

Research on primary school science practical activities based on an integrative approach—A case study of the "Weather" unit in the education science press edition

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Abstract. Against the policy backdrop of the "addition" in science education, this study focuses on the design and implementation of practical activities in primary school science, conducting an empirical exploration through the "Weather" unit in the Education Science Press edition. The study emphasizes that integrating science practical activities with the science curriculum is essential for promoting students' integration and application of knowledge and for cultivating their core scientific competencies. To prevent practical science activities from becoming an additional burden on students, the study proposes that the core strategy lies in constructing such activities in close alignment with the national science curriculum system. Fragmented activity designs detached from the national curriculum are prone to increasing cognitive load, thereby undermining the goal of "reducing burden while enhancing effectiveness." Accordingly, this study advocates embedding an integrative, post-unit practical activity after the completion of national curriculum instruction for a specific unit. This activity is designed to systematically connect the core knowledge of the unit and to guide students in comprehensively applying, transferring, and deepening their learning in authentic or simulated contexts. This practice model, which is deeply integrated with the national curriculum, effectively avoids increasing students' learning burden while significantly enhancing their holistic understanding and application of scientific concepts. It represents an efficient pathway for deepening national curriculum learning and promoting the development of students' core scientific competencies.

Keywords: science education "addition", primary school science education, integrative approach, practical activities

1. Introduction

How to achieve unity between "competency enhancement" and "academic burden reduction" through structural reform has become a central issue in contemporary science education research. Grounded in the core competency requirements of the new curriculum standards, this paper proposes a key strategy of embedding integrative practical activities within the national curriculum framework to guide students' transition from mere "knowledge acquisition" to "transfer and application." Based on the structure and characteristics of the

primary school science curriculum, and employing an integrative approach, the study takes the "Weather" unit in the Education Science Press edition as an empirical case to examine the design logic and implementation pathways of post-unit practical activities. It further explores how to avoid the risk of increased learning burden resulting from activities detached from the curriculum, and how to effectively realize the goals of the "addition" in science education.

2. The necessity of integrating science curriculum and practical activities

The "integrative approach" refers to a way of systematically combining different elements, perspectives, theories, methods, or practices to form a more comprehensive, coherent, and effective whole for understanding or solving problems [1]. Through the logic of "dual-track learning of problems and themes—cognitive progression from the concrete to the abstract—an error-correction and iterative mechanism aligned with core competencies," the integrative approach enables deep integration between practical activities and the science curriculum. At the same time, it takes into account learners' cognitive development and affective experiences, thereby fostering students' scientific literacy.

Primary school science is a discipline that integrates multiple fields, including biology, microbiology, ecology, physics, chemistry, earth science, and astronomy. The primary school science curriculum emphasizes the integration of knowledge across disciplines, avoids an opposition between the scientific world and students' lived world, and highlights both personal relevance and social significance of learning content [2]. From the perspective of the characteristics of the primary school science curriculum, science education at this level should focus on the integrative nature of curriculum content and promote the development of students' scientific literacy without imposing additional academic burden.

2.1. Integration of science curriculum and practical activities aligns with the nature of science

The nature of science encompasses epistemological dimensions, cognitive processes, and social attributes. Erduran points out that science teaching needs to integrate "cognitive components (such as modeling and explanation)" and "social components (such as discourse validation)," dimensions that cannot be revealed through the mere transmission of knowledge [3] and therefore require the incorporation of practical activities. Through hands-on engagement, practical activities allow learners to experience the interweaving of observation and reasoning, helping them understand that scientific knowledge is not absolute truth but a provisional construction based on evidence.

With regard to understanding the nature of science, constructivist theory holds that learners must engage in active inquiry in order to construct knowledge. McComas emphasizes that the myth of the "step-by-step scientific method" commonly presented in traditional textbooks needs to be dismantled through practice. For example, by having students design a "water-making machine" through a "black-box experiment" that simulates a "water increase phenomenon," students are guided to investigate the mechanism by which "a small input of water produces a larger output." Through this process, they come to understand the roles of "evidence-based reasoning" and "model construction" in scientific inquiry, break away from the stereotype of "a single correct scientific conclusion" [4], and discover through conjecture and verification that science does not follow a uniform methodology, but rather relies on the interaction between creative hypotheses and evidence testing. Thus, the construction of an understanding of the nature of science within the science curriculum can only be complete when supported by practical activities.

