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RESEARCH ON PRIMARY SCHOOL SCIENCE EXPERIMENT TEACHING BASED ON LITERACY GOALS

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ABSTRACT

Primary school science experiments are crucial methods and pathways for achieving literacy goals. They play a significant role in cultivating primary school students' interest and thinking in science, enhancing their understanding of scientific concepts, and mastering scientific laws. However, the current state of primary school science experiment teaching is far from satisfactory. Students find it challenging to "learn by doing" and "think while learning" during science experiments. Primary school science teachers should focus on cultivating students' scientific literacy as their primary goal. This involves clarifying the connotation and characteristics of experiments, making comprehensive plans for experiment teaching, selecting appropriate teaching content, innovating experimental teaching designs, and implementing diverse evaluation methods. These measures are essential to achieving the literacy goals of primary school science experiment teaching.

KEYWORDS: *Literacy Goals, Primary School Science, Experimental Teaching, Science Teachers*

1. INTRODUCTION

In 2019, the Ministry of Education of the People's Republic of China issued the *Opinions on Strengthening and Improving Experimental Teaching in Primary and Secondary Schools*, stating that experimental teaching is a vital component of the national curriculum plan and standards. It serves as an essential means of cultivating innovative talents. The *Compulsory Education Science Curriculum Standards (2022)* (hereinafter referred to as the "new curriculum standards") further emphasize the importance of science experiment teaching. These standards advocate diverse teaching methods based on inquiry and practice, requiring a total of 78 mandatory science experiments at the primary school level (Ministry of Education of the People's Republic of China, 2022), including 13 for Grades 1-2, 31 for Grades 3-4, and 34 for Grades 5-6.

However, primary school science teachers face numerous challenges when dealing with the science experiments outlined in the curriculum. Questions such as the connotation and characteristics of primary school science experiments, how to select suitable content for these experiments, and how to effectively cultivate students' scientific literacy through experimental teaching are critical topics that warrant in-depth exploration.

2. CHALLENGES IN PRIMARY SCHOOL SCIENCE EXPERIMENT TEACHING

Research indicates that the current state of primary school science experiment teaching is far from satisfactory. Nearly 40% of primary school science teachers rarely use laboratories, and only 46.8% of students frequently engage in hands-on experiments (Wang & Lin, 2021). Many teachers neglect teaching objectives during scientific inquiry, reducing inquiry elements to procedural steps without fostering higher-order thinking skills in students (Cai, 2023). In some cases, experiment teaching is rushed, limiting students' autonomy (Wang, 2014). Moreover, experimental teaching often lacks innovation due to rigid adherence to textbook arrangements (Hu, 2022). Incomplete understanding of experiments among teachers leads to poorly designed experimental content (Wang, 2017).

Many science teachers lack professional knowledge in science education, which hinders their ability to integrate interdisciplinary knowledge and implement diverse inquiry-based practices in teaching (Wang, 2023). Frequently, teachers replace hands-on experimental processes with simple demonstrations or video presentations,

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overemphasizing the validation of laws and principles. This approach, akin to "prescription-following“, eliminates the need for student exploration (Wang, 2015, p. 66). Additionally, 31.4% of students demonstrate low confidence in learning science despite showing high interest (Education Quality Monitoring Center of the Ministry of Education, 2021). Some experiments remain superficial, with weak inquiry elements (Ma, 2011), resulting in students' poor hands-on abilities, limited firsthand experience, and a lack of independent thinking. Consequently, this inhibits their ability to apply scientific knowledge and skills in practice.

The factors affecting the effectiveness of primary school science experiment teaching are multifaceted. The primary issue is teachers' insufficient understanding of experimental connotations, which leads to a dilution of teaching objectives and neglect of students' scientific thinking development. As a result, students struggle to "learn by doing“ "think while learning“, and "create through thinking".

