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Integrating STEM education for sustainable development through a context-based probiotic foods project in a Vietnamese secondary school

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ABSTRACT

This study reports on how context-based STEM (Science, Technology, Engineering, and Mathematics) education can be integrated with Education for Sustainable Development (ESD) in secondary schools through a probiotic food project. Conducted at a public high school in Can Tho City, Viet Nam, the project involved 100 tenth-grade students in designing and producing probiotic products from locally sourced ingredients. The curriculum was structured around a seven-step STEM instructional model emphasizing problem identification, interdisciplinary learning, and community relevance. Quantitative data were collected via a 15-item Likert-scale survey measuring students' reflections on STEM competencies, sustainability awareness, and engagement. A structured teacher reflection journal provided qualitative insights into pedagogical transformation and implementation challenges. Findings indicated that students developed stronger problem-solving skills, close connections between STEM content and real-world agricultural contexts, and increased interest in sustainability-related careers. The teacher's reflection revealed shifts from traditional content delivery to facilitation, along with practical constraints related to time and coordination. This study contributes to the growing body of literature on localized STEM-ESD integration and highlights the value of authentic, place-based learning in promoting both scientific and civic competencies among secondary school students.

1. INTRODUCTION

In the twenty-first century, education systems worldwide are undergoing a transformative shift toward approaches that emphasize interdisciplinarity, real-world relevance, and future-oriented competencies. Among these, STEM education and ESD have emerged as two influential paradigms driving innovation in curriculum and pedagogy (Bybee, 2010; Jamali et al., 2023; the United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020). Both STEM and ESD place learners at the center of inquiry-based, experiential learning, seeking not only to improve academic performance but also to equip students with the capacities needed to navigate complex global challenges. However, while STEM focuses primarily on technical and problem-solving skills, ESD calls for a broader shift in the purpose of education, embedding sustainability values, systems thinking, and critical reflection at the heart of teaching and learning (UNESCO, 2017).

Efforts to reform secondary education increasingly advocate for a convergence of STEM and ESD, recognizing that the challenges of the Anthropocene, climate change, food insecurity, biodiversity loss, and social inequity, require holistic thinking and multi-perspective engagement. As Kelley and Knowles (2016) argue, integrated STEM education provides the structural scaffolding for interdisciplinary exploration, but without ethical and environmental anchoring, it risks promoting technocratic rather than transformative thinking. ESD offers this critical dimension. Rooted in the principles of the 2030 Agenda for Sustainable Development, particularly Goal 4.7, ESD urges educators to develop learners' abilities to understand, anticipate, and act upon sustainability issues in ways that are locally grounded yet globally informed (UNESCO, 2020).

In Vietnam, the recent curricular reforms by the Ministry of Education and Training (MOET, 2018) have actively supported STEM integration across subjects, and there is growing institutional momentum to embed sustainability themes into classroom practice. However, bridging STEM and ESD remains a nascent endeavour. Few secondary-level projects simultaneously address content mastery in science and mathematics while also fostering students' critical awareness of their social and ecological environments. Against this backdrop, the STEM Probiotic Foods Project was conceptualized as a school-based, interdisciplinary learning initiative aiming to connect scientific inquiry with sustainable food practices.

The project tasked students with investigating local agricultural waste, designing probiotic food solutions through fermentation techniques, and developing product prototypes that reflected both nutritional value and environmental consciousness. By involving students in identifying real-world problems, researching microbial applications, and creating locally adapted innovations, the project offered a concrete platform to realize context-based STEM education (Sutaphan & Yuenyong, 2019) while advancing the core ESD competencies of systems thinking, anticipatory skills, collaboration, and self-awareness (UNESCO, 2017). In addition, the integration of arts and design elements in packaging and branding encouraged aesthetic appreciation and creative engagement, aligning with STEAM-based (STEM + Arts) approaches to sustainable learning (Madden et al., 2013).

