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DEVELOPING ENVIRONMENTAL SCIENCE COMPETENCY FOR STUDENTS THROUGH A LOCALLY CONTEXTUALIZED STEM PROJECT

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Abstract

This paper proposes a teaching process based on the socially-contextualized STEM (STEMS) model to develop students' environmental science competency, aligned with the PISA 2025 Science Framework. Based on an analysis of the components of environmental science competency in PISA 2025 and the STEMS teaching process, the study develops a 6-step teaching process that explicitly links learning activities to the formation of specific competencies. This process is illustrated through the design of the "Simple Incense Drying Device" project a theme that addresses a practical problem in a traditional craft village, helping local people stabilize production and increase their income. The research results show that the proposed model not only helps students apply interdisciplinary knowledge to create useful technological solutions but also fosters empathy, a sense of social responsibility, and the capacity to act for the sustainable development of the community. This actualizes the goal set by PISA 2025 of forming "Agency in the Anthropocene."

Keywords:

Environmental science competency, PISA 2025, STEM education, STEMS model, local context, project-based learning, and sustainable development.

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1. Introduction

The world is entering the Anthropocene Epoch, a period where human activities are causing profound and uncertain changes to Earth's systems. This context places an urgent task on education: to equip the young generation not only with scientific knowledge but also with systems thinking skills, a sense of responsibility, and the ability to act for a sustainable future. In response to this call, the Programme for International Student Assessment (PISA) 2025 Science Framework has made a landmark shift, for the first time including "Environmental Science Competency" and the concept of "Agency in the Anthropocene" as one of the core educational outcomes to be measured globally (PISA, 2023).

In line with this trend, Vietnamese education is undergoing a fundamental and comprehensive reform as guided by the 2018 General Education Curriculum (Bùi, 2023). The focus of this curriculum is to shift from knowledge transmission to the holistic development of qualities and competencies for students, emphasizing the connection between theory and practice and bringing real-life issues into lessons (T. X. Lê et al., 2024).

In this context, STEM (Science, Technology, Engineering, and Mathematics) education has emerged as an effective teaching method (Hán & Đỗ, 2023; H. P. H. Lê & Lê, 2024), directly addressing the new curriculum's goals by organizing interdisciplinary learning activities that guide students to solve practical problems. However, for learning to be truly meaningful and to create social impact, the integration of STEM knowledge needs to be more deeply connected to the living environment, culture, and specific issues of the local community.

From this requirement, the STEMS (STEM + Social) model was born as a natural development, emphasizing the social element as a core and cross-cutting component of the teaching process (Anderson, 2001; Nguyễn & Trần, 2023). Applying the STEMS model not only helps students develop scientific competencies but also fosters a sense of civic responsibility, love for their homeland, and the ability to solve problems unique to their community.

Although there is a similarity in goals among the orientation of PISA 2025, the 2018 General Education Curriculum, and the philosophy of the STEMS model, the development of a specific, systematic teaching process to realize these goals in the Vietnamese context remains a research gap. Teachers need a clear methodological framework to design and organize learning projects that both develop environmental science competency according to international standards and are rich in cultural identity and local context.

For these reasons, this paper proposes the development of a detailed teaching process based on the STEMS model, aimed directly at developing the components of environmental science competency as oriented by PISA 2025. Through the design and analysis of a specific illustrative project, we hope to provide a feasible model that can be widely applied, helping to effectively connect global educational goals with the reality of teaching in localities across Vietnam.

2. Theoretical Basis

2.1. Environmental Science Competency in the PISA 2025 Science Framework

The PISA 2025 Science Framework marks a significant development in the perception of the goals of science education, moving beyond merely equipping students with the knowledge and skills to explain natural phenomena to preparing them to become proactive and responsible citizens in the face of the complex challenges of our time (PISA, 2023). At the core of this change is the concept of "Agency in the Anthropocene," defined as the capacity to exist and act in a world where humans are positioned as an inseparable part of the ecosystem, acknowledging and respecting the interdependence of all life. This competency requires students not only to understand environmental issues but also to believe that their actions have value, are effective, and can contribute to creating positive change (Nguyễn & Trần, 2023; PISA, 2023).