Primary school science experiments span a broad scope, encompassing knowledge in physical sciences, life sciences, Earth and space sciences, as well as engineering and technology. Although experimental teaching resources are diverse, insufficient emphasis by teachers limits their willingness to invest time and effort in exploring beyond the textbooks. Rigidly following textbook-prescribed experimental steps and methods stifles creativity, undermines teaching goals, and diminishes novelty and engagement. Studies show that hands-on experiments can significantly improve students' science achievement (Education Quality Monitoring Center of the Ministry of Education, 2021).
Primary school science experiments are characterized by foundational, practical, and integrative traits. Experimental materials should closely relate to students' daily lives. Pursuing novelty in form should not come at the expense of guiding and exploring scientific questions. Teachers who fail to bridge the gap between sensory experimental phenomena and abstract scientific concepts or lead students to systematic recognition through task-driven or inquiry-based approaches will ultimately fall short of the teaching goal: cultivating students' scientific literacy.

3. CONNOTATION AND CHARACTERISTICS OF PRIMARY SCHOOL SCIENCE EXPERIMENTS

3.1 Connotation of Primary School Science Experiments

Experimentation is a fundamental scientific research method. When integrated into the curriculum, it becomes both a teaching and learning approach. Science experiments represent a practical way of exploring nature and a methodology for scientific inquiry. According to the *Philosophy* volume of the *Chinese Encyclopedia*, a scientific experiment is defined as "a scientific method in which humans study an object under artificially controlled conditions to achieve a predetermined purpose. It is a practical form through which humans acquire and verify knowledge" (Editorial Committee of the Encyclopedia of Philosophy of the Chinese Encyclopedia, 2002, pp. 410-411). Similarly, the *Ci Hai* dictionary defines scientific experiments as "a social practice form that, for a specific purpose, utilizes certain instruments, equipment, and other material means under artificially controlled conditions to observe and study natural phenomena and their regularities" (Wang, 2015, p. 18).

Science experiments enable students to gain both sensory and conceptual understanding and serve as a key method for testing scientific hypotheses and theories (Zhao, 2013, p. 6). These definitions establish that scientific experiments are purpose-driven practical activities involving the use of specific equipment to observe and investigate natural phenomena. Experiments have become a vital aspect of quality and innovative education. The innovation of science curricula often uses experiments as an entry point and a breakthrough method (Wang, 2015, p. 2). Furthermore, science experiments significantly contribute to the holistic development of students' scientific literacy (Wang & Lin, 2021). In primary schools, science experiments play a critical role in fostering students' interest in science, training their scientific thinking methods, and enhancing their understanding of scientific concepts and laws (Zhao, 2013, p. 10).
The goal of science curricula is to develop students' core literacy, defined as the proper values, essential character, and key competencies required for lifelong personal and social development (Ministry of Education of the People's Republic of China, 2022). Scholar Lin Chongde emphasizes that literacy involves interdisciplinary and integrative learning, representing a comprehensive expression of knowledge, abilities, and attitudes formed through education (Lin, 2018, p. II). Among the 35 subject standards investigated in China's basic education phase, learning literacy is the most frequently mentioned, followed by language literacy and scientific literacy, demonstrating the importance attached to scientific literacy.

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Scientific literacy, as the overarching goal of science education, is guided by four dimensions: scientific concepts, scientific thinking, inquiry practices, and responsible attitudes. These dimensions provide fundamental principles for primary school science experiment teaching. The connotation of scientific literacy continues to expand, encompassing not only basic knowledge and skills but also a deep interest in and rigorous attitude toward science, emphasizing the cultivation of inquiry methods and critical thinking (Wang, 2023). Based on the four-dimensional goals outlined in the new curriculum standards, this study proposes a four-dimensional framework for teaching primary school science experiments, as shown in Figure 1.

Science experiments serve as essential tools for constructing scientific concepts and principles, understanding and mastering scientific knowledge, and cultivating observational, experimental, practical, logical, and creative thinking abilities—critical aspects of scientific inquiry.

