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Preliminary Research: SDGs-Based STEM Approach for Middle School Students

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Abstract

This preliminary study investigates the perceptions and readiness of junior high school teachers and students regarding the integration of STEM-based learning aligned with the Sustainable Development Goals (SDGs) in science education. The study aims to explore their understanding of STEM-SDGs, confidence levels, and perceived challenges. A descriptive, quantitative method was employed, with questionnaires distributed to 15 science teachers and 124 students at a public junior high school. The results show that 100% of teachers were unfamiliar with the term SDGs, although 70% had implicitly applied STEM elements to develop students' critical thinking. Furthermore, 90% of teachers rarely linked science concepts to socio-environmental contexts, while 75–80% acknowledged the potential of STEM-SDGs to foster critical thinking and environmental awareness. On the student side, 70% had never heard of SDGs, and 60% had never been involved in environmental projects. However, both groups showed high confidence in the relevance of implementing SDGs-based STEM learning. The main barriers identified were a lack of teaching materials, limited time, and inadequate teacher competence. This suggests a strong psychological readiness but a gap in technical support. Recommendations include developing STEM-SDGs teaching guidelines, conducting structured teacher training, and improving laboratory infrastructure with accessible tools to support contextual science learning.

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INTRODUCTION

In the face of technological advancements and environmental challenges, students must be equipped with critical, creative, and innovative thinking skills to navigate complex real-world problems (Mulyana, 2023; Zhai et al., 2024). These competencies are particularly important in science education, which plays a key role in preparing learners to respond to dynamic social, economic, and ecological changes (Naharia et al., 2024; Muttaqiin, 2023). Thus, science learning should not only prioritize conceptual understanding but also foster the application of knowledge in relevant and contextual situations (Kerimbayev et al., 2023; Zamiri & Esmaeili, 2024).

In response to global issues such as climate change, environmental degradation, and social inequality, the international community adopted the Sustainable Development Goals (SDGs) in 2015, comprising 17 interconnected goals to promote prosperity while protecting the planet (Arafatir et al., 2024). One of the key goals is to ensure inclusive and quality education and promote lifelong learning opportunities (Kumar, 2016; Khusniati & Yamtinah, 2024)

However, understanding and implementation of SDG principles in school-level education, particularly at the junior secondary level, remain limited (Ali et al., 2023; Arafatir et al., 2024). Most teachers and students are not yet familiar with what SDGs entail or how they can be meaningfully integrated into classroom instruction. Furthermore, the use of interdisciplinary approaches, such as STEM (Science, Technology, Engineering, and Mathematics), integrated with SDG themes, is still rarely applied in a structured and sustainable manner. This lack of understanding limits the potential of education to instill environmental awareness and 21st-century competencies in students.

One promising strategy for integrating the SDGs into education is the STEM-based project-based learning (PjBL) approach. This method not only reinforces students' understanding of scientific and technological concepts but also equips them to apply these concepts to solve real-world sustainability problems, such as waste management, renewable energy, and biodiversity conservation (Eka et al., 2024; Prajoko et al., 2023).

This study offers a novel contribution by exploring the implementation of an SDGs-based STEM approach in junior high schools—an area that has not been widely researched. While previous studies have mostly focused on higher education or theoretical frameworks, this research emphasizes practical, project-based applications of SDGs in STEM classrooms. It also aligns with Indonesia's "Independent Curriculum" policy, which supports character education and context-based learning as part of national education reform.

The Independent Curriculum offers a significant opportunity to adopt flexible, context-based teaching strategies, including project-based learning focused on sustainable development themes (Prayogi & Verawati, 2024). One of the key character values promoted is environmental awareness, which must go beyond cognitive understanding to include concrete actions (Indarta et al., 2022; Baena-Morales et al., 2024). The SDGs-based STEM approach holds great potential to shape students' awareness and responsibility for environmental sustainability through meaningful, contextual learning (Ardoin et al., 2020; Tasrif, 2022).