To operationalize this concept, PISA 2025 identifies three constituent components of environmental science competency:

(1) **Explain the impact of the interaction between humans and Earth's systems**: This competency requires students to apply interdisciplinary scientific knowledge (physics, biology, chemistry, Earth science) to analyze and explain complex environmental issues, from local to global scales. Students need to understand cause-and-effect relationships, feedback loops, and the impact of economic, cultural, and social factors on natural systems.

(2) **Make informed decisions to act based on evaluating diverse sources of evidence and applying creative and systems thinking**: This is the core competency of an active citizen. Students must be able to seek and evaluate the reliability of information from various sources (scientific, social, economic), analyze potential solutions, anticipate consequences, and make responsible decisions aimed at sustainability.

(3) **Demonstrate respect for diverse perspectives and hope in seeking solutions to socio-ecological crises**: This component emphasizes the ethical, emotional, and social aspects. Students need to be able to evaluate actions based on concern for humans and other species, demonstrate resilience, hope, and self-efficacy when facing negative issues, while respecting and seeking consensus from diverse viewpoints.

The formation of these three competencies requires the integration of three types of scientific knowledge: Content knowledge (concepts, theories), Procedural knowledge (how scientific inquiry is conducted), and Epistemic knowledge (the nature of scientific knowledge, the role of evidence and models) (PISA, 2023).

2.2. Teaching Based on the Socially-Contextualized STEM (STEMS) Model

To realize the goals set by PISA 2025, a suitable teaching method is needed, one that can transform competency requirements into meaningful learning activities. The STEMS model of teaching is a potential approach that meets this need.

2.2.1. The Role of Social Context in Learning

Vygotsky's (1978) social constructivist learning theory and Lave and Wenger's (1991) situated learning theory have shown that the learning process cannot be separated from the cultural and social context in which it occurs. Knowledge is most effectively constructed when learners are engaged in solving authentic problems that are meaningful to their own lives and their community (Smith et al., 2018). In science education, incorporating socioscientific issues (SSI) into teaching has been proven to help students develop their argumentation and decision-making skills and gain a deeper understanding of the relationship between science, technology, and society (Sadler, 2004; Zeidler, 2014).

The STEMS model inherits and expands on these perspectives by placing the local social context as the starting point and the guiding thread throughout the entire teaching process. The context is not just an illustrative example but the source of the problem to be solved, the environment for testing solutions, and the beneficiary of the learning outcomes (Trà et al., 2025). This approach helps break down the barrier between school and real life, creating strong intrinsic motivation for students (Bybee, 2013).

2.2.2. The STEMS Model Teaching Process

Based on the foundations of project-based learning (Anazifa & Djukri, 2017; Châu, 2024) and experiential learning theory (Kolb & Kolb, 2017), the proposed STEMS teaching process consists of 6 steps, organically integrating the social element into each activity (Trà et al., 2025):

- Step 1: Contextualize & Identify Challenges: Students explore and identify a real challenge or need within their community (economic, cultural, environmental).
- Step 2: Define the Task: The practical problem is specified as an interdisciplinary learning task/problem that requires the application of STEM knowledge to solve.
- Step 3: Ideate & Design: Students discuss, propose, and design creative solutions, considering feasibility, effectiveness, and appropriateness for the cultural and social context.
- Step 4: Research Foundational Knowledge: Students proactively research, practice, and conduct experiments to acquire the necessary scientific and technological knowledge to develop the solution.
- Step 5: Build, Test & Refine: Students build the product, test the solution in a simulated or real environment, collect data, and make improvements.
- Step 6: Share & Disseminate: Students present and share their product and process; assess the solution's impact on the community and propose directions for future development and dissemination.

The key advantage of this process is that the "Social" element is not an add-on but is tightly integrated, from identifying a social problem and designing a socially-conscious solution to evaluating the social impact of the learning outcome. This not only makes STEM learning more engaging and practical (Chen & Chen, 2024; Holmlund et al., 2018) but also significantly contributes to fostering social awareness, complex problem-solving skills, and civic responsibility in students (Asunda, 2018; Bybee, 2010), which is fully compatible with the goal of developing "Agency in the Anthropocene" targeted by PISA 2025.