2.2. Integration of science curriculum and practical activities compensates for the limitations of knowledge fragmentation in primary school science teaching

Knowledge fragmentation in the primary school science curriculum makes it difficult for students to grasp the systemic interconnections underlying natural phenomena—for example, climate change involves interactions among multiple systems such as the atmosphere, hydrology, and biology. Concepts such as "energy transformation" in physics and "energy flow in ecosystems" in biology belong to the same logical framework, yet they are often presented in a fragmented manner in primary school science textbooks. This fragmentation leads students to form "disciplinary knowledge islands," leaving them unable to address real-world problems—such as global warming—that require multidisciplinary perspectives [4]. As the limitations of such partial curricula become increasingly apparent, the demand for integrative approaches grows stronger, aligning closely with the developmental needs of primary school students' competencies.

The integration of curriculum and activities enables teachers to move from reliance on textbooks to the construction of a "dynamic resource repository," thereby generating triple educational value in cognition, practice, and understanding of the nature of science. In essence, such integration represents a fundamental reconstruction of "what science is" and "how science is learned." When students are able to draw upon disciplinary knowledge and comprehend the social nature of science, the limitations of fragmented science teaching are effectively dissolved through authentic scientific practice activities.

2.3. Integration of science curriculum and practical activities promotes students' holistic development and the enhancement of core competencies

Empirical studies by Samuel and colleagues show that students commonly perceive traditional, fragmented science learning as "abstract and tedious," whereas science learning supported by integrative practical activities, situated in authentic contexts, can significantly enhance learning interest [5]. Engaging, hands-on, and minds-on activities greatly stimulate students' curiosity and desire for knowledge, transforming them from passive recipients into active inquirers. The cultivation of scientific literacy is difficult to achieve fully within traditional science classrooms; however, integrating activities related to socio-scientific issues—such as environmental protection, energy use, and public health—enables students to understand the interactions among Science, Technology, Society, and the Environment (STSE), while fostering social responsibility and decision-making abilities.

The Compulsory Education Science Curriculum Standards (2022 Edition) (hereinafter referred to as the "New Curriculum Standards") are highly consistent with integrative approaches to science education in terms of their core competency framework, forming an intrinsic theoretical alignment. The New Curriculum Standards explicitly require science learning activities to progress from simple to complex, to organically integrate learning content with learning activities, and to plan spiral, progressively advancing core competency goals and curriculum content appropriate to different educational stages. They also call for the design of inquiry and practical activities suited to different grade levels [6], thereby addressing the fragmented tendencies of traditional teaching. For example, in teaching the core concept of "levels of organization in life systems," the New Curriculum Standards clearly require its integration with the cross-disciplinary concepts of "structure and function" and "systems and models." Teaching practice further demonstrates that organizing instructional content through theme-centered practical activity models effectively supports students in constructing coherent knowledge networks. Such models are not limited to the thirteen major themes outlined in the New Curriculum Standards, but also extend to unit themes within specific textbooks. For instance, the "Magnets" unit in the second-grade, second-semester Science textbook published by the Education Science Press in 2018 can likewise serve as a theme within a theme-centered instructional model.

3. Implementation strategies for primary school science practical activities based on an integrative approach

When the design and adjustment of practical activities are detached from the national curriculum, they inevitably impose additional learning tasks on students beyond the completion of mandated coursework, while also creating a sense of structural and cognitive discontinuity in science learning. Therefore, the fundamental principle for implementing practical activities in primary school science is close alignment with the national curriculum, selecting appropriate practical activities directly from its content. The key question, then, is how to enact an integrative approach within practical activities while remaining grounded in the national curriculum. Based on the logic of the integrative approach, this study distills three core steps for the implementation of practical activities.

3.1. The dual anchoring strategy of "problem + theme" based on the national curriculum

The "problem + theme dual anchoring strategy" is an instructional design model rooted in the national curriculum standards, in which authentic problems drive cognition while overarching themes integrate knowledge. This strategy aims to address persistent issues in traditional instruction, such as fragmented knowledge and insufficient learning motivation, and to facilitate the deep implementation of core competencies. Ideally, this strategy involves posing universally relevant real-world problems under a unit theme and organizing practical activities around those problems. However, due to constraints related to instructional resources and curriculum structure, not all units can support the parallel operation of both dimensions. Teachers may therefore choose to anchor instruction at either point depending on contextual conditions.

The "problem anchoring strategy" begins with the core knowledge of a national curriculum unit and extracts authentic problems closely related to students' daily lives, social issues, or natural phenomena to serve as the primary driving force of practical activities. For example, following the "Magnets" unit, instruction may focus on the question: "Under what circumstances do objects containing magnets in daily life experience functional interference?" This guides students to explore concepts such as magnetic attraction of iron-containing objects, the directional properties of magnetic poles, and interactions between poles. Anchoring learning in authentic problems enables the integration of "cognitive content" (knowing that) with "practical intent" [7], thereby stimulating learning motivation.

