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# Perceptions of Physics Education Students at Universitas Negeri Medan on the Role of Physics Education in Sustainable Development Goals

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**ABSTRACT**

**Purpose –** This study explores the perspectives of physics education students to understand the integration of SDGs in physics learning. Furthermore, to examine these perspectives, it is important to determine the extent of physics education students' perceptions of SDGs.

**Methodology –** This research adopts a quantitative questionnaire and is also supported by qualitative approaches. There are 120 physics education students from Universitas Negeri Medan selected through purposive sampling. The questionnaire consists of Likert-scale items, followed by semi-structured interviews with 10 randomly selected respondents. Triangulation was applied to integrate both datasets, providing a comprehensive understanding of students' knowledge, attitudes, and experiences related to ESD in physics learning.

**Findings –** The results reveal that students perceive physics as a key discipline that contributes to addressing global challenges, including climate change, renewable energy innovation, and sustainable technology development. Physics is viewed as providing conceptual and analytical frameworks essential for sustainability oriented problem solving. However, students' literacy regarding the SDGs remains limited. Many participants demonstrate general awareness but lack the ability to explicitly connect SDG concepts with physics topics or classroom practices. The integration of ESD in physics learning is still partial.

**Contribution –** One of the contributions of this study presents a significant opportunity to begin integrating physics education, particularly in relation to the perceptions of physics education students, with the SDGs. This study also make a valuable reference for understanding the real contribution of physics education toward achieving the SDGs.

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## INTRODUCTION

Education is both an independent goal and a means to achieve the 2030 Agenda (SDG 4) (Ministry of Finance and Economic Development, 2016). It has a catalytic impact on sustainable development (Rieckmann, Marco; Mindt, Lisa; Gardiner, 2017). Physics is a core discipline that provides a scientific foundation for understanding natural phenomena and environmentally friendly technologies. One example of current practical physics applications is in renewable energy, energy efficiency, and carbon emission analysis (Hidaayatullaah et al., 2024). Physics practicums and project-based modules encourage systems-level thinking. They demonstrate how local actions, such as reducing friction in machinery, can have global effects, including lowering greenhouse gas emissions. This demonstrates the relevance of physics to the SDGs (Hnatyuk et al., 2024). Beyond scientific understanding, physics education enables students to see how physics concepts relate to the daily sustainability challenges they face. Integrating physics education with sustainable development education is crucial for fostering students' environmental awareness and developing their sustainability values. Ultimately, this shapes a more sustainable future (Wang, 2024).

Although integrating sustainability principles into physics education holds great potential, most academic research focuses more on curriculum design and improving ESD (Education for Sustainable Development) competencies for teachers than on empowering students, especially future physics teachers. The literature shows the main focus remains on teacher competencies, learning modules, and curricula. There is little research on how physics education students understand, perceive, and connect physics learning with the SDGs (Wang, 2024). Yet, students' understanding and awareness are key to successful ESD implementation (Hidaayatullaah et al., 2024). These students will be future educators who carry sustainability values into the classroom (Hák et al., 2016). Without knowing how students see the relationship between physics and the SDGs, curriculum development risks being normative and missing actual behavioral change or competency gains (Cachero et al., 2023).

(Suprapto & Hidaayatullaah, 2023) introduced the SDGs PE instrument to measure the extent to which physics students integrate the concept of sustainability into their cognitive framework and learning behaviour. This instrument has been tested and proven valid for measuring perceptions (Suprapto & Hidaayatullaah, 2023). However, the research remained focused on establishing validity without exploring the meaning, interpretation of experiences, and motivation of students in the context of real sustainability challenges. In line with this, higher education institutions are also expected to shape students' sustainable attitudes and behaviours (Leal et al., 2024). The problem that arises is that we know what to measure, yet we still lack information on how and why physics education students should connect their physics knowledge with sustainability-oriented actions. As a result, there is a gap in the literature that does not adequately explain the extent to which students can interpret their learning experiences within the framework of sustainability and global challenges. This clearly creates an important gap that needs to be addressed, considering that students, as prospective physics teachers, are in a strategic position to integrate environmental, technological, and social issues into the learning process in future classrooms (Miqdad et al., 2020).