In addition to character building, critical thinking is one of the essential competencies in the 21st century. It includes the ability to analyze information, evaluate arguments, solve problems, and make evidence-based decisions (Wardani & Fiorintina, 2023; Syauqiah et al., 2024). In the context of the SDGs, critical thinking is particularly important for addressing complex and interdisciplinary challenges.

Based on the above considerations, this study aims to explore how implementing an SDGs-based STEM approach can improve the quality of science learning in junior high schools. Specifically, the study has two main objectives: 1) To examine how the SDGs-based STEM approach is implemented in junior high school science classrooms. 2) To identify the needs, challenges, and support systems required by teachers and students to effectively and sustainably apply the SDGs-based STEM approach in classroom practice.

Overall, this preliminary study is expected to make a significant contribution to improving educational quality by promoting not only academic excellence but also environmental awareness and critical thinking among students. These competencies are essential for preparing students to face future global challenges (Hidayah & Nugraheni, 2024; Koçulu & Topçu, 2024).

METHODS

This study is a preliminary investigation employing a quantitative descriptive approach through a survey method. The primary aim is to explore the initial conditions for understanding and implementing an SDG-based STEM learning approach at the junior high school level. The research subjects consisted of 10 science teachers and 50 students from junior high schools/Islamic junior high schools in the Pekanbaru area. Teachers and students were randomly selected from the same schools to ensure alignment and coherence between instructional practices and students' learning experiences.

The instrument used in this study was a questionnaire designed to measure several important aspects, namely: (1) the level of understanding and implementation of the STEM approach in schools, (2) the extent of the integration of SDGs values and principles in the science learning process, and (3) the potential of the SDGs-based STEM approach in developing students' critical thinking skills and environmental concerns.

The teacher questionnaire consists of 30 statement items, while the student questionnaire consists of 23 items. The instrument has been tested for content validity by experts and then tested for reliability using the KR-20 coefficient. The test results show that the teacher questionnaire has a reliability of 0.76, while the student questionnaire has a reliability of 0.71, which falls within the quite reliable and suitable for use in educational research category.

The collected data were analyzed descriptively using percentage techniques to identify general trends regarding the level of understanding, needs, and beliefs of teachers and students regarding the importance of implementing an SDGs-based STEM approach in science learning in secondary schools. Table 1 presents the detailed needs analysis categories used in this study.

Table 1 Categories of needs analysis

No	Percentage	Category
1.	$88 < N \leq 100$	Very high
2.	$76 < N \leq 88$	High
3.	$65 < N \leq 76$	Quite High
4.	< 65	Low

Rochim & Budiyanto (2021)

RESULTS AND DISCUSSION

The analysis conducted as the basis for implementing learning with a STEM approach based on SDGs is an initial activity carried out as a description of the extent of teacher and student knowledge regarding the application of learning with a STEM approach, knowledge of SDGs, and a description of students' critical thinking skills and environmental care attitudes. Based on the results of the questionnaire conducted on science teachers and students, an initial description of the focus of the research was found as follows in Table 2.

Table 2 Aspects of teachers' understanding and perception of STEM-SDGs in science learning

No	Statement	SD	D	A	SA
1	I rarely relate science learning to social and environmental issues to foster an attitude of caring for the environment.	0%	10%	60%	20%
2	I have integrated science, technology, engineering, and mathematics (STEM) knowledge to develop critical thinking skills in science learning.	0%	0%	70%	30%
3	I have never heard the term Sustainable Development Goals (SDGs).	0%	10%	60%	20%