This study thus addresses two interrelated objectives. First, it explores how a context-driven STEM curriculum, built around local issues of agricultural sustainability and microbial science, can operationalize ESD principles in a meaningful way for secondary students. Second, it investigates students' learning outcomes and self-reported reflections concerning their cognitive, social, and affective development throughout the project. The aim is not only to assess the pedagogical efficacy of the Probiotic Foods Project but also to contribute to broader conversations about the role of interdisciplinary, practice-based learning in cultivating future-ready, sustainability-conscious citizens.

In doing so, this paper positions the STEM Probiotic Foods Project as a prototype of integrated STEM-ESD curriculum innovation, one that bridges theory and practice, local and global, and science and values. As the international education community continues to search for models that prepare learners to act ethically and effectively in uncertain futures, initiatives like this underscore the transformative potential of education grounded in relevance, responsibility, and reflection (Tytler, 2020; Tarlochan et al., 2025).

2. MATERIALS AND METHOD

2.1. Project context and participants

The STEM Probiotic Foods Project was implemented at a public secondary school in Can Tho City, Vietnam, during the 2023–2024 academic year. The school was selected for its active engagement in STEM-oriented teaching innovation and its capacity to support project-based learning. A total of 100 students from Grade 10 (approximately 16 years of age) participated in the project as part of their biology and interdisciplinary elective coursework. All participants were recruited on a voluntary basis.

Prior to data collection, informed consent was obtained from students and their legal guardians. The research design was reviewed and approved by the school's ethics committee and followed the ethical guidelines set by the local Department of Education and Training. Students were assured of the confidentiality of their responses and informed that their participation or non-participation would not affect their academic standing. After the project's completion, all participants were invited to voluntarily complete an anonymous survey about their learning experiences.

2.2. Context-based STEM curriculum design

The Probiotic Foods Project was conceptualized and executed using the context-based STEM education model proposed by Sutaphan and Yuenyong (2019). This model consists of seven iterative stages that guide the integration of real-world issues into STEM instruction. The project was embedded in students' biology curriculum but was intentionally interdisciplinary, incorporating mathematics (e.g., measuring ratios in fermentation), technology (e.g., documenting and presenting prototypes), and visual arts (e.g., product design and packaging).

The curriculum was co-designed by teachers and STEM education specialists to align with national curricular goals and local agricultural contexts. The stages included:

Identification of local problem: Students explored the rapid spoilage of local agricultural produce and its implications for health, economy, and sustainability.

Information gathering: Students conducted research on probiotics, microbial fermentation, and food preservation through library sources, online databases, and interviews with local producers.

Knowledge acquisition: In small groups, students applied microbiology concepts to understand fermentation, designed product formulas, and studied mathematical principles for accurate measurement and scaling.

Decision-making: Students presented their proposed probiotic product plans and received feedback from peers and teachers to refine their designs.

Prototype development: Students prepared their probiotic food products at home using local ingredients and documented their process with images and videos.

Presentation and peer feedback: Groups presented their products to classmates and teachers for evaluation, incorporating rubrics for scientific reasoning, creativity, and practical feasibility.

Iterative refinement and community sharing: Students created short vlogs and promotional materials to introduce their products to a wider audience, including school events and social media channels.

This process was guided by teachers who acted as facilitators, encouraging student-led inquiry, collaborative problem-solving, and the practical application of STEM and ESD competencies.

2.3. Data collection instruments

To evaluate student learning and project impact, two primary qualitative and quantitative data collection tools were employed.

2.3.1. Student reflection survey

A 15-item Likert-scale questionnaire was developed to capture student perceptions of the project. Items were designed to assess three overarching domains:

Interdisciplinary learning: e.g., "I enjoyed how biology, mathematics, and art were connected in the project."

STEM skill development: e.g., "This project improved my problem-solving and collaboration skills."

ESD-related awareness: e.g., "I became more aware of local agricultural challenges through this project."

Each item was rated on a 5-point scale (1 = strongly disagree to 5 = strongly agree). The survey was administered anonymously at the end of the project and completed by all 100 participating students.

