

Integrating Sustainability Literacy Cultivation into STEM Education: A Pathway for Teacher Professional Development

Yvonne Tang

Smart Education Research Branch of the Chinese Society for Tao Xingzhi Studies,
Nanjing 210000, Jiangsu, China

“The scientist is not a person who gives the right answers, he's one who asks the right questions.”

- Claude Lévi-Strauss

IN the context of intensifying climate change, depletion of natural resources, and biodiversity loss, education has the responsibility for fostering sustainability literacy in future citizens. Sustainability literacy, one of the key 21st-century competencies, enables the individual learners to understand the interconnections between the environmental, economic, and social dimensions of sustainable development, as well as to make informed decisions in complex real-world situations (Evans et al., 2017).

STEM education, as an interdisciplinary approach to science education that integrates science, technology, engineering, and mathematics, is inherently aligned with the goals of sustainability education. STEM education provides students with a practical framework that facilitates them combining scientific knowledge with engineering design processes to address actual environmental, social, and economic challenges (Awad et al., 2025). This interdisciplinary structure supports the inclusion of sustainability-related issues, such as energy efficiency, renewable energy, and waste management, into teaching practices, while also encouraging the development systems thinking and problem-solving skills in students (Fathurohman et al., 2023).

In recent years, endeavors to explore the paths for integrating STEM education and sustainability literacy training are many. For example, Anggraini et al. (2022) conducted an innovative study in Indonesia, developing a renewable energy instruction program based on the integration of multi-representation, project-based learning (PjBL George Lucas), and STEM education, aimed at fostering students' sustainability literacy.

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Using the ADDIE (standing for Analyze, Design, Develop, Implement, and Evaluate) instructional design model, the study developed a comprehensive teaching resource package including lesson plans, electronic manuals, student worksheets, comics, and posters. The results showed that the experimental class demonstrated significantly greater gains than the control class in the four dimensions of sustainability literacy: knowledge, attitudes, skills, and behaviors. Sihombing et al. (2025) systematically examined the effectiveness of STEM teaching materials in supporting scientific literacy and sustainability awareness through a critical review of 18 international journal articles published between 2019 and 2024. The study's findings reveal that STEM education and relevant teaching materials hold potential for enhancing scientific literacy and promoting sustainability awareness, with particularly notable improvements in the two areas when STEM-based instructional materials are used. Chan and Nagatomo (2022) proposed the "STEM Education for Sustainability" framework (STEM4S), which aims to extend the STEM approach to a not just interdisciplinary but also critical thinking-based approach to addressing global challenges such as climate change and barriers to Sustainable Development Goals (SDGs). Empirical research applying this framework in the "disaster project" course at the Department of Design, National Taiwan Normal University, revealed significant improvements in students' critical thinking, teamwork, and confidence in facing challenges.

From the perspective of teacher education, Barth and Rieckmann (2016) emphasized that sustainability literacy development in students requires teachers' understandings of the interrelationships among environmental, economic, and social systems and to integrate them into their teaching practices in a comprehensive and coherent manner. However, existing studies have shown that teachers often interpret sustainability primarily from an environmental standpoint and face considerable challenges in integrating economic and social dimensions into their teaching practices (Ferreira et al., 2019). These practical challenges highlight the necessity of developing structured professional training programs for teacher sustainability literacy training.

Sustainability-Oriented STEM Professional Development Program: Developing Teachers' Competencies in this issue is an examination of the effects of a six-day sustainability-oriented STEM professional development program on teachers' conceptual understanding of sustainable development, sustainability literacy, and their competencies in planning and implementing sustainability-oriented STEM education practices using qualitative research design. By adopting a pre- and post-program qualitative content analysis method, the study reveals positive changes in the teachers' understanding of sustainability, STEM education, and their teaching implementation competences following their participation in the program (Zhao, 2026). On the level of teacher training, the study identifies a teacher professional development pathway for cultivating sustainability literacy and validates the feasibility of integrating sustainability literacy development into STEM education, making a unique contribution to the literature. However, it must be acknowledged that the study's design has certain limitations: the sample is of small size and consists of voluntary participants, which may introduce self-selection bias; the data is from teachers' self-reports rather than from direct observations of actual classroom implementation; and the relatively short duration of the program makes it difficult to assess the long-term sustenance of the observed changes. Future research that focuses on long-term effects, integrates multiple sources of evidence, and delves deeply into the patterns of change is highly anticipated.

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Correspondence to:

Yvonne Tang

Smart Education Research Branch of the Chinese Society for Tao Xingzhi Studies

Nanjing 210000, Jiangsu

China

E-mail: yvonnetaqi@foxmail.com

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