3. Content and Research Methods

3.1. Research Objectives

The research focuses on the following specific objectives:

(1) To systematize the theoretical basis of environmental science competency according to the PISA 2025 Science Framework and the STEMS teaching model linked to local context.
(2) To propose a project-based teaching process according to the STEMS model, which establishes a clear link between learning activities and the development of the components of environmental science competency.
(3) To design an illustrative project ("Simple Incense Drying Device") to clarify the feasibility and effectiveness of the proposed process.

3.2. Research Methods

To achieve these objectives, the study employs a combination of the following methods: Analyzing, synthesizing, and systematizing domestic and international scientific documents, including the PISA 2025 Science Framework, research papers on STEM/STEMS education, project-based learning, and teaching socioscientific issues. This method is used to build a solid theoretical foundation for the study. Based on the systematized theories, the study proceeds to model a teaching process with specific steps, establishing logical and dialectical relationships between objectives, content, teaching activities, and the competency components to be developed.

3.3. Research Content: Proposing a STEMS Project-Based Teaching Process to Develop Environmental Science Competency

To effectively connect the STEMS teaching model with the PISA 2025 goal of developing environmental science competency, we propose a detailed teaching process that clarifies the competency target for each step (Figure 1).

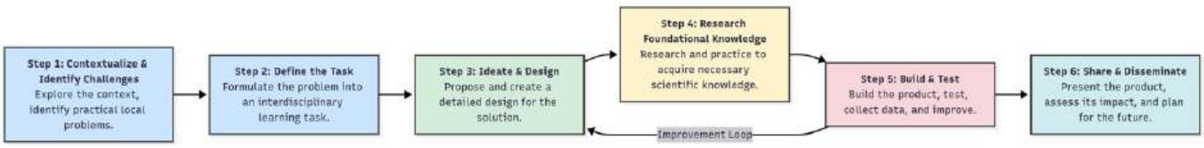

Figure 1. STEMS Project-Based Teaching Process for Developing Environmental Science Competency

Step 1: Contextualize – Identify Socio-Ecological Challenges

The process begins by having the teacher organize field surveys, interviews, and information gathering sessions focused on a real issue within the local community, such as a traditional craft village or a pollution problem. Working in groups, students identify the core challenges, conflicts, and stakeholders involved. This initial activity is designed to build the PISA 2025 competency of explaining the impact of the interaction between humans and Earth's systems, as students begin to describe the interplay between human activities and the natural environment. It also fosters the ability to demonstrate respect for diverse perspectives by requiring students to listen to and understand the different viewpoints of community members like artisans and local residents.

Step 2: Define the Task – Formulate an Interdisciplinary Problem

Based on the challenges identified in the first step, the teacher guides students to discuss and formulate a specific, open-ended learning task or problem that requires a solution. This problem must necessitate the integrated application of knowledge from various STEM fields and embody social values. This stage further develops the competency of explaining the impact of the interaction between humans and Earth's systems, as analyzing and defining the problem requires students to delve deeper into the cause-and-effect relationships and the scientific, technological, economic, and social factors that shape the issue.

Step 3: Ideate – Design a Systemic and Creative Solution

Students work in groups to brainstorm ideas and potential solutions using creative thinking techniques. They then select the most promising concept and develop a detailed design, which must specify the operating principles, required materials, implementation process, and criteria for evaluating the final product. This phase centrally focuses on the PISA 2025 competency of making informed decisions to act, as it challenges students to apply both creative and systems thinking to design potential solutions that consider sustainability factors and their multidimensional impacts.

Step 4: Research Foundational Knowledge – Explore and Practice

Under the teacher's guidance, students proactively engage with textbooks and other research materials and conduct hands-on experiments to acquire the necessary scientific knowledge spanning content, procedural, and epistemic domains that is essential for developing and refining their designed solution. This stage provides the solid foundation of scientific knowledge that serves as a critical prerequisite for the effective development of all three components of environmental science competency in the steps that follow.