When limitations in learning resources make it difficult to extract authentic problems directly from the core knowledge of a curriculum unit, a "theme anchoring strategy" may be adopted instead. This strategy constructs a systematic inquiry framework independent of external contexts by deeply exploring unit themes and reorganizing content across disciplines. Under conditions of limited cognitive resources, the integration of multiple intelligences can enhance learning effectiveness. Through "multimodal task design," the theme anchoring strategy activates different forms of intelligence to compensate for resource constraints. For instance, in the unit "The Life Cycle of Animals," it may be impractical—due to resource limitations—for students to conduct a complete, real-world investigation of an animal's entire life cycle. However, multimodal tasks can be designed to facilitate embodied experiences (such as role-playing) and symbolic representations (such as poster creation), enabling the transformation from "abstract concepts to concrete expression" even in resource-constrained settings.

3.2. A cognitive progression strategy from the concrete to the abstract

The core value of practical activities lies in the "transfer and application of knowledge," and such transfer is grounded in the systematic organization of cognitive structures. Progressing from concrete cases (such as "waste sorting on campus") to abstract concepts (such as "material cycles") helps students construct transferable knowledge frameworks. The first step in achieving cognitive progression is to anchor concrete phenomena through embodied experiences. By exploring phenomena through authentic problems and themes, students engage in inquiry-based practice that enables advancement in both the science curriculum and the development of core scientific competencies. Accordingly, the design of activities should align with students' stages of cognitive progression, organizing tasks through problem chains or tiered task structures to facilitate step-by-step inquiry.

Post-unit practical activities are particularly well suited to inquiry that emphasizes cognitive progression. Pre-unit practical activities (conducted before unit instruction) require students to operate on concepts they have not yet systematically encountered, resulting in high trial-and-error costs. When students are required to process new conceptual knowledge and operational tasks simultaneously, intrinsic cognitive overload may occur, weakening the depth of inquiry. Scientific inquiry typically follows a closed loop of "focusing → exploration → discussion → extension." If practical activities are embedded within the unit itself, they may fragment instructional time and be compressed into piecemeal operations (such as practicing thermometer readings only), thereby violating the integrity of the inquiry cycle. In contrast, post-unit practical activities allow students to build upon structured knowledge schemata, enabling them to concentrate cognitive resources on problem solving and strategy optimization. Moreover, post-unit practical activities are more likely to trigger near transfer of knowledge and cognition, thus reducing students' learning burden.

3.3. An error-correction iterative mechanism aligned with core competencies

Scientific knowledge is a "provisional construction based on evidence," rather than absolute truth [8]. The iterative process of error correction is, in essence, the process by which students progressively approximate scientific concepts through cycles of "hypothesis—verification—revision." While practical activities must ensure the cultivation of students' core competencies, they must not increase academic burden; instead, "burden reduction with quality enhancement" can only be achieved through structural optimization and resource integration. The error-correction iterative mechanism serves as a safeguard for such structural optimization. When designing post-unit activities, teachers need to deliberately reserve space for iteration and pre-plan corrective strategies for anticipated errors.

Post-unit practical activities can also serve as evaluative components of unit learning, allowing students to summarize and reflect on what they have learned, thereby deepening their understanding. In the final reflective stage, students apply their error-correction experiences to new contexts, achieving the transfer of ability from "this problem" to "that problem." For example, experience gained from "error correction in a campus weather station" can be transferred to the task of "calibrating a household hygrometer." Therefore, prior to the implementation of post-unit practical activities, teachers should establish an error-correction iterative mechanism so as to present the dynamic process of core competency development. Finally, based on core competencies, dynamic feedback and reflection on the outcomes of practical activities should be formed.

4. Case analysis of primary school science practical activities based on an integrative approach

The design of post-unit practical activities follows principles such as relevance, progression, and engagement, with an emphasis on incorporating authentic contexts and promoting students' active participation. Under the post-unit practical activity model, activities should be capable of accommodating diverse formats and aligning with the implementation pathways of science instruction, so as to effectively enhance students' scientific literacy without increasing their academic burden. Having clarified the implementation strategies of the integrative approach, the following section concretizes the entire process of a practical activity through a case study of the "Weather" unit.

4.1. Analysis of the instructional content of the "Weather" unit

First, because the implementation of practical activities is grounded in the national curriculum, it is necessary to analyze the instructional content prior to activity design. Taking the "Weather" unit in the Science textbook for Grade 3, Semester 1, published by the Education Science Press, as an example, and in accordance with the requirements of the New Curriculum Standards, students are expected to achieve the following core competencies:

1. Be able to understand weather forecasts and recognize that the atmosphere is in motion.
2. Under teacher guidance, use meteorological data to describe temperature changes over the course of a day and establish connections between meteorological data and weather conditions.
3. Under teacher guidance, learn to use instruments to measure meteorological data.
4. Demonstrate curiosity and an exploratory interest in weather phenomena; be willing to conduct hands-on experiments, accurately record observational results, and develop an awareness of reasoning based on evidence.

