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STEM-ESD Learning for Sustainability: Efforts to Improve Students' Self-Awareness Competencies in Organic Waste Management

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ABSTRACT

Waste management is an important issue in Indonesia, and awareness and actions in all sectors, including students in schools. This study aims to examine the effect of the STEM-ESD model on students' self-awareness competency in the context of environmentally friendly organic waste management. This study used a quasiexperimental method with a non-equivalent control group design, applied to 48 seventh-grade students at a Madrasah Tsanawiyah school in Sukabumi, West Java, Indonesia, which were divided into an experimental group (n=24) who received STEM-ESD project-based learning through the manufacture of liquid organic fertilizer, and a control group (n=24) who received conventional learning. Self-awareness competency was measured using a 4-point Likert scale questionnaire that included four indicators: conceptual awareness, experiential awareness, awareness to engage, and awareness to adapt. Data analysis was carried out using the Shapiro-Wilk normality test, Levene's homogeneity test, and the Mann-Whitney U Test (α = 0.05) through IBM SPSS Statistics Version 25. The results showed a statistically significant difference (p = 0.003). Analysis per indicator shows that awareness to adapt resulted in the highest increase (N-Gain = 0.38), while awareness to engage obtained the lowest but still positive increase (N-Gain = 0.29). These findings confirm that the STEM-ESD model is an effective, contextual, and sustainability-oriented pedagogical approach, in line with the Curriculum.

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INTRODUCTION

The 21st-century education has undergone a fundamental paradigm shift, from merely transmitting cognitive knowledge to developing integrated socio-emotional and sustainable competencies. Within this framework, self-awareness competencies (self-awareness) is recognized as a core competency by various leading international frameworks, including the OECD Learning Framework 2030 and the roadmapEducation for Sustainable Development UNESCO (OECD, 2019; UNESCO, 2020). Self-awareness competency encompasses an individual's ability to recognize emotions, personal values, strengths, limitations, and the ecological consequences of their actions on the social and natural environment. In the context of sustainability education, this competency serves as a prerequisite for transformative behavioral change, namely the ability to bridge scientific understanding and responsible action (Alexander, 2018; Wals & Benavot, 2017). Without a solid foundation of self-awareness, students' environmental knowledge will not automatically lead to sustainable, pro-environmental behavior.

Within the framework Education for Sustainable Development (ESD), self-awareness competency is one of the eight core sustainability competencies formulated by Kioupi & Voulvoulis, 2019), along with systems thinking, normative, strategic, and problem-solving competencies. (UNESCO, 2020) emphasizes that ESD must produce transformative learning outcomes that are reflective, experiencebased, and contextual. From an emotional intelligence perspective, Goleman (2020) defines selfawareness competency as a core ability that enables a person to recognize emotions, assess themselves accurately, and act with confidence. Furthermore, Sen et al. (2021) operationalizes selfawareness competency as a dynamic and gradual process through four indicators: (1) conceptual awareness, namely an individual's understanding of material content; (2) experiential awareness, namely the connection of content to personal experience; (3) awareness of engagement, which refers to the frequency and quality of engagement with related issues; and (4) awareness of adaptation, namely the ability to respond to and internalize relevant policies. These four indicators provide a comprehensive and structured measurement framework for research on self-awareness competency in the educational context.

In the context of Indonesian national education, the development of self-awareness competencies is in line with the mandate of Law Number 20 of 2003 concerning the National Education System, which requires the formation of students who are faithful, have noble character, are knowledgeable, creative, independent, and responsible as citizens. The Independent Curriculum issued by the Ministry of Education, Culture, Research, and Technology (2022) strengthens this vision through the Pancasila Student Profile, specifically in the dimensions of faith and devotion to God Almighty, independence, and mutual cooperation which substantively demand the realization of self-awareness competencies in attitudes and actions towards oneself, society, and the natural environment. The implementation of the Sustainable Lifestyle theme in the strengthening the pancasila student profile or P5 program explicitly directs students to analyze the impact of human behavior on the environment and develop environmentally friendly innovation-based solutions through authentic projects. This underlines the urgent need for a learning model that can systematically foster ecological self-awareness competencies as an inseparable part of science learning outcomes at the junior high school/Islamic junior high school level.