This study contributes to the literature by examining physics education students' perceptions of the role of physics in the SDGs. The research emphasises not only measuring perceptions, but also analysing how students may link physics to sustainability solutions. By focusing on students' perspectives, this study broadens SDG-oriented research in physics education. It is not only about assessing abilities, but also about understanding meaning and action orientation. This approach offers a new perspective that has not been widely explored. The novelty can be seen in how ESD competencies and Society 5.0 demands are perceived by prospective physics teachers. The aim is to identify how physics learning helps shape students' sustainability-oriented knowledge, attitudes, and behaviours. The study also examines the pedagogical implications of embedding sustainability more effectively into physics education (Arntzen et al., 2025).

Based on the explanation above, this study aims to identify how well physics education students understand the integration of the SDGs into physics learning. The study also examines how these

perceptions align with ESD principles and the demands of Society 5.0. The expected results are to provide empirical support for developing more contextual and sustainability-oriented physics learning strategies. In this way, physics is not only a scientific discipline but also a tool for social transformation, addressing global issues.

## METHODOLOGY

### Research Design

This research employed a mixed-methods design with a descriptive, sequential, explanatory approach. The use of both quantitative and qualitative methods was methodologically justified to obtain a more comprehensive understanding of students' perceptions regarding the role of physics education in supporting the Sustainable Development Goals (SDGs). The quantitative data provided measurable patterns and tendencies, while the qualitative data offered deeper explanations and contextual nuances underlying those patterns. The sequential design enabled the quantitative results to inform the focus of the qualitative exploration, ensuring triangulation and strengthening the overall validity of the findings (John W. Creswell & Vicky L. Plano Clark, 2006).

### Participants

There were 120 active students from the Physics Education Study Program at Universitas Negeri Medan who participated, comprising 14% male and 86% female students. The sampling technique used was purposive sampling. Inclusion criteria were active students in the even semester of the 2024/2025 academic year. Respondents who did not meet these criteria or refused to participate were excluded. Thus, the selected participants were expected to provide valid and representative data to support the external validity of the results. After the questionnaire, ten participants were randomly chosen for interviews. Two male and eight female students were selected.

### Data Collection

Data collection was conducted in two stages: 1) Quantitative phase: A structured online survey was conducted using Google Forms, which remained open for responses for a one-month period. Respondents completed the survey voluntarily. The average time to complete the survey was approximately 15 minutes. 2) Qualitative phase: Semi-structured interviews were conducted with 10 volunteer participants representing diverse gender backgrounds. Each interview lasted between 25 and 35 minutes and was conducted face-to-face. Interview guidelines were prepared to ensure consistency, focusing on participants' reflections on the relevance and application of Sustainable Development Goals (SDGs) concepts in the context of physics learning (Saunders et al., 2018). This multi-stage collection process enhances transparency and replication of research by other researchers.

### Instruments

The main instrument was a standardised questionnaire adapted from Suprapto and Hidaayatullaah (2023): the Questionnaire for SDGs in Physics Education (SDGs PE), available at https://unesa.me/SDGsinPE (FIGURE 1). This questionnaire has two main parts: 1) The quantitative section comprises 15 statements, each with a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree), to measure students' perceptions, awareness, and attitudes towards the integration of the SDGs in physics education. 2) The qualitative section comprises 10 open-ended questions that provide respondents with the opportunity to elaborate on their experiences and views in greater depth.

This instrument was validated in previous studies and had good psychometric results. In this study, Cronbach's Alpha reliability tests were conducted again for the whole scale and each subscale. This ensured the internal consistency of the results in this research context.

**Data Analysis**

Quantitative data were analysed using descriptive statistics (mean, standard deviation, and Cronbach's Alpha reliability). Meanwhile, qualitative data from open-ended questions and interviews were analysed using thematic analysis based on six stages, namely: data familiarisation, initial coding, theme search, theme review, theme naming, and analysis report compilation. The integration of quantitative and qualitative data was carried out through an explanatory sequential strategy, in which quantitative results were analysed first to find general patterns, and then these results were explained and explored in depth with qualitative data. This approach enables triangulation and provides a more comprehensive understanding of the phenomenon under study.