The post-unit practical activity for this unit needs to reflect the cultivation of the above aspects of scientific literacy. In combination with the specific content of each lesson in the unit, a practice activity theme centered on exploring weather changes can be established.

4.2. Analysis of the practical activities in the "Weather" unit

Following the analysis of the textbook content, the next step is to design practical activities in accordance with the implementation strategies outlined above. The first task is to complete the dual anchoring of "problem + theme" for the "Weather" unit. Because authentic problems must arise from real-life contexts, the unit theme of "weather" needs to be situated in students' everyday experiences, enabling them to identify problems within realistic and familiar settings. During classroom instruction, teachers can guide students to reflect on how the knowledge gained throughout the unit can be used to address real-world weather-related issues. Through classroom inquiry, a universally relevant and operational real problem within the school context can be formulated. For example, in Primary School A, Wednesdays are designated as "free dress days," when students are particularly concerned about their clothing comfort. In practice, however, unexpected weather changes often prevent students from fully enjoying the emotional benefits of free dress, and in some cases, delayed clothing adjustments even lead to colds. This situation gives rise to an authentic problem: how to predict weather changes in real time in order to make appropriate clothing choices. At the same time, a theme of constructing a campus weather station can be developed around the "Weather" unit content to address this real-life problem. In this way, both problem anchoring and theme anchoring are accomplished.

The second component involves implementing practical activities based on the cognitive progression strategy. Given the characteristics of weather phenomena, instruction can begin with weather elements. For example, students can be guided to establish an inquiry chain that progresses from "weather element phenomena → measurement of weather elements → construction of measurement tools → application of measurement tools → recording of meteorological data → analysis of meteorological data → weather forecasting." Through this sequence of practical activities, students achieve cognitive progression from the concrete to the abstract, from knowledge to application, and from phenomena to underlying patterns. The progressive chain of individual weather elements does not constitute the entirety of the cognitive progression strategy; rather, these separate chains need to be integrated to form a comprehensive weather map. Such integration supports higher-level cognitive advancement and, in the process, enables students to develop an understanding of weather consultation and synthesis.

The third component of the practical activity implementation strategy is the establishment of an error-correction iterative mechanism aligned with core competencies within the "Weather" unit. Grounded in the New Curriculum Standards' view of scientific knowledge as a provisional construction, and combined with the knowledge transfer characteristics of post-unit practical activities, a closed loop of "error identification → causal analysis → solution iteration → transfer and application" can be constructed. For instance, during weather element measurement activities, students' initial use of thermometers may yield temperature readings 3–5°C higher than official forecasts due to insufficient installation height (e.g., only 1 meter above ground). At this point, teachers can guide students to compare multiple sets of measured data with standard meteorological data, and then remeasure using methods such as the "set-square vertical calibration method" and a "1.5-meter height benchmark," thereby identifying and correcting cognitive biases related to the influence of measurement location on data accuracy. This iterative mechanism can be extended to home contexts as well. Students can transfer their experience of error correction from the campus weather station to the task of "calibrating household hygrometers," using the saturated salt solution method (with a known humidity of 75%) to verify instrument error, and then write a *Household Meteorological Observation Improvement Report*. In this way, transfer and extended feedback from "this problem" to "that problem" are achieved. Throughout the process, core competencies—such as scientific concepts (the provisional nature of scientific knowledge), scientific thinking (critical analysis of sources of error), inquiry practices (instrument adjustment and data collection), and attitudes and responsibility (commitment to evidence and reflective improvement)—are integrated, allowing students to experience the dynamic construction of scientific knowledge.

5. Conclusion

Through theoretical analysis and empirical classroom-based evidence, this study demonstrates that post-unit practical activities constitute an effective pathway for addressing the challenges posed by the "addition" in science education. By employing a triple-integrative logic, such activities achieve a dialectical unity between "competency enhancement" and "academic burden reduction." Anchored in authentic problems, they integrate scientific knowledge to construct web-like cognitive networks, thereby mitigating the drawbacks of knowledge fragmentation in primary school science.

Practical activities grounded in an integrative approach closely align with the core competencies articulated in the New Curriculum Standards, embedding knowledge application and social participation within a unified task chain to enable the coordinated cultivation of competencies. The practice of the "Weather" unit demonstrates that, by deeply embedding post-unit practical activities within the genetic structure of the national curriculum, this model effectively avoids the burden-increasing risks associated with traditional

extracurricular activities. Its design paradigm—using textbook units as the foundational matrix and authentic problems as the driving force—offers a solution that is both theoretically rigorous and broadly applicable for the effective implementation of the "addition" in science education.

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