Step 5: Build and Test – Act and Reflect

In this highly active phase, students construct their product or model based on their design, then proceed to test it, systematically collecting and analyzing data. Based on the results, they reflect on their solution's effectiveness and work collaboratively to make necessary adjustments and improvements. As students are directly engaged in action, this step is crucial for developing their ability to make informed decisions. They must evaluate the evidence gathered from their experiments, compare it against their established criteria, and make data-driven choices to optimize their solution.

Step 6: Share and Disseminate – Evaluate and Chart the Future

The project culminates with student groups presenting their products and sharing their entire implementation journey, often with community representatives and parents in attendance. This final step involves evaluating the potential environmental, economic, and social impacts of their solution and proposing ideas for future expansion. The act of sharing and receiving feedback from a diverse audience hones students' capacity for dialogue and respecting differences. By reflecting on their achievements, students strengthen their confidence, hope, and sense of self-efficacy, reinforcing their identity as true "agents" capable of creating positive change.

4. Results and Discussion: Illustration through the "Simple Incense Drying Device" Project

To clarify the feasibility and effectiveness of the proposed teaching process, we designed and analyzed an illustrative project named "Simple Incense Drying Device." This project is based on the economic and social context and the practical challenges of the Phia Thap incense-making village (Cao Bang province), a distinctive cultural heritage of the Nung An people.

4.1. Project Context and Problem

The Phia Thap incense village is famous for its traditional craft of handmade incense, which is the main livelihood for many households and a cultural beauty to be preserved. However, the production process, especially the drying stage, is entirely dependent on the weather. This reality creates major challenges:

- Socio-economically: On rainy, humid days, the incense cannot dry, leading to mold, reduced quality, and an inability to be sold. This directly affects the income and lives of the local people, reducing the attractiveness of the traditional craft for the younger generation.
- Scientifically and technologically: The local people lack a simple, low-cost technological solution to take control of the production process. Applying basic scientific principles could help resolve this bottleneck, stabilizing productivity and product quality.

These challenges constitute a specific socio-economic issue, providing an ideal context for organizing a learning project based on the STEMS model, directly connecting Physics knowledge (thermodynamics, electricity) with the community's needs.

4.2. Organizing Teaching Activities according to the 6-Step Process

The teaching process for the STEMS project "Simple Incense Drying Device" to develop environmental science competency is conducted in 6 steps (Figure 2).

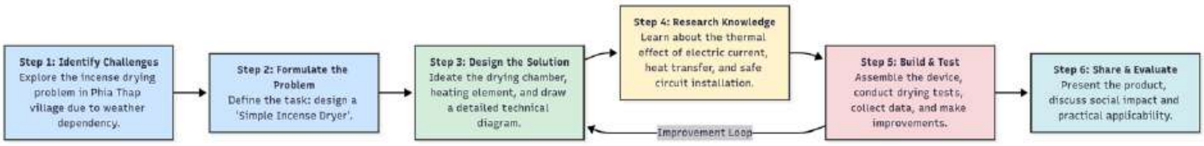

Figure 2. Teaching Process for the STEMS Project "Simple Incense Drying Device"

Step 1: Contextualize – Identify Challenges

To begin, students are immersed in the project's context by watching videos and documentaries about the Phia Thap incense village, focusing on the struggles villagers face when trying to dry incense during periods of rain. The teacher then prompts a discussion with questions like, "Why is drying incense so important?" and "What difficulties do the villagers face with unfavorable weather?". Through this, students collaborate to identify the core problem: the village's dependence on weather creates significant economic risk and threatens the sustainability of their traditional craft. This initial step allows students to begin explaining the impact of a natural factor (weather) on a human socio-economic activity while also learning to respect the perspectives and understand the hardships of the local people.

Step 2: Define the Task – Formulate the Problem

Building on the identified problem, the teacher guides students to formulate a clear and actionable project goal: "How can we design and build a 'Simple Incense Drying Device' using easy-to-find materials, with low cost and safe operation, to help the people of Phia Thap village dry incense effectively even on rainy, humid days?". This problem statement requires students to explain the impact of various physical factors such as temperature, humidity, and air convection on the process of evaporation and then apply this understanding to devise a practical technical solution.