## FINDINGS

**University Student Perception on SDGs Integration**

The research data were collected from physics education students at various semester levels at Universitas Negeri Medan, ranging from early to late semesters. The primary data collection was conducted through a survey using a questionnaire, which was subsequently supplemented with data from interviews. The quantitative questionnaire contained 15 Likert scale statements designed to measure students' perceptions related to three main constructs, namely: (1) perception of the relevance of the Sustainable Development Goals (SDGs) to physics education (abbreviated as SDGs), (2) understanding of Education for Sustainable Development (ESD), and (3) awareness or perception of the 2030 SDGs Agenda. Students' perceptions of the SDGs PE construct are specifically presented in Table 1.

**Table 1**. Students' Perceptions of the SDGs PE

| Code | Statement | SDGs Indicator | The Most Respondents Response |
|---|---|---|---|
| V1.1 | Physics teaching nowadays successfully integrates aspects of sustainability and innovation that are relevant to the Era Society 5.0. | Quality Education (4) Innovation and Infrastructure (9) | 41,67% (Agree) |
| V.1.2 | I have sufficient understanding of Physics concepts relevant to the development of technology and society in the Era of Society 5.0. | Innovation and Infrastructure (9) | 23,33% (Agree) |
| V1.3 | A deep understanding of Physics can make a significant contribution to addressing sustainable development challenges, such as climate change, finite natural resources and inequality. | Climate Change (13), Life on Land and Underwater (15), and Inequality (10) | 34.17% (Strongly Agree) |
| V1.4 | I have difficulty in understanding or teaching Physics concepts related to the development of advanced technology in the Era of Society 5.0. | Innovation and infrastructure (9) | 26,67% (Agree) |
| V1.5 | The application of Physics concepts in the development of new technologies can make a positive contribution to the achievement of SDGs. | Industry, Inovation, and Infrastructure (9) | 34,17 (Agree) |

The survey results in Table 1 show that not all students are aware of the integration of physics with sustainability issues. A total of 41.67% of students agreed that physics learning has integrated aspects of

sustainability and innovation, while only 23.33% felt they had an adequate understanding of physics concepts related to technological developments and society. This suggests a curriculum gap: traditional physics education often does not link material to real-world contexts and sustainable values (Utama et al., 2018). These results suggest that strengthening sustainable education is necessary in the physics curriculum, so that the concepts of Society 5.0 and global issues are integrated into core courses. Further data shows that some students have realised the important role of physics in facing global challenges. A total of 34.17% of students strongly agree that an understanding of physics can contribute significantly to sustainable development challenges such as climate change, limited resources, and inequality, and the same percentage believe that the application of physics in new technologies can support the achievement of SDGs. These results are consistent with the literature, which suggests that physics education contributes to the SDGs by promoting an understanding of energy processes and resource use (Wang, 2024). As Wang (2024) emphasises, learning physics enables students to better understand how energy is generated, transformed and utilised, thereby increasing awareness of resource limitations. The fact that a third of students recognised this role of physics points to an opportunity: more contextualised physics learning (e.g., through renewable energy cases) can strengthen awareness of the SDGs. This aligns with the global outlook, where the international physics community is advocating for the field's active role in green economic development (Malavoloneque & Costa, 2022).

Based on Table 2, the perception of university students regarding ESD in society is 5.0. Some students provided positive responses regarding the role of physics education in addressing Society 5.0. About 34.17% strongly agree that physics education is important to prepare generations to face the demands of Society 5.0. This reflects the awareness that physics as a basic science can be a means of strengthening holistic Education for Sustainable Development (ESD). UNESCO emphasises that ESD aims to equip learners with knowledge, skills, values, attitudes and behaviours that support environmental, economic and social sustainability (Saphira et al., 2023). In the context of Society 5.0, a vision of Japan's futuristic society in which the physical and virtual worlds merge with advanced technologies such as AI, IoT, and robotics (Kioupi & Voulvoulis, 2019), the need for integrating sustainability principles is even more evident. A total of 28.33% of students strongly agreed that Society 5.0 principles need to be integrated into the physics curriculum.

