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Research on the Implementation Strategies of Chemistry Science Popularization for Lower Grades in Primary Schools

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Abstract: Chemistry science popularization for lower grades (Grades 1–2) in primary schools is an important part of science enlightenment education. However, in practice, it generally faces practical dilemmas such as insufficient content adaptability, a single implementation method, and a lack of coordination mechanisms. Based on Piaget's Cognitive Development Theory and the STSE (Science, Technology, Society, Environment) educational concept, this study constructed a four-in-one strategy system of "content development–teaching implementation–collaborative linkage–guarantee support" through literature analysis, action research, and empirical comparison. An empirical study was conducted in two primary schools for one academic year. The results show that this strategy system can increase students' interest in participating in chemistry science popularization by 42 percentage points, the compliance rate of observation ability reaches 85%, and the collaborative participation of families, schools, and society rises to 85%. The core strategies formed in the study, including "age-appropriate content screening, interactive teaching implementation, three-dimensional collaborative promotion, and full-process guarantee support," provide a replicable practical model for the standardized and efficient development of chemistry science popularization for lower grades in primary schools. They also offer empirical references for fulfilling the requirement of "strengthening the pertinence and effectiveness of science popularization" in the Law of the People's Republic of China on Popularization of Science and Technology (revised in 2024).

Keywords: Lower grades in primary schools; Chemistry science popularization; Implementation strategies; Science enlightenment; Collaborative education

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1. Introduction

The phased characteristics of science enlightenment education determine that the lower grades of primary school (for students aged 6–8) are a critical window period for cultivating scientific interest and thinking. The

Primary School Science Curriculum Standards for Compulsory Education (2022 Edition) advances the starting grade of the science curriculum to the first grade, among which the "material science" field explicitly includes chemical enlightenment content such as "properties and changes of substances," accounting for approximately 30% of the total class hours [1]. The Law of the People's Republic of China on Popularization of Science and Technology (revised in 2024) further emphasizes that "science popularization work should conform to the cognitive characteristics of groups at different age stages and adopt accessible and vivid methods." These two policies together provide an institutional basis for the systematic development of chemistry science popularization for lower grades in primary schools [2]. Therefore, systematically exploring the implementation strategies of chemistry science popularization for lower grades in primary schools can not only fill the gap in practical guidance in this field but also provide important support for the connection of science enlightenment education across school stages and the improvement of its quality, which has distinct theoretical value and practical significance.

2. Content development strategy: Age-appropriate, engaging, and safe three-dimensional screening

2.1. Age-appropriate screening: Focusing on cognitive characteristics

Based on Piaget's theory, content must adhere to the "Three No Principles": no introduction of abstract concepts, no involvement of complex logic, and no requirement for standardized expression. Specifically, content is delivered through two types of activities: "phenomenon observation" and "simple operation":

(1) Phenomenon observation: Select visible chemical phenomena in daily life, such as "leaves turning yellow," "iron rusting," and "milk spoiling." Preliminary cognition is built through "looking, touching, and smelling" (under safe conditions);

(2) Simple operation: Design operational activities with ≤ 3 steps, such as "sugar dissolution" (adding sugar → stirring → observing) and "red cabbage juice color change" (juicing → adding vinegar/alkali → observing color changes) [3].

2.2. Engagement-oriented transformation: Enhancing participation motivation

Drawing on the "analogical transformation method" from UK projects, scientific content is integrated into games, stories, and daily-life scenarios:

(1) Gamified design: For example, the "Dissolution Game" — add different substances (sugar, salt, sand) to water and let students "find the missing partners"; the "Color Magic"—use red cabbage juice to test the color changes of different liquids, allowing students to act as "little chemical magicians";

(2) Storytelling packaging: Adapt experimental processes into short stories, such as "The Journey of Little Water Droplets" (three states of water change) and "The Disappearance of Little Sugar Babies" (dissolution phenomenon), to boost interest through role engagement;

(3) Daily-life connection: Design content based on daily scenarios, such as "Mom's Kitchen" (observing flour fermentation) and "Little Cleaning Helper" (comparing the number of bubbles between soap and washing powder) [4].

2.3. Safety verification: Consolidating the implementation baseline

A three-in-one safety verification mechanism covering "materials, operations, and environment" is established:

(1) Material safety: With reference to BASF (Germany) standards, food-grade materials (e.g., white sugar,

flour, red cabbage) are prioritized. The Negative List for Low-Level Chemical Science Popularization Materials is formulated, explicitly prohibiting alcohol, strong acids, strong alkalis, sharp tools, and other hazardous items;

(2) Operational safety: High-risk operations such as heating and grinding are avoided. For instance, the "egg boiling" experiment is modified to "observing Mom boiling eggs" instead of being conducted by students themselves [5];

(3) Environmental safety: Anti-slip mats and round-edged tables are installed in the experiment area, and cleaning supplies such as wet wipes and trash bins are provided to prevent risks like accidental ingestion of materials and slippery tabletops.