While the policy provides clear direction, empirical evidence from Indonesian classrooms consistently reveals a significant gap between expected and actual outcomes in students' socio-environmental competencies. Students rarely receive opportunities for critical inquiry, authentic environmental engagement, or structured self-reflection on their roles and responsibilities towards the environment. These findings align with research by Fadhilatunnisa & Bahrudin (2026) which documentedteacher teaching consistencyin state madrasas, as well as Supriatna et al. (2026) who found that biology learning in sschool inIndonesia rarely integrates contextual problem solving and reflection. value-based. This condition has a direct impact on low student participation in environmentally friendly organic waste management practices, both at school and at home.

To address this pedagogical gap, STEM (Science, Technology, Engineering, and Mathematics)-based learning approaches have received increasing attention in science education research. STEM project-based learning integrates cross-disciplinary knowledge in authentic problem-solving contexts

and has been shown to enhance students' higher-order thinking skills and conceptual understanding (Bybee, 2013; Kelley & Knowles, 2016). However, conventional STEM implementations are often criticized for their scientific orientation, which overemphasizes innovation and productivity, while neglecting the ethical, social, and environmental dimensions of scientific application (Solihat et al., 2024). These limitations have prompted researchers to integrate STEM with ESD principles, resulting in the STEM-ESD model: an interdisciplinary, contextual, project-based, action-oriented, and sustainable learning framework that enables students to address real-world environmental challenges through the lens of scientific reasoning and social responsibility (Annisa et al., 2024; Martín-Sánchez et al., 2022).

Empirical evidence supports the influence of the STEM-ESD model in fostering sustainability competencies, including self-awareness competencies. Martín-Sánchez et al. (2022) showed that STEM-ESD project-based learning encourages changes in mindset andself-reflectionstudents through involvementexperientialwith ecological issues. Djirong et al. (2024) found a direct positive correlation between self-awareness competency regarding sustainability issues and pro-environmental behavior in the school environment, particularly within the framework of a green curriculum. Hariyadi et al. (2023) reported that environmental project-based learning in biology classes in Indonesia contributed significantly to increasing students' ecological awareness and pro-sustainability attitudes. Wals & Benavot (2017) argued that project-based ESD learning, when implemented with real-world contextual relevance, produces affective and behavioral changes that traditional content delivery cannot produce. Overall, these findings build a strong theoretical and empirical foundation for testing the STEM-ESD model in the context of science learning at the junior high school/Islamic junior high school level

The selection of liquid organic fertilizer production as the project context in this research is based on strong scientific and social reasons. Organic waste is a dominant fraction of solid waste generated by school communities in Indonesia, yet its management remains very minimal at the school level. The process of producing liquid organic fertilizer integrates core Biology content such as decomposition, microbial ecology, material cycles, and ecosystems with design engineering principles, mathematical measurement, and the application of appropriate technology, making it an ideal context for STEM integration (Kelley & Knowles, 2016). Critically, this project requires students to confront the ecological challenges of waste disposal behavior, engage in handson problem-solving, and reflect on their personal roles in creating a sustainable school environment. This combination of cognitive challenges, practical engagement, and reflection creates the most conducive conditions for activating and developing students' self-awareness competencies across the four indicators formulated by Sen et al. (2021).

Although the literature on STEM-ESD integration and its potential for fostering sustainability competencies continues to grow, research specifically examining the influence of the STEM-ESD model on students' self-awareness competency in the context of science learning in Indonesia remains very limited. Most existing studies focus on cognitive learning outcomes or general environmental attitudes, without implementing a structured and layered measurement of self-awareness competency based on a strong theoretical framework as a distinct ESD competency (Kioupi & Voulvoulis, 2019). This study aims to fill this gap by using Sen et al. (2021) four-indicator framework to in-depth examine the impact of STEM-ESD project-based learning on students' self-awareness competency in environmentally friendly organic waste management.

Based on the description above, this study aims to: (1) analyze the differences in students' self-awareness competencies before and after the application of the learning model. STEM-ESD on environmental change material; (2) analyzing student activeness in science learning using the STEM-ESD learning model; and (3) analyzing student responses to the STEM-ESD project-based learning model. The resulting findings are expected to contribute both to the theoretical development of STEM-ESD integration as a development competency framework, as well as to practical guidance for science teachers seeking a contextual and sustainabilityoriented pedagogical approach in the Independent Curriculum. The proposed hypotheses are as follows: H_0: There is no significant influence of the STEM-ESD model on students' self-awareness competency in environmentally friendly organic waste management; H_1: There is a significant positive influence of the STEM-ESD model on students' self-awareness competency in environmentally friendly organic waste management.

