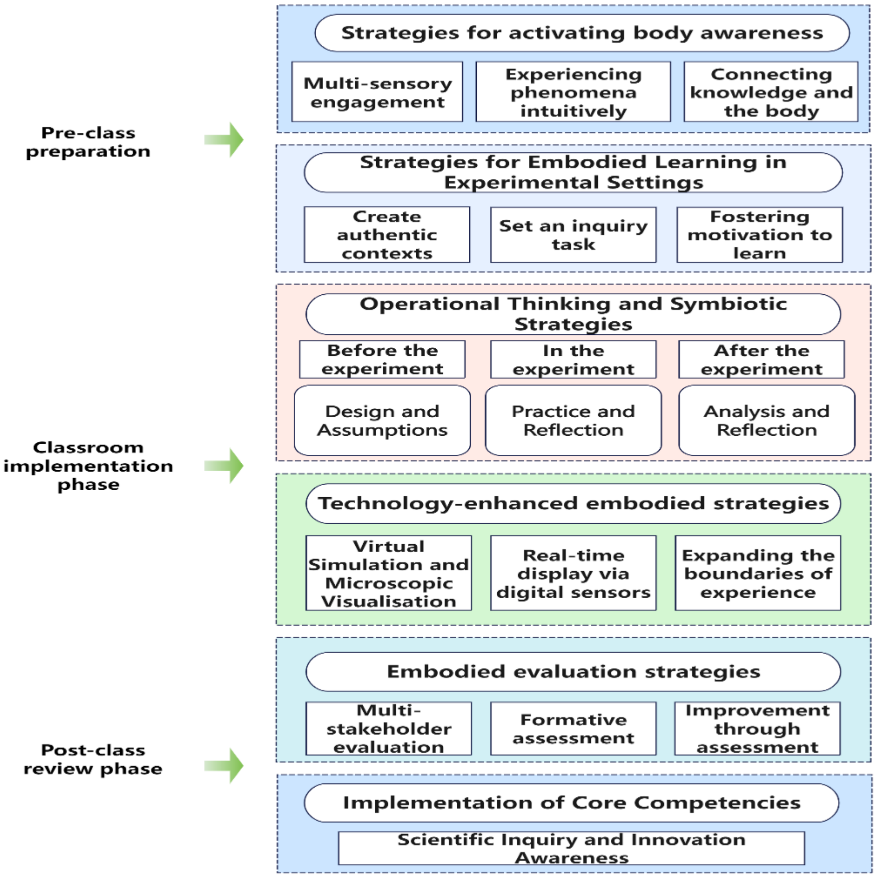

Figure 2. Embodied Teaching Is Integrated into High School Chemistry Experiment Teaching Strategy

5. The Practical Significance of Incorporating Embodied Teaching into the Reform of High School Chemistry Experiment

Under the context of the new curriculum standard emphasizing the cultivation of core literacy and the shift from knowledge-based to ability-based teaching, integrating the concept of embodied teaching into high school chemistry experiment instruction holds significant practical value [14]. It addresses current challenges in experimental teaching, optimizes classroom methodologies, and fosters the development of students' core chemistry literacy.

First, it helps resolve the challenges of traditional chemistry experiment teaching. Presently, high school chemistry experiment classrooms face issues such as excessive teacher demonstrations, limited student practice, overemphasis on experimental results, and insufficient focus on the inquiry process. Students often engage in passive observation and rote memorization, lacking meaningful experiences and critical thinking. The introduction of the embodied teaching model can actively engage students' multiple senses in the experimental process, enabling them to gain direct experience through hands-on activities, personal perception, and immersive scenarios.

Secondly, it facilitates the transformation of experimental classrooms into environments that integrate "doing and thinking," thereby enhancing students' scientific inquiry abilities. Embodied teaching emphasizes the simultaneous development of physical actions and cognitive activities, advocating for the construction of knowledge and the cultivation of thinking through practical experiences. Applying this approach to chemistry experiments can guide students to observe during operations, think through experiences, and reason during inquiries. This breaks the limitations of traditional experiments that focus on "hands but not brain," fostering the development of scientific thinking patterns such as evidence-based reasoning, experimental inquiry, and innovative questioning. This approach effectively supports the goal of cultivating core competencies in scientific inquiry and innovation.

