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ARTICLE

The Design and Practice of a "Dual Mainlines" School-Based Scientific Inquiry Curriculum System

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ABSTRACT

This study explores the construction and implementation of a scientific inquiry curriculum system. Centered on cultivating students' interest in science and emphasizing the decisive role of science education in shaping scientific literacy, the curriculum proposes a "dual mainlines" instructional model. This framework integrates scientific knowledge, thinking, methods, and ethos into teaching materials and classroom practices. Through project-based teaching and a "learning-practice- reflection" framework, the curriculum guides students to progressively deepen their understanding of the nature of science. Grounded in real-life scientific phenomena and practical applications, the course sparks student engagement while prioritizing scientific inquiry as a core learning approach. By encouraging questioning and experimentation, it fosters students' capacity for autonomous exploration.

1. The Guiding Philosophy of Scientific Inquiry Curriculum System Framework Development

1.1 Cultivating a Universal Passion for Science

The rapid advancement of science and technology serves as the cornerstone driving comprehensive societal progress. It profoundly shapes the trajectory of social development by revolutionizing human modes of production, lifestyles, and cognitive frameworks. The objectives of science education extend far beyond equipping students with foundational scientific concepts and their interconnections. More crucially, it aims to cultivate students' skills and methodologies in scientific inquiry, enhance collaborative competencies and communication proficiency, while fostering a scientific mindset characterized by critical thinking, innovative exploration, and evidence-based reasoning. As the decisive catalyst in shaping individual scientific literacy, science education embodies the fundamental mission of elevating the scientific capabilities of every learner.

1.2 Developing a "Dual Mainlines" Framework for Teaching Content and Classroom Structure

The science curriculum design proposes a complementary "Dual Mainlines" model through the deep integration of content and pedagogical design. By systematically embedding scientific knowledge, thinking paradigms, methodologies, and ethos into both instructional materials and classroom practices, we establish dual distinctive pathways: content innovation and teaching process optimization. Guided by the "Dual Mainlines" framework, the scientific inquiry curriculum employs project-based teaching as its operational vehicle. The content framework revolves

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around a "learning- practice-reflection" progression, while the instructional design adopts an "observe- reflect-articulate-apply" cycle for holistic classroom integration. This structured approach enables students to gradually unravel the essence of science, fostering intellectual curiosity, scientific passion, and civic responsibility. Simultaneously, it equips learners with science-informed problem-solving strategies applicable to academic challenges and daily life contexts.

1.3 Constructing a Knowledge Framework Anchored in Everyday Scientific Phenomena

Science education must be rooted in students' cognitive development patterns and lived experiences, allowing them to recognize the significance of scientific principles through familiar life contexts. This pedagogical approach enables learners to progressively acquire skills in analyzing and addressing practical scientific issues. Instructional content is systematically integrated with real-world examples that illuminate scientific phenomena, guiding students to discover science in daily life. Through this design, learners experience both the intellectual wonder and practical relevance of science, fostering enduring engagement and curiosity.

1.4 Positioning Scientific Inquiry as the Central Learning Paradigm

Scientific inquiry, as the essential characteristic of scientific research, holds profound educational significance. Guiding students through authentic investigative processes not only safeguards their innate curiosity but also ignites proactive engagement in scientific learning. Within the "Dual Mainlines" curriculum framework, inquiry-based pedagogy manifests through intentional classroom design.

Pre-class engagement: Stimulating interest via science anecdotes aligned with lesson themes.

Exploratory learning: Resisting premature conclusion delivery; instead, posing strategic questions to scaffold hypothesis formulation and experimental reasoning.

Application bridging: Connecting theoretical findings to real-world problem- solving scenarios through multi-stage exploration.

This structured yet flexible approach diversifies learning modalities while sustaining student engagement, ultimately cultivating scientific habits of mind that transcend disciplinary boundaries.

1.5 Developing a Project-Based Guided Scientific Inquiry Curriculum System with a Progressive Structure

Grounding the curriculum in project-based learning, the program selects 16 core concepts per semester across domains including physical sciences, life sciences, earth sciences, physics, and chemistry, commencing from Grade 1. Aligned with developmental readiness, a spiral progression approach organizes these concepts through hierarchical design.

Conceptual decomposition: Each core concept is deconstructed into age- appropriate sub-concepts with scaffolded complexity levels.

Competency development: Students progress from conceptual understanding to applied mastery through iterative cycles of exposure and practice.

These systematically structured concepts constitute essential scientific literacy for lifelong learning and modern societal adaptation, while simultaneously serving as vehicles for cultivating scientific competencies and nurturing evidence-based mindsets.

2. Specific Design Approach

In our school's efforts to support the distinctive development of primary and secondary education, we have designed and implemented a dual mainlines school-based curriculum for scientific exploration, tailored to the psychological characteristics of students across different age groups and aligned with the practical needs of elementary school specialty programs. Living in an era of rapid scientific and technological advancement, we are constantly surrounded by the profound impacts of science and technology. The scientific exploration curriculum aims to cultivate scientific literacy among primary school students, with a focus on hands-on experimentation and inquiry-based learning. By integrating foundational disciplinary knowledge essential to students, the curriculum fosters scientific thinking skills and problem-solving abilities.