METHOD

This research uses a quasi-experimental method with a research design Non-equivalent control group design. This study aimed to determine the effect of the STEM-ESD model on students' self-awareness competencies in environmentally friendly organic waste management. This study involved a sample of 48 seventh-grade students from a MTs school in Sukabumi, Indonesia, who were studying environmental change as part of the Merdeka curriculum. The sample was divided into two groups: an experimental group of 24 students who were treated with the STEM-ESD model and a control group who were treated with the conventional learning model. The STEM-ESD steps used can be seen in Table 1.

Table1. Stages of the STEM-ESD Model (Widodo, 2021)

Model Stages	Structure in Students	Structure in Teacher
Formulation of the problem	Identify the problems that can be solved by developing technology	Presentinng the problem that the solution is technology
Think	Thinking about the form of the technology	Directing technology that can developed
Design	Designing technology design	Guiding design creation
Production	Making technology	Guiding product creation
Test	Identifying deficiens and the advantages of technology that developed	Directing students to evaluate the advantages and disadvantages of technology which are made
Design Improvements	Improving technology design	Guiding design improvements

The instruments used in this study were the self-awareness competency instrument developed by (Sen et al., 2021), a student response questionnaire, and a student activity observation sheet. The selfawareness competency instrument consists of four indicators: 1) conceptual awareness, 2) experiential awareness, 3) awareness of involvement, and 4) awareness of adaptation. The instrument was measured using a 4-point Likert scale questionnaire with the following options: strongly agree (SS), agree (S), disagree (TS), and strongly disagree (STS)

Data analysis using IBM SPSS software Statistics Version 25, analysis was conducted on pretest and posttest data to examine the effect of the STEM-ESD model on students' self-awareness competencies. Prior to the hypothesis testing, prerequisite tests were conducted, including data normality tests using the t-test. Shapiro-Wilk ($n < 50$) and homogeneity test using the testLevene's. If the data is normally distributed, hypothesis testing is carried out using a paired sample t-test; If it is not normal, a test is usedMann Whitney U testas an alternative non-parametric test. The significance level used was $\alpha = 0.05$. This analysis allows researchers to assess the effectiveness of the STEM-ESD model on students' self-awareness competencies in environmentally friendly organic waste management.

RESULTS AND DISCUSSION

Results

To analyze the influence of the STEM-ESD model on students' self-awareness competencies, a series of statistical tests were conducted on pretest and posttest data, including normality tests, homogeneity tests, and hypothesis tests. The results of the data analysis are presented in the following Table 2.

Tabel 2. Results of statistical test analysis of self-awareness competency

Stage	Normality		Homogeneity	Hypothesis	Information
	Experimental	Control			
Pretest	0.466	0.052	0.460	0.438	Not significant
Postest	0.062	0.039	0.097	0.003	Significant

Based on Table 2, the results of the pretest data normality test for the experimental class were 0.466 and the control class were 0.052, both greater than 0.05, so the pretest data were declared normally distributed. The pretest homogeneity test showed a value of 0.460 (>0.05), meaning the variances of both classes were homogeneous. Since the parametric requirements were met, the pretest hypothesis test was conducted with Independent Sample t-test, yielding a significance value of 0.438 (>0.05). This indicates that there was no significant difference in initial ability between the two classes before treatment was administered.

In the post-test data, the normality test for the control class showed a value of 0.039 (<0.05), indicating that the data were not normally distributed, while the experimental class obtained a value of 0.061 (>0.05), which is considered normal. Because one of the groups was not normally distributed, the hypothesis test was conducted using a nonparametric test.Mann-Whitney U TestThe results showed a significance value of 0.003 (<0.05), indicating a significant difference between the post-test of the experimental and control classes. Thus, the STEM-ESD model has been shown to have a significant effect on students' self-awareness competencies.

To see the extent of the increase in self-awareness competency, a value calculation was carried out. N-Gainin each group. The results of the analysis are presented in Table 3.