4	I feel there is a connection between SDGs and science learning that focuses on environmental issues.	0%	0%	70%	30%
5	According to me, it is not too important to link STEM and SDGs in IPA learning.	0%	60%	20%	20%
6	I feel that the integration of STEM-SDGs in science learning helps improve critical thinking skills and fosters an environmentally conscious attitude towards future challenges.	0%	0%	70%	30%
7	I understand the relationship between the STEM learning approach and the goals of the SDGs in the context of IPA teaching at school.	10%	60%	30%	0%
8	I am able to explain how STEM concepts can be applied to address sustainability issues in science learning.	70%	30%	0%	0%
9	I know the main goals in the SDGs that are relevant to science subject matter.	10%	70%	20%	0%
10	I feel the SDGs-based STEM approach helps students understand the impact of science on society and the environment.	0%	10%	60%	30%
11	I realize the importance of integrating STEM approaches and SDGs values into the science learning process in the classroom.	0%	0%	80%	20%
12	I believe that implementing an SDGs-based STEM approach can improve students' critical thinking skills and environmental awareness.	0%	0%	70%	30%

The results of the questionnaire distributed to science teachers showed that the implementation of an SDG-based STEM approach in science learning at the junior high school level remains suboptimal. Most teachers (90%) stated that they rarely link science learning to social and environmental issues, which are the main drivers of achieving SDG-based learning goals. This indicates that educators have not fully understood or implemented the contextual and transdisciplinary approaches characteristic of STEM-SDGs.

However, many teachers (70%) stated that they had integrated science, technology, engineering, and mathematics (STEM) knowledge in science learning, especially to improve students' critical thinking skills. This indicates awareness of the potential of the STEM approach to enhance learning quality. However, only a small number of teachers (10%) stated that they had explicitly linked the approach to SDGs values. This finding is in line with research by Gul et al. (2023), which states that although teachers understand the importance of the STEM approach, many still do not have the competence or resources to integrate it with global issues such as the SDGs.

Interestingly, all respondents stated they had never heard of the term SDGs, reinforcing the finding that the integration of SDGs into science curricula remains very limited. This reinforces the importance of teacher training and professional development to equip them with a deep understanding of the SDGs goals and how to implement them in the context of STEM-based science learning. Initiatives such as those conducted by Science on Stage Europe, which developed the learning materials "Act Now for the UN Sustainable Development Goals-SDGs in STEM Education," can be a reference for teachers in integrating SDGs into STEM learning (Nuraimas et al., 2023; Surahman, 2024).

Nevertheless, most teachers showed a positive attitude towards the potential of STEM-SDGs integration. As many as 60% stated that this integration can help improve critical thinking skills and foster environmental awareness in students. In fact, 80% of teachers understand that integrating STEM and SDG approaches can be achieved through the development of problem-based projects relevant to students' real lives. This is in line with the approach recommended by Koçulu & Topçu (2024), who emphasize the importance of linking STEM learning to real-world contexts to increase student engagement.

However, challenges were also identified, including the lack of appropriate learning resources, time constraints in planning project-based learning, and insufficient training on STEM and SDGs integration. Several teachers (30%) stated that this approach was too complex to implement in the context of science learning in their schools, underscoring the urgent need for institutional and policy support to strengthen sustainable education. The study by Lestari et al. (2024) also highlighted the importance of institutional support in overcoming the challenges of implementing STEM-based education in schools.

Overall, these results suggest that, despite the enthusiasm and basic understanding of STEM approaches among science teachers, their understanding and implementation of SDG values remain very limited. Therefore, this study emphasizes the importance of teacher professional development programs that build capacity to integrate STEM approaches with global sustainability issues to prepare a young generation of critical thinkers and environmentally conscious individuals. Aspects of students' understanding and perception of STEM-SDGs in science learning are listed in Table 3.