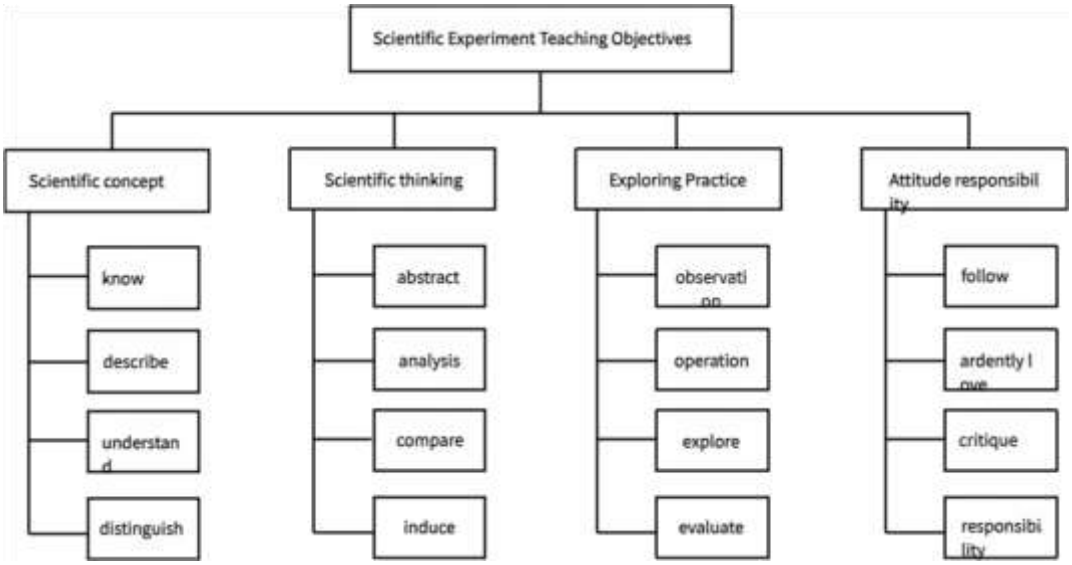

Figure 1. Four-Dimensional Goals of Primary School Science Experiment Teaching

3.2 Characteristics of Primary School Science Experiments

Science experiments are commonly categorized based on their characteristics. Zhao Jiming classifies experiments into two main types according to their complexity: fundamental process skills experiments and integrated process skills experiments. Fundamental process skills experiments include activities such as observation, measurement, and classification, while integrated process skills experiments encompass exploratory experiments, confirmatory experiments, simulation experiments, and production-based experiments (Zhao, 2013, pp. 15-20). Lin Changchun and Peng Shujin classify primary school science experiments into four types based on their purpose, difficulty level, and main features: observation experiments, confirmatory experiments, exploratory experiments, and design-and-production experiments (Lin & Peng, 2019, pp. 78-81).

The complexity of these experiments increases progressively from observation experiments to design-and-production experiments, reflecting a transition from fundamental science process skills to more integrated skills. Observation experiments primarily involve using sensory organs or tools to directly observe, measure, classify, and record the characteristics of research objects, followed by describing or comparing results. For example, observing a snail is a typical observation experiment. Confirmatory experiments involve understanding or hypothesizing specific scientific phenomena or questions, followed by simple experimental processes to verify the accuracy of these hypotheses, such as learning to use a compass to determine direction.

Exploratory experiments require employing specific methods or techniques to analyze and judge the intrinsic properties or fundamental laws of research objects. For instance, connecting a simple circuit to determine the cause of a bulb's failure is an exploratory experiment. Design-and-production experiments emphasize searching for

materials, designing, and creating models or simulating scenarios with specific functional attributes. Examples include building a periscope or simulating rainfall processes.
As students progress from observation experiments to design-and-production experiments, the complexity of the tasks increases, enhancing their cognitive levels. This progression also marks the shift from mastering hands-on practical operations to strengthening scientific thinking.