Step 3: Ideate – Design the Solution

In this creative phase, student groups research and discuss various technical approaches to solve the problem. Their ideas center on key components, including a heating element (using incandescent bulbs or a heating coil), a drying chamber (using recycled materials like foil-lined cardboard boxes or a custom frame), and a ventilation system (designing convection vents or adding a small fan). Each group must then produce a detailed design plan, complete with a technical drawing of the chamber, a safe electrical circuit diagram, and a cost estimate for materials. This process directly develops their competency to make informed decisions to act by applying creative and systems thinking to generate a concrete technical solution.

Step 4: Research Foundational Knowledge – Explore and Practice

To successfully execute their designs, students are guided through learning activities focused on foundational knowledge from the Physics and Mathematics curriculum. They study the thermal effect of electric current by exploring the Joule-Lenz law (Q=I2Rt) to understand how their heating elements work. They also research heat transfer (convection and radiation) and the principles of evaporation, and review their knowledge of electrical circuits to ensure safe installation. This pivotal step equips students with the necessary scientific and mathematical knowledge to confidently build and test their proposed solutions.

Step 5: Build and Test – Act and Reflect

Drawing on their designs and newly acquired knowledge, student groups proceed to construct their incense drying devices. Once built, they begin a systematic testing process: placing damp incense inside the chamber, measuring the internal temperature over time, and recording how long it takes for the incense to dry completely, comparing it to natural methods. Through this "Build-Test-Improve" cycle, they identify issues like uneven drying or excessive heat and propose modifications, such as adding more vents or changing the bulb's wattage. This hands-on process strongly develops their ability to make informed decisions to act as they must continually evaluate experimental evidence to optimize their final product.

Step 6: Share and Disseminate – Evaluate and Chart the Future

The project concludes with a presentation session where each group showcases their final product, shares their design journey, and presents their test results and lessons learned. This event fosters discussion and critique, as other students and the teacher provide feedback on each device's effectiveness, cost, and safety. The class then reflects on the project's broader social impact, considering how the solution could bring positive change to Phia Thap village and what would be needed for villagers to build it themselves. By seeing how their creation can solve a real community problem, students reinforce their hope and sense of agency, realizing their own capacity to use science and technology for beneficial change.

5. Conclusion and Recommendations

5.1. Conclusion

The study has successfully developed a 6-step teaching process based on the STEMS model and illustrated its effectiveness through the "Simple Incense Drying Device" project. This process shows that:

- The proposed teaching process is a feasible and effective way to specify the requirements for developing environmental science competency according to the PISA 2025 Science Framework within the context of Vietnamese education. By closely integrating activities with the target competencies, this process creates a structured pathway for teachers to implement systematically.
- Using the local context as a starting point is the key factor that creates meaning and motivation for learning activities. The "Simple Incense Drying Device" project was not just an exercise in applying physics knowledge, but became a task with a clear social purpose: to help the community solve a practical problem. This motivated students to develop not only scientific competency but also empathy, a sense of responsibility, and a desire to contribute to society.
- The STEMS model, when implemented through practical projects, has demonstrated great potential in transforming students from passive knowledge recipients into active "agents of change." Students are given the opportunity to apply scientific knowledge

to create technology and solve problems, and through this, they realize their own power to create positive impacts, even on a small scale. This is the core spirit of the "Agency in the Anthropocene" concept that PISA 2025 aims for.

5.2. Recommendations

Based on the research findings, a coordinated effort is required for this teaching model to be successfully applied and scaled. Teachers are encouraged to be bold and creative in utilizing practical local contexts to build learning projects, and they should be supported through professional development programs on project-based and interdisciplinary methods. On the part of educational administrators, it is necessary to create a flexible mechanism that encourages teacher autonomy, provides material support, and fosters a strong cooperative relationship between the school and the community, such as by inviting local artisans and experts to participate in the teaching process. Finally, future research should focus on implementing larger-scale experiments to verify the model's effectiveness, as well as on developing and standardizing an assessment toolkit for environmental science competency aligned with the PISA 2025 orientation—to objectively and scientifically measure its impact.

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