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INTEGRATING SCIENCE, TECHNOLOGY, ENGINEERING, ARTS, AND MATHEMATICS (STEAM) AND SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN SUSTAINABLE CITY PROJECTS TO IMPROVE ECOLITERACY OF ELEMENTARY SCHOOL STUDENTS

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Abstract

This study aimed to examine the impact of a science, technology, engineering, arts, and mathematics (STEAM)-based sustainable city project on the ecoliteracy of elementary school students within the context of sustainable development goals (SDGs). Using a pre-experimental One-Shot Case Study design and a mixed-methods approach, data were collected through tests, questionnaires, documentation, and interviews. The results demonstrated improvement in students' knowledge and attitudes regarding sustainability and environmental responsibility. This occurred because the integration of science, technology, engineering, arts, and mathematics helped students understand ecological issues and develop solutions through contextual learning. Additionally, qualitative data showed enhanced skills in critical thinking and collaboration during project implementation. The project motivated students by involving them in real-world applications aligned with the SDGs. This suggests that combining STEAM and SDG principles in project-based learning can meaningfully foster ecoliteracy at the elementary level.

Keywords: Ecoliteracy, Elementary students, SDGs, STEAM, Sustainable city project.

1. Introduction

Ecoliteracy refers to the ability of individuals to understand ecological principles and apply them in daily life through knowledge, awareness, and responsible action toward environmental sustainability [1, 2]. In educational settings, ecoliteracy plays a critical role in shaping future citizens who are environmentally responsible and capable of responding to complex ecological challenges [3]. However, current evidence shows that elementary students' ecoliteracy remains underdeveloped, often due to limited exposure to experiential learning and contextual environmental education [4, 5]. To address this, educators have emphasized the integration of sustainability themes within school curricula, particularly through interdisciplinary approaches that promote not only knowledge acquisition but also behavioural change and ecological values [6].

One innovative method to foster ecoliteracy is through project-based learning that situates students in real-life contexts where they actively solve environmental problems. The Sustainable City Project is one such approach [7, 8], where students conceptualize and construct models of eco-friendly urban systems involving waste management, renewable energy, transportation, and green spaces [9, 10]. Many reports regarding city development have been developed [11-16]. Here, the project allows students to experience sustainability as a tangible, achievable goal, while aligning their learning with broader initiatives such as the Sustainable Development Goals (SDGs) [17], particularly SDG 4 (Quality Education) and SDG 13 (Climate Action) [18, 19]. When implemented in elementary education, this model supports cognitive development, instils environmental ethics and encourages collaboration among young learners [20].

To strengthen the impact of such initiatives, the Sustainable City Project in this study is enriched with the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach. STEAM supports students' holistic understanding by encouraging critical thinking, creativity, and problem-solving across disciplines [21, 22]. It fosters deeper connections between scientific knowledge and real-world action, making sustainability issues more relatable and engaging for students.

This study aims to investigate the impact of implementing a STEAM-based Sustainable City Project on the ecoliteracy of elementary school students. The novelty lies in applying a STEAM framework to a sustainability-focused learning model at the elementary level, highlighting how integrative, contextual, and hands-on learning can empower students as agents of ecological change.

2. Literature Review

Figure 1 illustrates the process of creating a sustainable city project, which integrates multiple aspects of environmental, technological, and social considerations. This process involves students in simulating the development of eco-friendly cities by applying real-world knowledge in science, engineering, and design. A sustainable city incorporates principles of long-term environmental, economic, and social resilience, emphasizing renewable energy, waste reduction, and smart infrastructure to mitigate carbon footprints [9, 10]. Through the Sustainable City Project, students engage in constructing conceptual models of urban systems such as renewable transport, green spaces, and water management, fostering awareness of how ecological and human systems interact [18, 19].

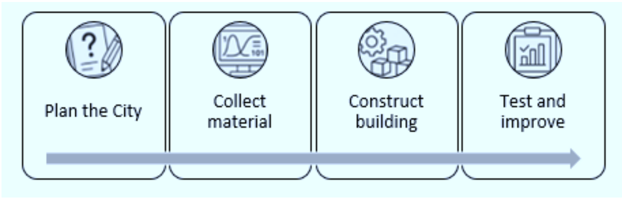

Fig. 1. Sustainable city project process.

Figure 2 presents an example of a student-designed sustainable city layout, highlighting biogas utilization, urban farming, and resource loops. Students learn how environmental technologies can be applied in practical settings, integrating knowledge of biology, physics, and systems thinking into environmental solutions [23, 24].

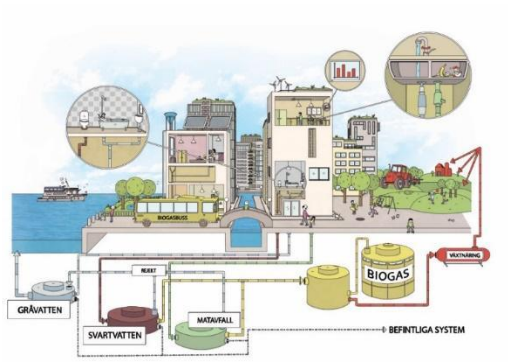

Fig. 2. The example of sustainable city project.

Figure 3 outlines the STEAM project map, indicating how each discipline is applied across stages of the sustainable city model. The STEAM approach enhances this project by combining five core disciplines (science, technology, engineering, arts, and mathematics) into cohesive learning experiences that are both hands-on and inquiry-driven [21, 25]. It not only supports ecoliteracy development through conceptual integration but also strengthens creative thinking and problem-solving abilities.