Science experiments constitute a crucial component of primary school science curricula and practical activities, characterized by their "foundational“, "practical“, and "integrative" nature. The materials for these experiments are typically derived from everyday life and are relatively simple. However, they incorporate humanity's constructed understanding of nature and embed methods and skills of scientific inquiry.

To maximize the potential of each science experiment, teachers must deeply understand the concepts and principles outlined in the new curriculum standards. They should grasp the characteristics and rules of science experiments, design and plan them appropriately based on students' cognitive development, and creatively modify textbook experiments when necessary. These efforts can make experiments more engaging, help students acquire knowledge effectively, build problem-solving skills, and ultimately achieve the goal of fostering scientific literacy—the core aim of science education.

4. SUGGESTIONS FOR IMPROVING PRIMARY SCHOOL SCIENCE EXPERIMENT TEACHING

4.1 Align with Curriculum Standards and Develop Comprehensive Planning

Comprehensive planning is the foundation for effective science experiment teaching in primary schools. First, science teachers must adhere to the scientific literacy principles outlined in the new curriculum standards, thoroughly understanding the core concepts and objectives of primary science education. Teachers should reference the mandatory experiments specified for Grades 1-6 in the new curriculum standards to plan and design science experiments systematically. This involves clearly defining the teaching goals and requirements for different grades and thematic units, clarifying the relationships between experiments, and categorizing them accordingly.

Science teachers should select experimental content based on specific teaching objectives and the progressive learning stages of students, adhering to the principle of "fewer but better". Teachers should avoid attempting to cover every aspect of scientific knowledge comprehensively and instead focus on integrating scientific thinking skills and problem-solving abilities into their teaching.

Science education should not impart fragmented, abstract theories and facts disconnected from daily life. Instead, it should help children construct a comprehensive understanding of the world (Wynne Harlen, Trans. Wen & Wei, 2011). Primary school science experiment teaching should align with students’ cognitive development stages, progressing from simple to complex and from superficial to deep understanding.

For lower grades, observation-based experiments should dominate, helping students form initial perceptions of scientific facts and concepts. These activities encourage children to use their sensory organs to perceive and experience their surroundings. For example, in the "Objects Around Us" unit, students can use observation and measurement to understand the basic properties of substances like water and air, fostering the awareness that "science is everywhere" and "science is enjoyable".

In contrast, for middle and upper grades, more focus should be placed on confirmatory, exploratory, and design-and-production experiments. As students’ cognitive abilities and logical thinking develop, they are better able to recognize the application of knowledge in real-world and societal contexts. This enhances their participation, initiative, and autonomy. For instance, in the "Sinking and Floating" unit, beyond verifying whether objects sink or float, students can learn about China’s development of underwater gliders for marine exploration. This approach not only stimulates interest in new technological achievements but also underscores the practical value of scientific knowledge in everyday life.

4.2 Clarify the Connotation of Science Experiments and Innovate Teaching Methods

Science teachers should classify each experiment in the curriculum and clearly define its objectives. Observation-based experiments rely on sensory perception (Ye, 2013). In designing these experiments, teachers can use simple methods such as analogy, induction, and deduction to deepen students' understanding of scientific concepts. Confirmatory experiments often involve hypotheses about unknown scientific problems, with experiments designed to verify the accuracy of these hypotheses. Examples include testing whether objects sink or float and using a compass to identify directions. Context creation and problem-driven approaches can guide students to think critically and explore actively.

Exploratory experiments, similar to confirmatory ones, are conducted when scientific questions are unclear. These experiments aim to discover the underlying principles or laws of scientific problems through experimentation, analysis, and judgment. Exploratory experiments are more complex and comprehensive than confirmatory ones. Examples include investigating the nutritional content of food, analyzing the primary components of soil, and examining the magnetic properties of materials. Such experiments help students understand the relationship between scientific phenomena and their essential principles and recognize multiple influencing factors behind these phenomena.