2.4. Modular integration: Forming a content system

Based on the above screening criteria, four thematic modules are constructed. Each module contains 3–5 activities and adopts a spiral design of "K1 Basic Version – K2 Advanced Version" (see **Table 1**).

Table 1. Design of low-level chemical science popularization content modules for primary schools

Thematic module	K1 Basic Version activity design	K2 Advanced Version activity design	Scientific core
Food chemistry	1. Observation of sugar/salt dissolution 2. Observation of fruit discoloration after cutting	1. Comparison of flour fermentation (with yeast vs. without yeast) 2. Observation of changes in eggs before and after boiling	Substance dissolution / state change
Cleaning chemistry	1. Formation of soap bubbles 2. Surface tension of water	1. Comparison of the number of bubbles from different detergents 2. Simple stain removal experiment (cleaning oil stains on cloth)	Surface tension / emulsification
Natural chemistry	1. Recording the process of leaves turning yellow 2. Observation of iron rusting	1. Red cabbage juice discoloration experiment 2. Relationship between seed germination and water	Substance change / acid-base reaction
Material chemistry	1. Comparison of water absorption of different papers 2. Waterproof test of fabrics	1. Color change of mixed plasticine 2. Floating and sinking experiment of different materials	Material properties / substance mixing

3. Teaching implementation strategy: Three-stage interaction of "situation-inquiry-expression"

The implementation of teaching should break through the traditional "teacher demonstration-oriented" model and build a three-stage interactive process of "situation creation–inquiry implementation–expression and sharing." Each link should match the cognitive characteristics of low-level students.

3.1. Situation creation: Stimulating inquiry interest

Situation is the starting point of inquiry, which needs to be created through three steps: "real object display–problem-driven–task introduction":

(1) Real object display: Present daily-life objects, such as "a cut apple (one half turns brown due to oxidation, the other half remains unchanged)" and "a rusted iron nail and a new iron nail." Visual contrast is used to create cognitive conflict.

(2) Problem-driven: Raise simple questions, such as "Why does the apple turn brown?" and "Why does the

iron nail rust?” The questions should conform to the principle of “perceivable and investigable” and avoid abstract questions (e.g., “What is an oxidation reaction?”).

(3) Task introduction: Transform the inquiry into specific tasks, such as “Today, we will act as ‘little detectives’ to find out the secret of the apple turning brown.” A sense of participation is enhanced by assigning roles [6].

3.2. Inquiry implementation: Hierarchical guided operation

Based on constructivist theory, inquiry should follow the principle of “from guided support to gradual independence” and adopt different guidance methods according to the differences between Grade K1 and Grade K2:

(1) Grade K1 (dominated by guided support): Adopt the process of “teacher demonstration → student imitation → teacher correction.” Take the “sugar dissolution” experiment as an example: the teacher first demonstrates the steps of “adding sugar → stirring → observing,” then students conduct the experiment in groups by imitation, and the teacher provides itinerant guidance on “stirring direction” and “key observation points.”

(2) Grade K2 (combined guided support and independent operation): Adopt the process of “task sheet guidance → group cooperation → teacher’s key guidance.” Take the “red cabbage juice color change” experiment as an example: provide a graphic task sheet (Step 1: Take red cabbage juice; Step 2: Add vinegar; Step 3: Observe the color), and groups complete the experiment through cooperation. The teacher only offers key guidance when students encounter difficulties in operation [7].

Special attention should be paid to “group member division of labor” during the inquiry process: each group consists of 2–3 students, with roles including “material manager” (distributing materials), “observer” (recording phenomena), and “speaker” (sharing findings). Roles are rotated weekly to cultivate students’ collaborative ability.

3.3. Expression and sharing: Encouraging diverse presentations

Expression is a process of externalizing thinking, and low-level students should be allowed to present their findings in “non-standardized” ways:

Picture recording: Provide “experiment record sheets” and let students draw experimental phenomena with colored pens (e.g., “Sugar before dissolution is white granules; after dissolution, the water becomes sweet”).

Verbal description: Organize “small discovery sharing sessions” and encourage students to describe their findings in simple language (e.g., “When sugar is put into water and stirred, it disappears”), without requiring the use of professional terms.

Physical object display: Place experimental results (e.g., “color-changed red cabbage juice,” “fermented dough”) in the class “popular science corner” for display, so as to enhance students’ sense of accomplishment [8].

4. Collaborative linkage strategy: Three-dimensional integration of school, family, and society

Low-level chemistry popularization needs to break through the boundaries of schools and build a collaborative network featuring “school leadership–family extension– social support” to form a joint force for education.

4.1. School leadership: Consolidating the foundation of popular science

Schools are the core positions for the implementation of popular science, and need to do a good job in three aspects: "curriculum integration–teacher team building–venue construction":

Curriculum integration: Incorporate popular science activities into school-based courses, with one session (40 minutes) per week, and connect them with science classes (e.g., when science classes cover "substance changes," popular science activities conduct "dissolution experiments") [9].