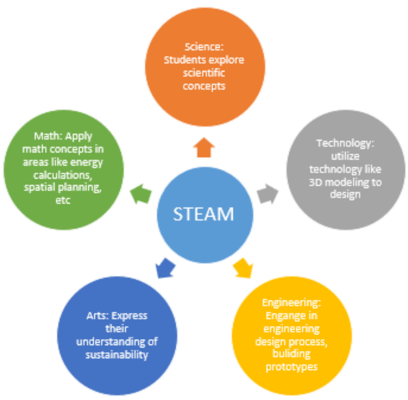

Fig. 3. Project map: STEAM in a sustainable project.

Holistic education strategies like STEAM are essential for fostering ecoliterate citizens capable of addressing real environmental challenges [20,22]. Moreover, connecting this model to the SDGs, particularly SDG 4 (Quality Education) and SDG 13 (Climate Action), aligns educational practice with global development priorities [26, 27]. Previous research has rarely combined STEAM with contextualized sustainability themes in elementary settings [28], signalling the novelty and relevance of this study.

3. Method

A pre-experimental One-Shot Case Study design was employed using a mixed-methods approach to assess the impact of the STEAM Sustainable City project on students' ecoliteracy [3, 5]. Detailed information regarding this method is explained elsewhere [29].

Quantitative data were obtained through tests and questionnaires, while qualitative insights were gathered from documentation and interviews. The study involved purposively selected fifth-grade students from three elementary schools in East Java, Indonesia (i.e. SDN Pakis 1 Surabaya, SDN Sidokumpul Surabaya, and SDN Prajuritkulon Mojokerto), ensuring contextual relevance in environmental learning (Hartono, 2020; Liu and Zhang, 2020) [6, 23]. We analysed statistics to get a better understanding of the results. Detailed information on how to analyse using statistical analysis is reported elsewhere [30-32].

4. Results and Discussion

We evaluated student activities during the group project, where collaboration and creativity were observed. The group-based nature of the STEAM Sustainable City project facilitated knowledge exchange, hands-on problem-solving, and the ability to apply environmental theories in meaningful tasks [5, 27]. Students were seen designing eco-friendly infrastructure such as green roofs, smart transport, and circular waste systems, aligning with the SDG framework and encouraging deeper ecological awareness [19].

We also focused on qualitative documentation of students' critical thinking and communication skills. They engaged in discussions, defended their ideas, and revised plans collaboratively, demonstrating the role of project-based STEAM in cultivating 21st-century competencies [20, 22]. The shift from passive learning to active engagement empowered students to see themselves as environmental problem-solvers.

The STEAM Sustainable City Project, effectively improved students' ecoliteracy skills, as shown by post-test scores of 88.25 (SDN Pakis 1 Surabaya), 74 (SDN Sidokumpul Surabaya), and 86.75 (SDN Prajuritkulon Mojokerto). A one-sample statistical test using SPSS 25 confirmed its effectiveness with a significance value of 0.000 ($p < 0.05$). The data indicate a significant increase in ecoliteracy knowledge, with scores ranging from moderate to high. The highest average score came from SDN Pakis 1 Surabaya, suggesting contextual factors such as school culture and teacher facilitation may have played a role [9, 33]. The statistical analysis using SPSS yielded a significance value of 0.000 ($p < 0.05$), confirming the project's effectiveness in enhancing ecoliteracy understanding through STEAM learning [4].

This improvement was supported by student interviews revealing high enthusiasm and motivation, especially during the hands-on activity of designing city models in groups. Students' joy in creating their first models contributed to deeper engagement and understanding of sustainability concepts. Motivation played a crucial role in enhancing ecoliteracy, encouraging students to actively learn, discuss, and apply environmental knowledge in daily life, ultimately fostering a stronger sense of responsibility and action toward environmental issues.

Figure 4 presents student responses analysed using Partial Least squares-structural equation modelling (PLS-SEM). The model shows strong loadings for constructs like contextual learning, ease in expressing opinions, and understanding of material. The path coefficients indicate that engaging and relevant learning environments significantly influenced student comprehension and motivation [28, 34]. These findings support the argument that STEAM contextualization enhances both affective and cognitive aspects of ecoliteracy.

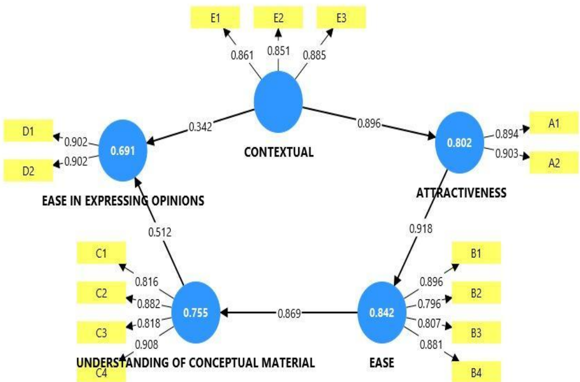

Fig. 4. PLS-SEM results showing the influence of contextual learning on student outcomes.

These results collectively demonstrate how STEAM-based project learning, when grounded in real-world environmental challenges and supported by SDG-oriented goals, improves not only knowledge and attitudes but also skills and values essential for ecological citizenship [25, 26]. This study adds new information regarding application of SDGs as reported elsewhere [35-40].

5. Conclusion

The implementation of the STEAM Sustainable City project effectively enhanced elementary students' ecoliteracy by integrating science, technology, engineering, arts, and mathematics within real-world sustainability contexts. Improvements were evident in students' knowledge, attitudes, and critical thinking skills because the project-based and contextual learning approach promoted engagement and deeper understanding. These outcomes align with SDG targets, particularly those related to education and climate action, highlighting the potential of STEAM to support transformative environmental education in early schooling.

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