Design-and-production experiments emphasize the flexible application of scientific knowledge through model design and creation. These involve advanced scientific process skills, such as simulating the formation of rain, wind, and earthquakes, or constructing bridge models. These activities require significant hands-on practice, enabling students to achieve a deeper understanding of scientific knowledge.

Science experiments should not be limited to "teacher demonstrations and passive student observation". Teachers must creatively adapt textbook experiments, emphasizing student agency. Through collaboration and interaction, students can achieve deeper understanding and critical thinking about scientific knowledge, truly realizing the principles of "learning by doing“, "thinking while learning“, and "creating through thinking".

Teachers must align the objectives of science experiments with students’ cognitive development and innovate experimental methods to balance difficulty and engagement. The use of science laboratories should be prioritized, with local production and daily life resources effectively integrated to provide authentic scientific learning environments. Digital resources, such as online science learning kits and educational games, should also be utilized to offer students diverse perspectives on scientific phenomena.

Moreover, experiments should not be confined to laboratories or classrooms. Activities can extend to campuses, science activity centers, fields, or parks, encouraging students to "do science" beyond traditional settings. This broadens their experiential learning opportunities and fosters a deeper connection to scientific exploration.

4.3 Emphasize the Evaluation of Science Experiments to Improve Teaching Quality

Evaluation is a critical measure to ensure high-quality curriculum teaching and a key driver of continuous innovation in science experiment instruction. The evaluation of science experiment teaching should follow a "literacy-oriented" approach to improve the quality of science courses. It is necessary to move beyond traditional single-outcome evaluations and instead emphasize process-based and multidimensional evaluations.

Before conducting science experiments, diagnostic evaluations should be carried out to understand students' prior knowledge and experiences. During the experiment, formative assessments should be prioritized, with attention paid to students' performance in expression, collaboration, and operations. Teachers should provide timely guidance on students' misconceptions and pay special attention to their creative ideas. After the experiment, teachers should consciously align their teaching activities with the new curriculum standards, conducting reviews and reflections. Tools such as electronic feedback forms can be used to collect and analyze students’ cognitive states during the experiment, including their interests, intentions, challenges, understanding of scientific concepts, and ability to transfer or apply knowledge.

Leveraging digital and media technologies, teachers can collect and organize data from multiple evaluation sources. On one hand, this helps verify whether the objectives of science experiment teaching have been met and enables reflection on the appropriateness of experiment designs. It also supports differentiated instruction in subsequent

teaching phases, such as selecting experimental content, gathering materials, and innovating teaching methods. On the other hand, these evaluations enable teachers to address individual student differences. Based on the results, targeted post-experiment interventions can be implemented to assist specific students in bridging knowledge gaps.
In alignment with the current "Double Reduction" policy for primary and secondary education and the call to "add" to science education, rich and diverse activities can be incorporated into science experiment teaching. These include societal science topics, small-scale technological projects, science observation journals, and science-themed creative performances. By combining evaluations from teachers, peers, and parents, a multidimensional evaluation system can be established. This system should aim to motivate and promote students' progress while enhancing the quality of primary school science experiment teaching.

5. CONCLUSION

The importance of science experiments in cultivating scientific literacy among primary school students cannot be overstated. The quality of science teachers' experimental instruction directly determines whether the teaching objectives of primary school science experiments are achieved. This study's in-depth exploration of the characteristics and types of primary school science experiments provides valuable guidance for teachers to reassess the importance of science experiments. It also offers a reference for exploring effective teaching methods in primary school science experiments.

The findings of this study enrich domestic and international research on primary school science experiment teaching and provide insights for the pre-service and in-service training of primary school science teachers. However, further exploration, combined with specific case studies, is needed to effectively implement different types of primary school science experiment teaching.

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Zhao Shudong (1981–), male, born in Nanyang, holds a Ph.D. in Science Education. He is a lecturer whose primary research focuses on science education.

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