Tabel 3. N-Gain Value of Self-Awareness Competence

Group	N-Gain	Category
Experiments (STEM-ESD)	0.33	Currently
Control (Convensional)	-0.09	There is a decline

Based on Table 3, the average valueN-GainThe experimental class was 0.33, which is included in the moderate category according to Hake, (1998) criteria, while the control class obtained -0.09, which indicates a decline. Furthermore, to get a more in-depth picture, analysis N-Gainconducted on each self-awareness competency indicator based on the indicator framework of Sen et al. (2021), namely: (1) conceptual awareness, (2) awareness based experience, (3) awareness to engage, and (4) awareness to adapt. The improvement profile per indicator is shown in Figure 1.

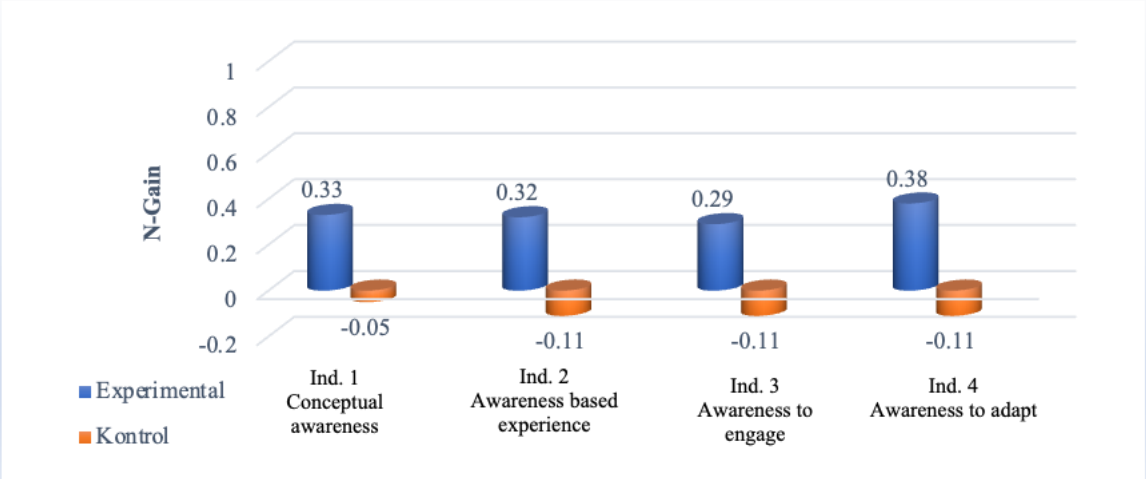


Fig.1. N-Gain indicator

Based on Figure 1, all self-awareness competency indicators in the experimental class experienced an increase in the low to moderate categories. The highest increase occurred in the

awareness to adapt indicator (N-Gain=0.38), followed by awareness to reflect, and the lowest indicator of awareness to engage (N-Gain=0.29). In contrast, the control class did not experience any improvement in any of these indicators.

Student responses to the implementation of the STEM-ESD model were measured using a questionnaire consisting of nine statements across four aspects using a Likert scale. The percentage of responses for each aspect is presented in Figure 2.