In the design of instructional content, the curriculum follows a "Learn—Practice— Reflect" framework. The instructional process begins with scientific storytelling to introduce concepts, followed by theoretical explanations of principles and guided observation and analysis of experimental phenomena to deepen understanding. It culminates in hands-on experimentation for students to actively explore and validate the principles. In classroom instruction, inquiry-based teaching and learning activities are organized around the ORDE framework (Observe—Reflect—Discuss— Experiment). Observation can direct students to actively investigate scientific phenomena, fostering intuitive understanding. Reflection can encourage students to connect scientific knowledge with daily life, identifying applications of science and technology, stimulating critical thinking by questioning "how" and "why."

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Discussion can facilitate teacher-student and peer interactions, summarizing and reflecting on acquired knowledge and methods. Experiment can guide students to cultivate a spirit of scientific inquiry.

The instructional content is designed to align with the cognitive development patterns of primary school students, leveraging post-class reflection tasks to deepen understanding and broaden knowledge horizons. Divided by grade level and semester, the curriculum adopts a spiral progression model centered on core scientific concepts. Each semester integrates 16 science experiments that synchronize with classroom instruction, with complexity and depth increasing progressively across grades. Students not only acquire discrete scientific facts but also develop holistic problem-solving skills by analyzing interdisciplinary challenges.

3. Case Analysis of the " Dual Mainlines " Scientific Exploration Curriculum

The scientific exploration curriculum is designed around tangible and engaging topics from four domains: physical science, life science, earth and space science, and technology and engineering. These topics are selected for their accessibility and ability to spark students' curiosity, with a focus on cultivating primary school students' interest in scientific inquiry, scientific thinking skills, and effective learning habits. Across each lesson, we systematically integrate four dimensions: scientific knowledge, scientific reasoning, scientific methods, and scientific ethos. Below, we illustrate the "Dual- Mainlines " scientific exploration model using the example of the "Dancing Paper Snippets" project.

3.1 Emphasizing Curriculum Design to Establish a Holistic Knowledge Framework

In the experimental project design, to stimulate student interest, the lesson begins with a scientific story—the Magdeburg Hemispheres Experiment—to introduce the core concept: atmospheric pressure. To deepen students' understanding of atmospheric pressure, the curriculum connects to familiar daily life experiences and practical applications, guiding students to solve simple real-world problems. The content emphasizes the application of scientific principles in everyday contexts, using examples related to atmospheric pressure to scientifically analyze and explain phenomena caused by it. Through case studies, students gain familiarity with atmospheric pressure and related concepts, culminating in hands-on experiments where they practice scientific inquiry methods, observe phenomena, and apply systematic approaches to explore scientific questions.

3.2 Emphasizing Inquiry-Based Pedagogy and Scientifically Structured Instructional Design

The design of classroom content forms the foundation for acquiring scientific knowledge and cultivating scientific literacy. Scientific teaching methods and instructional design serve as critical pathways for students to internalize and master scientific concepts—both are indispensable. Defined as a pedagogical approach where, under the guidance, organization, and support of teachers, students actively engage in hands-on, minds-on exploration to experience authentic scientific inquiry processes. Students are the central agents of the classroom, driving discovery through experimentation, observation, and collaboration. The teacher serves as the organizer (structuring inquiry tasks), guide (scaffolding critical thinking), and promoter (fostering curiosity and reflection).

3.3 Emphasizing Differentiated Instruction and Gradual Progression in Teaching

Grades 1–2 focus on cultivating imagination and developing manual dexterity. Grades 3–4 focus on enhancing imagination, observation skills, hands-on operational abilities, and foundational technical writing skills. Grades 5–6 focus on fostering creative skills, innovative thinking, advanced hands-on practical skills, and lab report writing. Education Courses are systematically integrated into the core curriculum for all students. Tailored projects and elective modules ensure individual talents and interests are nurtured, such as robotics clubs or environmental innovation labs.

4.Concluding Remarks

In this era of rapid technological advancement, cultivating scientific literacy is paramount for students. Through the establishment of the "Dual- Mainlines" scientific exploration curriculum, we have not only built a comprehensive knowledge platform for students but also prioritized nurturing their interest in scientific inquiry, critical thinking, and practical competencies. By grounding learning in real-world scientific phenomena and guiding students through project- based learning, we empower them to experience the wonders of science through hands-on practice while enhancing their scientific literacy through reflection. Our tiered pedagogical approach addresses the developmental needs of each age group, progressively unlocking their potential.

Looking ahead, we remain committed to refining curriculum design and exploring innovative teaching

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methodologies. Our unwavering goal is to nurture a new generation equipped with scientific rigor and creative problem-solving skills, ensuring that the seeds of science take root and flourish in every child's mind. Together, we pave the way for a future where curiosity and innovation drive meaningful progress.

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