2.3.2. Teacher's reflective journal

In addition to student data, the lead teacher who facilitated the project kept a reflective journal. The journal entries were structured using guiding questions adapted from ESD-informed teacher development frameworks (UNESCO, 2017). These questions explored areas such as:

– Motivations for designing the project

– Pedagogical strategies employed

– Observed student engagement and difficulties

– Perceived impact on student learning and sustainability awareness

The journal served as both a formative assessment tool during implementation and a post hoc reflection tool for research analysis.

2.4. Data analysis procedures

Survey responses were analyzed using descriptive statistics (mean scores, standard deviations) to identify general trends in student perceptions across the three domains. Reliability of the instrument was evaluated through Cronbach's alpha.

The teacher's reflective journal was subjected to thematic analysis using a deductive coding approach. Three primary thematic categories were pre-defined to align with the research objectives:

– STEM-related learning outcomes (e.g., collaboration, problem-solving, scientific understanding)

– Sustainability perception and relevance (e.g., understanding of local food systems, value of probiotics, community application)

– Engagement and motivation (e.g., student interest, ownership of learning, response to real-world relevance)

Coding was conducted independently by two researchers and reviewed collaboratively to ensure consistency and trustworthiness.

3. RESULTS AND DISCUSSION

3.1. Student reflections

To investigate students' responses to the STEM-based Probiotic Foods project, a structured Likert-scale survey was administered to 56 Grade 10 students. Although 100 students participated in the project, only 56 voluntarily completed the anonymous Google Form survey, which served as the basis for data analysis. The 15 items were grouped into three emergent clusters: (1) applied understanding of STEM; (2) awareness of local sustainability issues; and (3) increased motivation toward STEM futures. Descriptive statistics and reliability analysis were performed using SPSS.

As shown in Table 1, students consistently showed high levels of agreement across all three clusters. Items related to interdisciplinary learning, problem-solving, and microbial knowledge demonstrated strong mean scores and low standard deviations. The integration of biology, chemistry, mathematics, and art in the production of probiotic foods provided learners with opportunities to consolidate STEM knowledge through hands-on experimentation, an approach supported by prior research (Bybee, 2010; English, 2016).

Table 1. Descriptive statistics for student reflections by thematic cluster

Cluster	Item Code	Survey Item	Mean	SD	Cronbach's α
Cluster 1: Applied Understanding of STEM					
	Q1.1	The project helped me understand the real-world application of STEM subjects.	4.43	0.797	**0.930**
	Q1.2	It improved my problem-solving skills.	4.36	0.851	
	Q1.3	I feel more confident in group collaboration after the project.	4.16	0.910	
	Q1.4	The project enhanced my understanding of microbial applications.	4.50	0.831	
	Q1.5	I enjoyed the interdisciplinary nature of the project.	4.20	1.052	
	Q1.6	The project increased my interest in pursuing future research or careers in STEM.	4.23	1.002	
	Q1.7	Teacher guidance supported our success.	4.25	0.959	
Cluster 2: Awareness of Local Sustainability Issues					
	Q2.1	I found the practical activities (e.g., creating probiotic foods) educational and engaging.	4.32	0.901	**0.897**
	Q2.2	The project enhanced my awareness of local agricultural challenges.	4.02	1.034	
	Q2.3	I felt proud and satisfied in creating probiotic products.	4.39	0.867	
	Q2.4	Emphasizing the use of local produce was meaningful and appropriate.	4.25	0.958	
Cluster 3: Motivation Toward STEM Futures					
	Q3.1	The project inspired me to explore future STEM projects.	4.66	0.837	**0.929**
	Q3.2	The project encouraged creative and innovative thinking.	4.45	0.877	
	Q3.3	I developed valuable presentation and communication skills.	4.64	0.841	

Awareness of agricultural and environmental relevance was also strong. Items referencing local food systems, fermentation techniques, and ecological awareness yielded high mean ratings, affirming the importance of grounding STEM education in contextualized, real-world problems (Sutaphan & Yuenyong, 2019; UNESCO, 2020). This aligns with the core tenets of ESD, which emphasize linking learning to local sustainability challenges.