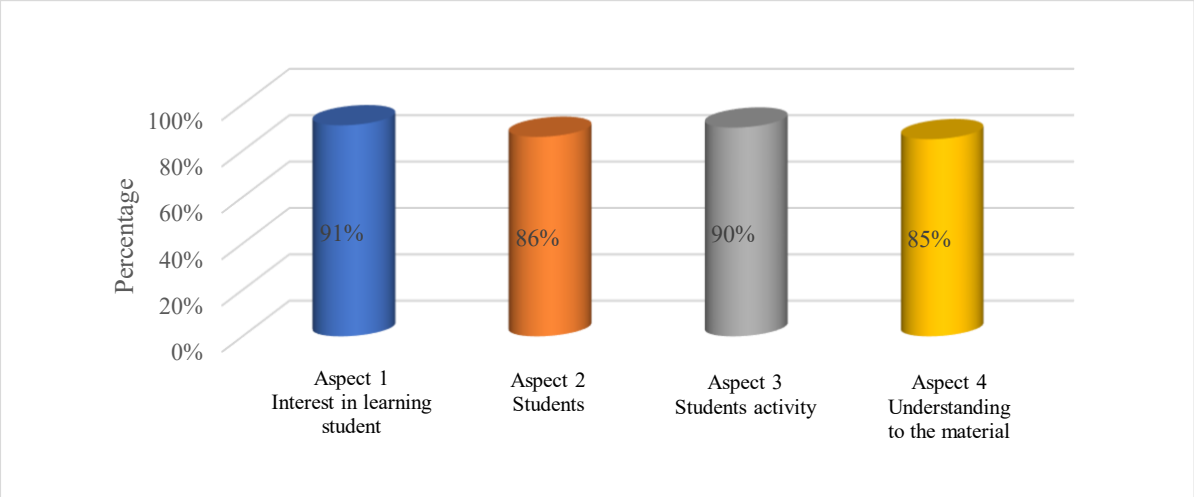


Fig.2. Percentage diagram of students' responses

Based on Figure 2, all aspects of student responses were in the excellent category. Aspect 1 achieved the highest percentage at 91%, followed by Aspect 3 at 90%, Aspect 2 at 86%, and Aspect 4 at 85%. Overall, these results indicate that students responded positively and very well accepted the implementation of the STEM-ESD model in the science learning process.

Student activity in the learning process was observed by observers using an observation sheet covering nine aspects. The observation results are presented in Table 4.

Tabel 4. Results of the Student Activity Observation Sheet in STEM-ESD Learning

No	Aspects Observed	Presentation	Information
1	Pay attention to the teacher's explanation with a focused attitude (eye contact, don't disturb friends)	88 %	Very Good
2	Trying to answer the teacher's questions (raising hand, answering when pointed at)	86 %	Very Good
3	Ask questions regarding material that is not yet understood	74 %	Good
4	Interact positively in groups (listen, give input, respect opinions)	94 %	Very Good
5	Actively seek information and convey ideas in group discussions	84 %	Very Good
6	Involved in designing experiments/investigations (contributing ideas, proposing steps)	90 %	Very Good
7	Demonstrate environmental awareness in discussions/actions (mentioning impacts, solutions, or concrete actions)	95 %	Very Good
8	Delivering relevant solutions to environmental pollution problems	85 %	Very Good
9	Presenting group work results clearly and systematically	75 %	Good

Based on Table 4, seven of the nine aspects of student activity were in the excellent category (>80%), and two aspects were in the good category (74%-75%). The highest percentage was obtained in the aspect of environmental awareness in discussions/actions at 95%, followed by positive

interactions within groups at 94%, and involvement in designing experiments/investigations at 90%. Aspects with relatively lower percentages were asking questions (74%) and presenting group work results systematically (75%), both of which were still in the good category

Discussion

The results of the posttest hypothesis test using Mann-Whitney U Test shows a significance value of 0.003 (<0.05), which proves that the STEM-ESD model has a significant effect on students' self-awareness competencies. This finding is in line with the results of research (Setiawan et al., 2023) which shows that the implementation of the STEM-ESD model has a significant effect on students' self-awareness competencies. Sustainability Project Based Learning significantly increased students' sustainability awareness competencies and engagement in biology learning at the high school level, with significant differences between the treatment and control classes. Futhermore, Olsson et al. (2022) confirmed through their study that ESD systematically integrated into science learning has been shown to be effective in significantly improving students' sustainability action competencies compared to conventional learning approaches.

The success of the STEM-ESD model is inseparable from the established ESD competency framework (UNESCO, 2017) where self-awareness competency is one of the eight core ESD competencies. This competency is defined as the ability to reflect on one's role in the local and global community, evaluate actions sustainably, and manage one's feelings and desires in the context of sustainability (Wibowo et al., 2024) . The integration of STEM and ESD creates learning conditions that encourage the development of ESD competencies holistically, because students are faced with the real issue of environmental pollution due to organic waste that requires scientific, technological responses, as well as sustainability values. This is also in line with research (Suhendar et al., 2025) which confirms that the dimensions of future thinking including visioning and emotion, predicting, planning, anticipating, and evaluating are interrelated competencies and can be strengthened through structured ESD-based learning designs, where the dimensions of visioning and emotion are proven to be the main drivers that influence other dimensions of sustainability competencies

This finding is also supported by research by Rahman et al. (2023) which reported positive perceptions of high school science teachers towards STEM for sustainable development, where STEM-ESD was assessed as being able to facilitate the development of critical thinking, collaborative thinking, and self-awareness competencies simultaneously. This is because students are faced with interdisciplinary problems that cannot be solved from a single scientific perspective, but rather require the integration of technological, engineering, mathematical, and socio-environmental perspectives. Azizah & Wahyuni (2024) also explained that the STEM-ESD approach builds a foundation of sustainable values through meaningful direct learning experiences (meaningful learning experience), which directly stimulates the development of self-reflection and concern for environmental sustainability.