**Table 2.** University Student Perception of ESD in Society 5.0

| Code | Statement | SDGs Indicator | The Most Respondents Response |
|---|---|---|---|
| V2.1 | Physics education has an important role in preparing generations to face the changes and demands in the Era of Society 5.0. | Quality Education (4) and Decent Work and Economic Growth (8) | 34,17 (Strongly Agree) |
| V2.2 | The education system should integrate the principles of Society 5.0 into the physics education curriculum. | Innovation and Infrastructure (9) and Quality Education (4) | 28,33% (Strongly Agree) |
| V2.3 | The current Physics Education system is adequate to produce graduates with relevant skills for Era Society 5.0. | Quality Education (4) | 26,67% (Agree) |
| V2.4 | Innovative approaches are needed in learning Physics so that students can apply concepts in the context of Era Society 5.0. | Innovation and Infrastructure (9) | 37,50% (Agree) |
| V2.5 | Technologies such as artificial intelligence (AI) are expected to improve the effectiveness of physics learning in the face of societal changes. | Innovation and Infrastructure (9) | 35,83% (Agree) |

However, only about 26.67% agreed that the current physics education system is adequate to produce relevant graduates for Era Society 5.0, indicating that the majority of students still doubt the suitability of the conventional curriculum. This finding aligns with the literature that emphasises the need for educational reform to support 21st-century learning. (Kioupi & Voulvoulis, 2019) notes that Society 5.0 demands a humanistic education paradigm and emphasises technological literacy, ethics, entrepreneurship, and lifelong learning to prepare students for rapid technological advances. Thus, the low percentage of agreement on item V2.3 indicates the need to update pedagogical strategies and the physics curriculum to align with the demands of ESD and the digital era.

When compared to previous studies, the results of this study are consistent with the patterns found in previous studies. (Vioreza et al., 2023) argue that Education for Sustainable Development (ESD) requires an active, interdisciplinary, and problem-based learning approach that allows students to explore solutions to environmental challenges. The moderate level of agreement in this study suggests that such an approach may not yet be systematically applied in physics classrooms.

This aligns with current findings, which suggest that students' recognition of the relevance of physics to the Sustainable Development Goals (SDGs) is partial and not strongly reinforced through instructional design. (Widya, 2024) emphasise that physics education has great potential to bridge scientific theory with real-world sustainability issues, but this potential is often not realised due to a lack of context in the learning process. Therefore, although the findings indicate students' openness to SDG-oriented physics learning, they also reveal that the alignment of the curriculum and pedagogical practices may not yet fully reflect ESD principles.

Figure 2. presents Education for Sustainable Development (ESD) in the era of society 5.0. The statements on this variable contribute to the SDGs indicators of Quality Education (4), Decent Work and Economic Growth (8), and Innovation and Infrastructure (9).