The third cluster, focused on motivation and orientation toward STEM futures, returned the highest mean scores. Students reported feeling inspired to pursue future STEM-related activities and expressed pride in creating tangible, health-promoting products. These findings support earlier studies noting the role of experiential, student-centered projects in cultivating identity and aspirations in STEM (National Academies of Sciences, 2018).

Despite these promising outcomes, the study acknowledges several limitations. The self-reported nature of survey responses may reflect a degree of social desirability bias. In addition, the absence of a control group limits comparative inferences about the specific effect of the intervention. Further studies may benefit from pre-post designs or mixed-methods triangulation.

3.2. Teacher reflection analysis

In parallel with the student survey, the teacher's structured reflection provided qualitative insights into the design and implementation of the Probiotic Foods project. The reflective journal was guided by prompts addressing project motivation, curriculum integration, instructional adaptations, observed challenges, and impacts on student learning. Thematic coding yielded three main categories: (1) practical constraints, (2) student-centered pedagogical shifts, and (3) perceived student transformations.

The most salient practical constraint reported was limited instructional time. The project was allocated only one month, while certain fermentation-based activities required longer durations to yield visible results. Additionally, scheduling conflicts and a lack of dedicated class periods necessitated improvisational solutions, such as assigning homework-based experimentation and leveraging idle periods within biology lessons. These time pressures mirror implementation barriers commonly noted in STEM-ESD integration in developing contexts (Le et al., 2021).

Logistical monitoring also proved difficult, especially as students created probiotic products at home. To ensure transparency, the teacher required students to record video documentation of their processes. Despite these efforts, assessing the integrity of out-of-class project work remained a challenge, echoing broader concerns in informal STEM learning environments (Braund & Reiss, 2006).

Crucially, the teacher's reflection signaled a reframing of her pedagogical approach. The project required a shift from content delivery to facilitative instruction, in which students took responsibility for inquiry, experimentation, and presentation. This aligns with the constructivist underpinnings of both STEM and ESD frameworks, in which teachers act as guides and learning is situated within authentic, problem-based contexts (Bybee, 2010; UNESCO, 2020).

Throughout implementation, the teacher observed marked improvements in students' collaborative engagement and ownership of learning. Learners assumed distinct roles within groups, coordinated task distribution, and were intrinsically motivated by the real-world relevance of their outputs. As reported: "Each member's contribution was essential to creating a finished product… they were more invested than in traditional learning." These findings resonate with prior research showing that contextualized STEM-ESD projects foster deeper engagement and teamwork (Sutaphan & Yuenyong, 2019).

Finally, the teacher expressed that the project had enriched her own instructional repertoire. The experience demonstrated how ESD values—locality, sustainability, and student agency—could be woven meaningfully into STEM lessons, moving beyond textbook exercises to community-relevant learning. While acknowledging that only highly engaged students maximized the project's benefits, she regarded the project as both professionally rewarding and pedagogically transformative.

In sum, the teacher's reflection substantiates the feasibility and educational value of integrating ESD through STEM in Vietnamese secondary schools, while highlighting critical contextual enablers and constraints that should inform future scaling or replication.

4. CONCLUSION

This study demonstrated the educational value of embedding ESD principles into STEM curricula through a context-based project on probiotic foods. Designed around a real-world issue—local fermentation practices and food sustainability—the project fostered interdisciplinary learning, engaged students in systems thinking, and cultivated essential 21st-century competencies. The approach empowered learners not only to apply scientific knowledge but also to reflect critically on local environmental and agricultural issues.

More broadly, the findings support the argument that ESD-aligned STEM projects offer a viable pathway to making science education more relevant and transformative, especially in Southeast Asian secondary contexts where sustainability challenges are deeply embedded in local realities. The study also highlights the importance of teacher agency and pedagogical adaptation, showing how meaningful instructional change can emerge from reflective, practice-based innovations.

Future research should extend this model to explore longitudinal impacts on students' career interests, civic agency, and scientific identity. There is also a need to examine how institutional support, curriculum integration, and teacher professional development can enhance the scalability and sustainability of ESD-STEM initiatives across diverse school systems.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to the research, authorship, or publication of this article.

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