Mark N-GainThe experimental class was 0.33 (moderate category) and the control class was -0.09 (a decrease occurred) showing a very contrasting difference between the two groups. N-Gain in the moderate category in the experimental class is pedagogically meaningful, although it has not yet reached the high category. This is understandable because self-awareness competency is affective and requires an internalization process that cannot be fully optimized within a limited intervention duration. As stated by Olsson et al. (2022) the increase in ESD competency in the awareness aspect tends to be categorized as moderate in short-term interventions, but remains statistically and pedagogically significant. Amprazis & Papadopoulou, (2025) strengthen this argument by stating that self-awareness competency within the ESD framework is most optimally developed through learning that connects science content with real, sustainable issues in a structured and iterative manner.

In the analysis per indicator, the highest increase occurred in the awareness indicator to adapt (N-Gain=0.38). This can be directly linked to the characteristics of STEM-ESD syntax which explicitly encourages students to identify real environmental problems, design science-technology-based solutions, and reflect on their own role in the context of environmental change. These activities directly stimulate students' adaptive abilities towards sustainability issues. This finding is in line with the results of research (Wibowo et al., 2024) which shows that in environmental project-based science learning,

awareness indicators related to adaptation and reflection are more easily developed because they are facilitated by the process of scientific investigation and group discussion.

The awareness indicator for involvement obtained the lowest increase but remained positive (N-Gain=0.29). This phenomenon is understandable because active involvement in real action requires a longer process of internalizing values and more mature self-confidence. (Salim Muljana & Luo, 2019) shows that high-level affective competencies such as active involvement tend to develop gradually according to the depth of the learning experience received.

All aspects of student responses were in the very good category (85%–91%), indicating that the STEM-ESD model was very positively received by students. This high response can be attributed to the characteristics of the STEM-ESD model which presents a learning context relevant to students' real lives. Learning that raises the issue of environmental pollution as an authentic problem not only stimulates interest and motivation to learn, but also raises students' emotional awareness of sustainability issues around them. In line with the findings of Suhendar et al. (2026), the integration of the ESD approach in science learning significantly increases environmental awareness while producing positive responses from students towards the learning process.

The excellent response obtained can also be explained through the principlemeaningful learning. When students perceive a real connection between learning content and real-life realities and contribute to problem-solving, their intrinsic motivation increases significantly. In the STEM-ESD context, students do not simply receive information, but actively design, investigate, and reflect on solutions to environmental problems. Agung et al. (2022) found similar findings that a STEM-PjBL-based science module oriented toward sustainability values was able to increase students' motivation and positive responses in the learning process. Furthermore, the collaborative approach in STEM-ESD syntax that encourages group discussions also contributes to high affective responses, as confirmed by Wibowo et al. (2024) who found that collaborative skills in environmental project-based science learning resulted in a more enjoyable and meaningful learning experience.

Overall, student activity was in the excellent category, with the environmental awareness aspect reaching the highest percentage (95%). This finding is highly relevant to the main objective of ESD, which is to foster students' awareness and concern for sustainability issues. The high level of environmental awareness that emerged during the learning process reflects that the STEM-ESD model, particularly through the context of environmental pollution material, successfully built strong affective awareness in students. This result aligns with Punzalan (2024) research, which showed a significant increase in students' environmental awareness after implementation. Ramadhan & Surjanti (2022) also emphasized that ecoliteracy and the ESD approach have a significant positive influence on students' environmental awareness.

The high percentage of positive interactions within the group (94%) indicates that the STEM-ESD syntax successfully fosters productive collaborative dynamics. Collaborative learning is an essential characteristic of STEM-ESD because sustainability issues are multidimensional and require collective solutions. de Jong et al. (2023) through a systematic review of collaborative inquiry confirmed that students' active involvement in group discussions and joint investigations is a strong predictor of increased scientific competence and self-awareness. The high level of involvement in designing experiments/investigations (90%) reflects the existence of an authentic scientific inquiry process, which is at the core of STEM integration into ESD.