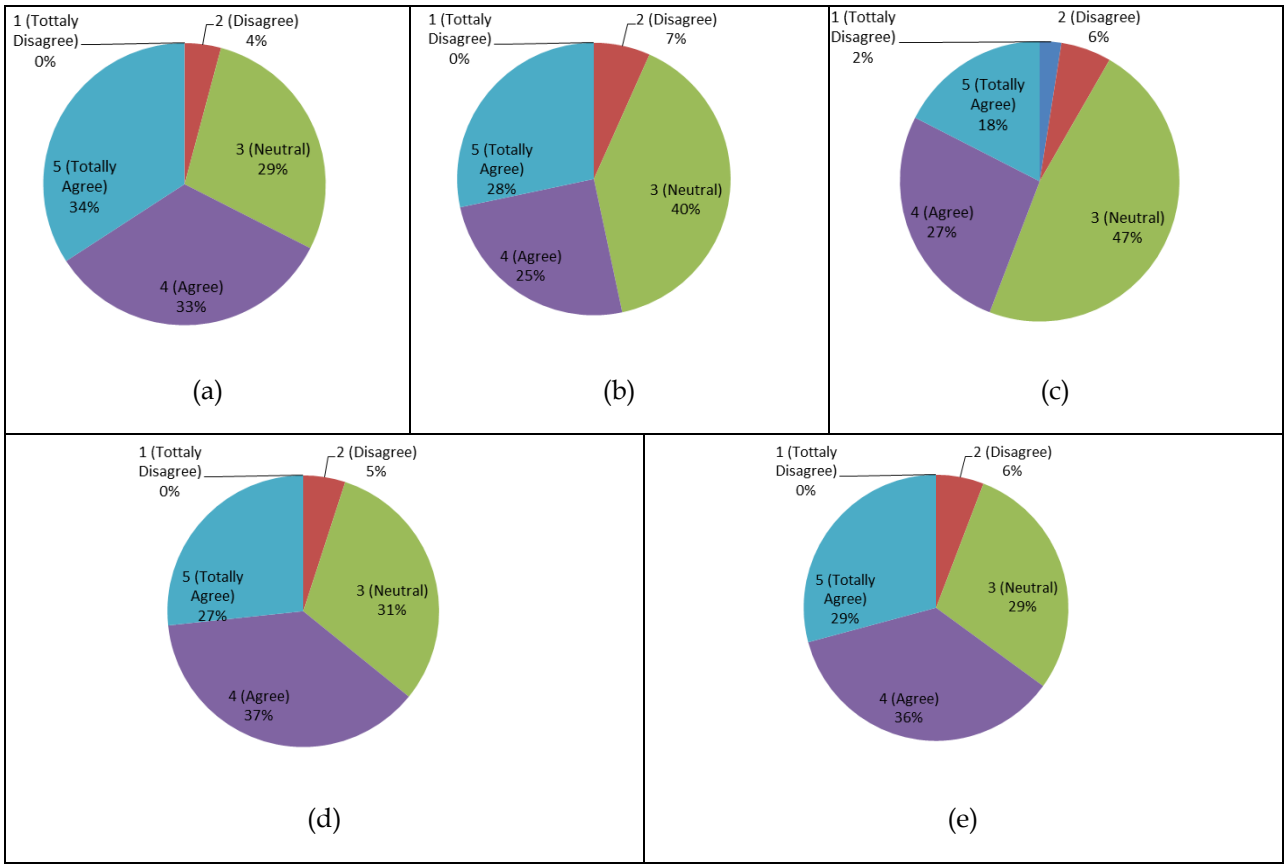


**Figure 2**. University Student Perception of ESD: (a) Question code V2.1; (b) V2.2; (c) V2.3;(d) V2.4; and (e) V2.5.

A detailed analysis was conducted on the third statement, which discussed the integration of physics education with the achievement of the 2030 SDGs. The survey results in the form of physics education students' responses to this item are shown in Table 3. The focus of this statement is associated with aspects of the SDGs represented by several indicators, including climate change, good welfare, quality education, innovation and infrastructure, and partnerships.

**Table 3**. University Student Perception of SDGs 2030

| Code | Statement | The Most Respondents Response |
|---|---|---|
| V3.1 | Physical Science has great potential to create sustainable solutions to challenges such as climate change and social welfare. | 32,50% (Agree) |
| V3.2 | An understanding of Physics concepts can encourage technological innovation that supports sustainable development goals. | 34,17% (Strongly Agree) |
| V3.3 | Efforts to integrate the concept of sustainable development into the Physics education curriculum are urgently needed. | 34,17% (Agree) |
| V3.4 | Collaboration between academia, industry, and government is crucial in developing innovative Physics learning solutions to achieve the 2030 SDGs. | 33,33% (Strongly Agree) |
| V3.5 | The physics education community/forum should be more active in addressing the challenges of sustainable development in the Era of Society 5.0. | 35,00% (Strongly Agree) |

Based on Table 3, one-third of students expressed strong agreement with statements emphasising the link between physics and the Sustainable Development Goals (SDGs). In the statement that physics has great potential in creating sustainable solutions for climate change and social welfare, 32.50% of students agree. Furthermore, in the statement that understanding physics encourages technological innovation to support the SDGs, around 34.17% of students strongly agree. This data reflects the limited recognition of the strategic role of physics in global issues. Research by Widya et al. (2024) suggests that physics education presents a unique opportunity to connect abstract scientific concepts with real-world problems, such as climate change, renewable energy, and resource management (Widya, 2024). The interpretation of this finding suggests that, on the one hand, some students are aware of this potential; however, on the other hand, the majority of respondents have not shown a high level of agreement. This is thought to reflect the need to improve understanding of the SDGs in physics learning.