Table 3 Aspects of students' understanding and perception of STEM-SDGs in science learning

No	Statement	SD	D	A	SA
1.	I have heard the term “Sustainable Development Goals (SDGs).	70%	30%	0%	0%
2.	The science teacher once explained what SDGs are in class.	70%	30%	0%	0%
3.	I once studied the concept of STEM (Science, Technology, Engineering, and Mathematics) in science class.	0%	60%	30%	10%
4.	The science teacher once explained what the STEM (Science, Technology, Engineering, Mathematics) elements were in science lessons.	0%	70%	30%	0%
5.	I have worked on science projects related to environmental issues (e.g. waste, clean water, and energy).	10%	70%	20%	0%
6.	I once created a science project that specifically supported one of the SDGs goals (for example, creating a water-saving device or recycling waste).	0%	70%	30%	0%
7.	I have used technology tools or applications in science learning	20%	50%	20%	10%
8.	Science lessons help me understand simple ways to protect the environment (e.g. saving water or separating waste).	0%	0%	70%	30%
9.	I am interested in learning more about STEM and SDGs in my next science lesson.	0%	10%	70%	20%
10.	I feel that the STEM SDGs project that I will be creating in class will provide real benefits to the surrounding environment.	0%	10%	70%	20%

The results of the student questionnaire showed that the introduction of the Sustainable Development Goals (SDGs) into science learning at the junior high school level remains very limited. As many as 100% of respondents had never heard the term "SDGs" and had not received an explanation from their science teachers regarding the Sustainable Development Goals. In fact, UNESCO (2024) emphasized that understanding SDGs must be an integral part of the science curriculum to shape students' global awareness and environmental responsibility. The absence of this topic can lead students to miss the relevance of science material to real-world sustainability challenges.

Furthermore, the data revealed that 70% of students rarely or never learn the concept of STEM — namely, the integration of Science, Technology, Engineering, and Mathematics in science classes — and that only 30% have ever received an explanation of its elements. In fact, Le et al. (2023) and Matitaputty et al. (2022) stated that an integrated STEM

approach can increase students' motivation and critical thinking skills, as well as facilitate authentic problem solving. The use of simple technological applications and tools in science activities can significantly increase students' understanding of concepts and interests (Eviota & Liangco, 2020; Muttaqiin, 2023)

In terms of project involvement, 70% of students admitted that they had never made a science project related to environmental issues or that specifically supports the achievement of an SDG target. In fact, the project-based learning (PjBL) model, grounded in local contexts, as described by Yennita et al. (2022), helps students see the real impact of problem-solving and encourages an attitude of environmental care. The use of recycled materials or natural objects as project media makes the implementation of PjBL/STEM-SDGs more accessible and relevant to students (Ardianti et al., 2020; Berg & Verster, 2023)

Although the use of technology in science practice is still low, with only 30% ever using tools or applications, around 25% of students feel that science lessons that integrate STEM and SDGs help them understand simple ways to protect the environment. In fact, student involvement in STEM-SDGs projects increases environmental awareness and critical thinking skills when the project provides meaningful outputs for the surrounding community (Ridarwati, 2024; Shernoff et al., 2017)

Figure 1 illustrates the level of teacher and student confidence in the need to implement SDGs-based STEM Learning.

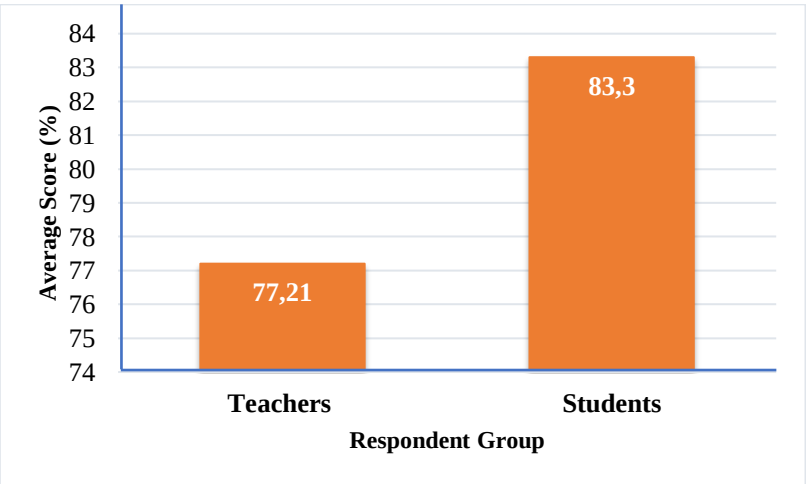

Figure 1 Confidence levels of teachers and students regarding the need for implementation