Third, it enriches the teaching methods of high school chemistry experiments and broadens the scope of classroom education. By employing strategies such as situational embodiment, operational embodiment, technological embodiment, and diverse evaluations, experimental teaching evolves beyond simple verification tasks. It adopts a multidimensional approach that includes situational engagement, physical participation, in-depth inquiry, technological integration, and comprehensive evaluation. This not only enhances the relevance and applicability of chemistry lessons by incorporating real-life contexts but also leverages modern technology to address challenges in high-risk or microscopic experiments. Consequently, it expands teaching resources, optimizes classroom structures, and improves the overall quality of education.

Fourth, it supports the development of a comprehensive experimental evaluation system, promoting students' individualized and holistic growth. Traditional experimental evaluations often focus solely on results and reports, neglecting students' experiential processes, cognitive development, and inquiry efforts. The process-oriented and diverse evaluation methods inherent in embodied teaching emphasize students' operational performance, engagement, inquiry thinking, and innovative behaviors. By respecting individual learning differences and emergent performances, this approach uses evaluation to enhance learning, thinking, and creativity, fostering the long-term development of scientific attitudes and a scientific spirit.

Fifth, it provides a replicable and practical paradigm for experimental teaching reform that frontline chemistry teachers can adopt [3]. The five-dimensional embodied teaching strategy system proposed in this study aligns with the real learning contexts and teaching practices of high school chemistry experiment classrooms. With clear pathways and strong operability, it offers practical guidance for teachers to implement experimental teaching reforms focused on literacy development. This paradigm facilitates the transformation of high school chemistry experiment classrooms from "knowledge transfer" to "literacy generation."

6. Summary and Outlook

Based on embodied cognition theory, this study addresses the practical problems of separation, superficiality, single-scenario application, and rigid evaluation in current high school chemistry experiment teaching, and systematically develops teaching strategies and conducts classroom practice research. The findings indicate that the principles emphasized by embodied teaching, including physical experience, situational interaction, and the integration of action and thinking, are highly consistent with the practical, exploratory, and generative characteristics of chemistry experiments, demonstrating strong theoretical relevance and disciplinary suitability. On this basis, the study constructs a five-in-one teaching strategy system that forms a closed-loop instructional pathway from situational introduction and physical participation to inquiry-based thinking and multidimensional evaluation. The results of teaching practice show that this strategy can effectively improve students' shallow learning characterized by passive observation and mechanical operation, significantly enhance experimental participation, inquiry thinking ability, and learning initiative in chemistry, and provide clear practical value for cultivating the core competencies of high school chemistry and promoting the continued improvement of experimental classroom teaching.

Although this research has achieved certain practical results, several limitations remain. The duration of the teaching practice, the scope of the research sample, and the broader applicability of embodied teaching strategies still require further verification. At the same time, the study mainly focuses on routine classroom experiments, with relatively limited attention to comprehensive innovative experiments and project-based experimental teaching contexts, and it does not yet provide hierarchical or differentiated embodied teaching schemes for students with different academic levels. In view of these limitations, future research may further expand the range of practice, extend the research cycle, and continuously refine and optimize the teaching strategy system. It may also integrate emerging instructional models such as large-unit teaching, project-based learning, and interdisciplinary inquiry to explore more precise and diversified implementation pathways for embodied experimental teaching, further improving the application framework of embodied cognition theory in high school chemistry experiment teaching and providing stronger practical support and reference for the ongoing development of chemistry experiment instruction from the perspective of core competencies.

Funding: The Graduate Innovation Project of Tianshui Normal University in 2025 "Model Construction of Virtual Reality Technology Deeply Integrated into Chemistry Experiment Teaching in Middle School" (Project No.: TCXM2536); 2026 Gansu Provincial University Postgraduate "Star of Innovation" Program (Project No.: 2026CXZX-989)

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