A total of 34.17% of respondents also agreed that integrating sustainable development concepts into the physics curriculum is very urgent. This result is sufficient to suggest that some students have recognised the importance of the curriculum in meeting current global demands. This is, of course, in line with national education policies that encourage the strengthening of the value of Education for Sustainable Development (ESD). This is in line with the Decree of the Minister of Education, Culture, Research, and Technology Number 56/M/2022, which states that the curriculum must integrate values, knowledge, and skills closely related to sustainable development. In theory, ESD emphasises an active, holistic, and interdisciplinary learning approach, which involves students in finding solutions to environmental problems. Thus, the integration of ESD into the curriculum, including physics courses, is considered essential for producing a generation of change agents committed to sustainability (Vioreza et al., 2023).

**University Student Perception of SDGs PE**

Interviews were then conducted to qualitatively analyse how physics education students in various semesters at Universitas Negeri Medan understand and perceive the relevance between physics learning materials and aspects of the SDGs. The interviews specifically explored their views on the potential

contribution of physics education in responding to global social, environmental and economic challenges. Topics explored in the interviews included: participants' level of knowledge about the SDGs; beliefs regarding the possibility of integrating the SDGs in the physics curriculum; the role of physics education in interpreting the implications of science for the achievement of the SDGs; relevant methods of teaching SDG concepts; identification of key challenges in integrating the SDGs; the impact of the use of technology in improving understanding of the SDGs; educational institution support for educators; and expectations for the outcomes and long term impacts of integrating SDG concepts in physics education.

The interview began with two key questions aimed at exploring the respondents' knowledge, understanding and level of familiarity with the SDGs. To provide a qualitative overview of the students' responses, selected examples of responses are presented. The results show that only a small number of students truly comprehend the concept of SDGs, while the majority of participants demonstrate a superficial understanding of the basic concepts of SDGs.

*A1: "As far as I know, the SDGs have 17 goals, one of which is to improve the quality of education"*
*B1: "Yes, the Sustainable Development Goals are 17 global goals set by the United Nations with a target of achievement by 2030"*
*A2: "Yes, I have some knowledge about the Sustainable Development Goals (SDGs)"*
*A3: "I know a little about the goals of the SDGs, which are to overcome poverty, hunger, climate change, and others"*

The discussion in the interviews then turned to questions regarding respondents' beliefs about the integration of SDGs in the physics curriculum, their views on the role of physics education in understanding the implications of science for achieving the SDGs, as well as methods of teaching SDG concepts in physics learning. Some relevant responses from the respondents regarding these topics are:

*R1: "Yes, because physics education has an important role in helping students understand the science concepts underlying the SDGs."*
*R2: "I think physics education can help students in understanding the implications of science in achieving SDGs by integrating the curriculum in physics through a problem-based learning approach to teach physics concepts."*
*R3: "Yes, because many physics concepts support SDGs, such as energy and green technology."*
*R4: "Yes, physics education can help students understand the implications of science in achieving SDGs by providing scientific understanding of various natural phenomena and technologies that support sustainability."*
*R5: "Yes, SDGs principles can be incorporated into physics lessons. For example: Renewable energy (solar, wind) → SDG 7 Climate change and global warming → SDG 13 Green technology → SDG 9 Energy-efficient buildings & transportation → SDG 11 Energy efficiency & resource saving → SDG 12. In this way, students learn physics while understanding how this science helps to take care of the earth."*

Furthermore, the interviews explored the main challenges of integrating the SDGs in physics education, the impact of technology on student understanding, and institutional support for educators. Based on the respondents' responses, a summary of the findings related to the challenges, expectations and long-term impacts of SDGs integration is as follows: The main challenge highlighted is the complexity and depth of physics material, which is considered difficult to connect with sustainable development.