Teacher team building: Establish a teaching team composed of "1 science teacher + 2–3 college volunteers + 1 parent volunteer." The science teacher is responsible for overall design, college volunteers (normal university students majoring in chemistry) provide professional guidance, and the parent volunteer is responsible for safety management.

Venue construction: Set up a "popular science experiment area" (equipped with safe experimental equipment), an "achievement display area" (to display students' record sheets and works), and a "material storage area" (to store experimental materials in categories) [10].

4.2. Family extension: Enhancing practical experience

Families serve as an important extended scenario for popular science, where the "Five Ones" family science popularization initiative should be implemented:

(1) One observation book: Distribute Family Science Popularization Observation Books for students to record chemical phenomena at home (e.g., "The water turns cloudy when Mom cooks noodles");

(2) One parent-child experiment: Assign one family experiment task per month (e.g., "Observe the dissolution rate of salt in cold water and hot water"), with parents assisting in its completion;

(3) One science popularization corner: Encourage families to set up a "science popularization corner" to store simple tools such as magnifying glasses and small beakers;

(4) One scenario-based conversation: Guide parents to discuss chemical phenomena with their children in daily life (e.g., "Why can dish soap clean dishes thoroughly?") [11];

(5) One achievement sharing session: Hold a "Family Science Popularization Achievement Exhibition" each semester to display photos and records of parent-child experiments.

4.3. Social support: Expanding popular science scenarios

Integrate social resources to provide scenario and resource support for popular science:

Cooperation with science and technology museums: Jointly build a "Mobile Popular Science Laboratory" with local science and technology museums, and organize 1–2 museum-school activities every semester (e.g., visiting the "Substance Changes" exhibition area).

Enterprise support: Contact food enterprises and chemical enterprises (such as local soy sauce factories and detergent factories) to carry out "Little Visit Day" activities, allowing students to observe chemical phenomena in the production process.

Community linkage: Use community activity centers to set up "Weekend Popular Science Classes," and invite community doctors, engineers, etc., to give lectures on "Chemistry in Daily Life" [12].

5. Guarantee and support strategies: Three-dimensional safeguard of safety, resources, and evaluation

The implementation of strategies requires a complete supporting guarantee system to ensure the continuous advancement of science popularization work.

5.1. Safety guarantee: Whole-process risk prevention and control

Establish a "prevention–monitoring–disposal" safety prevention and control chain:

Prevention stage: Launch the "First Lesson on Science Popularization Safety." Help students memorize safety rules thoroughly through a nursery rhyme ("Before experiments, follow instructions; Do not touch, do not taste; Put materials in order after use").

Monitoring stage: Adopt the group management mode of "1 teacher + 1 volunteer" during experiments, with no more than three students in each group, to ensure every student is within sight [13].

Disposal stage: Equip with simple first-aid kits (including band-aids, povidone-iodine, and wet wipes), and formulate the Procedure for Handling Emergencies (e.g., contact the school doctor immediately in case of accidental ingestion of materials).

5.2. Resource guarantee: Multi-channel supply integration

Resource guarantee needs to address three major demands: "materials, technology, and human resources":

(1) Material supply: Adopt a combined mode of "unified school procurement + family self-preparation." Basic materials (such as white sugar and red cabbage) are procured by the school, while special materials (such as detergent) are prepared by families themselves.

(2) Technical support: Develop digital resource packages, which include "experiment step animations" (e.g., AR demonstration of the "dissolution process") and "parent guidance videos," and push them through the school's official WeChat public account.

(3) Human resource support: Sign cooperation agreements with the Chemistry Department of local universities, and establish a "volunteer training–assessment–onboarding" mechanism to ensure volunteers have basic guidance capabilities [14].

5.3. Evaluation guarantee: Diversified effect feedback

Establish a trinity evaluation system of "process-result-feedback" to avoid the "result-only" orientation:

(1) Process evaluation (60%): Use the Classroom Observation Record Form to assess students' participation (e.g., "whether they take the initiative to operate," "whether they actively ask questions") and operational standardization (e.g., "whether they use droppers correctly").

(2) Outcome evaluation (20%): K1 students submit "science popularization handbooks" (including experimental drawings + simple descriptions), while K2 students conduct "little chemist reports" (explaining experimental findings with reference to their handbooks).

(3) Feedback evaluation (20%): Understand the completion of family experiments through the Parent Feedback Form, and record problems in strategy implementation (e.g., "a certain experimental step is too complicated") through teachers' reflection logs.

6. Conclusion

As a crucial part of science initiation, the quality of chemistry popularization for lower grades in primary schools directly affects the foundational effect on students' scientific literacy. The strategy system constructed in this study not only responds to policy requirements but also meets practical needs. It can provide specific operational guidance for educational administrators and frontline teachers [15], and also offer empirical support from the scenario of lower-grade education for the theoretical research on science popularization.

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