The aspect of providing solutions to environmental pollution problems (85%) shows that the learning process does not stop at the conceptual level of understanding, but has reached a higher level of applied competence. This is consistent with the ESD principle that quality learning must be able to developaction competence, namely the competence to take concrete action in addressing sustainability issues (Olsson et al., 2022). Two aspects with relatively lower percentages, namely asking questions (74%) and presenting results systematically (75%), are still in the good category and reflect high-level skills that require more intensive development of self-confidence and metacognitive competence over the long term.

Overall, the convergence of the four dimensions of findings significant statistical influence, meaningful increase in N-Gain, high positive responses, and active learning activities provides comprehensive empirical evidence that the STEM-ESD model is effective in developing students' selfawareness competencies. The integration of STEM and ESD in science learning is not only globally

theoretically relevant but also highly aligned with the policy direction of the Independent Curriculum (Kurikulum Merdeka) which emphasizes project-based learning (P5) with environmental and sustainable development themes in Indonesia (Rahman et al., 2023; Setiawan et al., 2023; Suhendar et al., 2026). Thus, the STEM-ESD model is worthy of recommendation as a science learning approach that not only improves academic competencies but also shapes students' character and sustainability awareness competencies as a whole.

CONCLUSION AND SUGGESTION

Based on the research results and discussion above, it can be concluded that the learning model Science, Technology, Engineering, and Mathematics - Education for Sustainable Development(STEM-ESD) has been proven to have a significant influence on students' self-awareness competency in science learning, especially in environmentally friendly organic waste management. The results of the hypothesis test on the post-test data showed a significance value of 0.003 (<0.05), which means there is a significant difference between the self-awareness competency of the experimental class and the control class after the treatment. The average N-Gain value of the experimental class was 0.33, which is included in the category, while the control class obtained a value of -0.09, which indicates a decrease. The analysis per indicator showed that all self-awareness competency indicators in the experimental class increased, with the highest increase in the awareness indicator to adapt (NGain = 0.38 in the medium category) and the lowest in the awareness indicator to engage (N-Gain = 0.29 in the low category). These findings indicate that the STEM-ESD learning model is an effective approach, both statistically, pedagogically, and in the learning process in developing self-awareness competency as part of the competency Education for Sustainable Development (ESD). Thus, this model not only increases conceptual understanding of environmental pollution issues, but also creates an effective and essential learning space for the realization of sustainability-oriented science learning.

Suggestions for further research are to extend the duration of learning using the STEM-ESD model in order to optimally increase self-awareness competencies, especially in the awareness indicator for involvement so that it can reach the medium to high category more effectively optimal. Then it is hoped to be able to measure other ESD competencies beyond self-awareness, such as systems thinking competencies, anticipatory competencies, and action competencies, in order to build a more comprehensive ESD competency profile, considering the 2030 Sustainable Development Goals (SDGs) agenda that placesQuality Education (SDG 4) as a top priority, strengthening ESD competencies in science learning is a strategic step whose implementation needs to be accelerated at all levels of primary and secondary education in Indonesia.

CONFLICTS OF INTEREST

The authors declare that this research was conducted without any conflicts of interest. This study on the impact of the STEM-ESD learning model on pupils' self-awareness was carried out independently and was not influenced by the personal, commercial or financial interests of any party. All stages of the research—from the development of the STEM-ESD teaching module and the research questionnaire, through to the implementation of the study and the writing of the research report—were conducted objectively for academic purposes and to advance learning.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, J.A. and S.Su.; methodology, J.A. and S.Su.; investigation, J.A.; data collection, J.A.; formal analysis, J.A.; data curation, J.A.; validation, S.Su. and S.Se.; writing—original draft preparation, J.A.; writing—review and editing, S.Su. and S.Se.; supervision, S.Su. and S.Se. All authors have read and approved the final version of the manuscript.

DECLARATION OF GENERATIVE AI SOURCES

The authors declarethat no generative artificial intelligence (AI) or AI-assisted technologies were used in the preparation of this manuscript.

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