Based on Figure 1, the level of trust of both teachers and students is in the high category. This shows that respondents view positively the potential to improve students' critical thinking skills and environmental attitudes through the implementation of a STEM approach grounded in the SDGs. These results confirm that the implementation of an SDG-based STEM approach is highly relevant to both main stakeholders, teachers and students, to facilitate the development of critical thinking and environmental attitudes. High trust in this model indicates teachers' psychological readiness to design integrated learning with real problems and students' desire to be actively involved in socially and ecologically meaningful projects (Setyowati et al., 2022; AlAli et al., 2023)

In more detail, teachers' beliefs hold that science content is no longer merely a transfer of knowledge but a bridge that fosters students' analytical skills in addressing the complexity of sustainability issues (UNESCO, 2024). Meanwhile, students' beliefs indicate their intrinsic motivation to learn that STEM and the SDGs provide a contextual and applicable

learning experience. This condition is in line with the 21st-century learning objectives that emphasize critical thinking, collaboration, and citizenship in a global context (Rochim et al., 2021; Herlinawati et al., 2024)

However, these initial findings also reveal several challenges. First, despite high trust, not all teachers have a learning design map that explicitly integrates SDGs indicators. Not all teachers have a learning design that explicitly includes SDG indicators; resources for simple project materials are still limited; and teacher competence in facilitating critical discussions needs to be strengthened (Herlinawati et al., 2024; Wati et al., 2024). Second, the availability of resources, both simple project materials and access to digital platforms, is limited in some schools. Third, teacher competence in facilitating critical discussions and student reflection on sustainability issues needs to be strengthened through intensive training programs (Shernoff et al., 2017a).

To follow up on these findings, several strategic steps need to be designed, such as: 1) Preparation of STEM-SDGs Guidelines (UNESCO, 2024), 2) workshops or mentoring for science teachers in designing, assessing, and moderating critical thinking discussions related to sustainability issues (Ekamilasari & Pursitasari, 2021; Mafugu, 2022) and 3) optimization of infrastructure such as the provision of simple experimental tools (Siregar & S, 2021). With these steps, it is hoped that the SDGs-based STEM Approach for Middle School Students will not only provide initial evidence of the model's effectiveness but also lay the foundation for wider-scale implementation at the secondary level to produce a critical generation that cares about global challenges.

CONCLUSION

The results of this preliminary study reveal that both teachers and students show strong enthusiasm and confidence in integrating SDG-based STEM learning into science education. This aligns with the first objective, which explores their perceptions, understanding, and perceived challenges. While many teachers have implicitly integrated STEM elements to develop students' critical thinking, their understanding of the SDGs remains limited and is rarely reflected in instructional planning. Likewise, most students are unfamiliar with the term SDGs and lack experience in sustainability-related projects, although they recognize the relevance and applicability of environmental topics in science learning.

In line with the second research objective, the study also identifies several key challenges hindering effective implementation. These include the lack of teaching materials that explicitly integrate the SDGs, insufficient teacher training in designing contextualized learning, and limited classroom infrastructure and project opportunities for students.

To address these issues, it is recommended that schools and education policymakers develop integrated STEM modules embedded with SDGs indicators, alongside providing targeted teacher training focused on designing, implementing, and evaluating sustainability-driven science lessons. Additionally, the provision of simple experiment kits and improved access to digital learning platforms can serve as enablers for more effective implementation. These strategic efforts are essential not only to enhance the practical adoption of STEM learning grounded in the SDGs but also to cultivate a generation of learners who are analytically skilled and environmentally conscious.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization: SP, YY, and SW; methodology: SP; data collection: SP and YY; formal analysis: SP and SW; original drafting: SP and YY; reference collection: SP, YY, and SW.

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