*R1: "The impact of integrating SDGs in physics education will be significant and transformative in the long run, shaping a generation that is more aware, responsible, and competent in facing global challenges."*
*R2: "My hope is that students/teachers/disciples become more aware of the importance of SDGs and their role in achieving them and that they become more capable in addressing issues related to SDGs."*
*R3: "In the long run, I believe this will create a generation that is not only academically proficient, but also has high social and environmental awareness, and is able to develop sustainable solutions to global challenges."*
*R4: "Schools/universities can organise workshops or seminars for teachers/lecturers on how to connect physics concepts with SDGs."*

*R5: "It can produce students who are more aware and understand global issues, able to apply physics knowledge to find innovative solutions, and can certainly increase the relevance of physics education."*

Qualitative data from the interviews were then analysed using a thematic approach to gain a deeper understanding of students' perceptions of the integration of Sustainable Development Goals (SDGs) in physics learning. The analysis was conducted by identifying patterns, main ideas, and recurring issues in the respondents' responses, then grouping them into themes and subthemes. This process captured the complexity of students' views regarding knowledge of the SDGs, the relevance of physics to sustainable development, and the challenges and expectations of implementing sustainable education in the physics curriculum. The following thematic matrix presents the clustering results, along with respondents' quotes, and the implications of the findings for physics learning in higher education are outlined in Table 4.

**Table 4.** Thematic Matrix of Interview Results

| Main Theme | Subtheme | Sample Respondent Statements | Implications for Physics Education |
|---|---|---|---|
| Knowledge on SDGs | Have heard of<br>Don't know<br>Know most of it | "as far as I know, the SDGs have 17 goals, one of which is to improve the quality of education" (R1)<br>"Have heard of the SDGs, but don't understand everything" (R2) | Need to strengthen basic SDGs literacy through introductory lectures, reflective projects, or contextualized quizzes. |
| Relevance of SDGs with physics | Physics helps with environmental solutions | I think physics education can help students in understanding the implications of science in achieving SDGs by integrating the curriculum in physics through problem based learning approach to teach physics concepts. (R14) | Develop contextualized learning such as SDG 7 and SDG 13 case studies |
| Forms of SDGs integration in physics learning | Case study<br>Interactive multimedia | "Maybe through videos or practices on global warming" (R6)<br>"Real case discussion" (R18) | Use project based methods (PjBL), case discussions, and digital media |
| The challenge of integration | Teachers do not understand SDGs<br>Curriculum is too complex | "it is very rare for lecturers to discuss SDGs" (R2)<br>"There is already a lot of physics material, it is difficult to add new topics" (R10) | Lecturer training and SDGs responsive curriculum redesign |
| Students' expectations for physics education & SDGs | Raising awareness<br>Creating green technology innovators | "Hopefully it can make us more concerned about the environment" (R3)<br>"Hopefully I can become a scientist who helps the world" (R16) | Emphasis on values, attitudes, and social roles through active and reflective learning |

The results of thematic analysis revealed that physics education students have the potential to understand and support the integration of SDGs in learning, although this requires systemic interventions (strengthening literacy, teacher training, responsive curriculum, technological support and learning resources). With its strategic position as a driver of sustainable transformation, physics education, if appropriately integrated, can produce graduates who are academically competent and contribute to sustainable global development.

This statement is supported by several previous studies that indicate the integration of the Sustainable Development Goals (SDGs) concept in learning has the potential to increase students' awareness and sense of responsibility regarding sustainable issues. For example, a study by Kioupi & Voulvoulis (2019) found that integrating the SDGs concept in the classroom can increase students' awareness of environmental and social issues. In addition, research by Mitarlis et al. (2023) showed that integrating SDG concepts into learning can help students understand the importance of sustainable development and motivate them to participate in efforts to achieve SDG goals.

## DISCUSSION

Based on the integration of quantitative and qualitative analysis results, it is concluded that physics education students show varying awareness regarding the integration of Sustainable Development Goals (SDGs) concepts in physics learning. Despite the recognition of the strategic potential of physics in facilitating technological innovation and sustainable solutions, the majority of students lack a comprehensive understanding of the SDGs concepts. This finding highlights the importance of enhancing SDG literacy as a crucial component of the physics education curriculum at the higher education level.

Through the establishment of sustainability values in physics learning, it is hoped that graduates who not only excel in mastering scientific concepts but also possess critical awareness, socially and environmentally responsible attitudes, and master 21st-century competencies will be vital in playing a role as agents of change in realising sustainable global development. In this regard, this article suggests a follow-up study to measure the effectiveness of ESD implementation in various physics courses with a wider scope and more in-depth analysis.

In contrast, students showed high support for new learning approaches. A percentage of 37.50% agreed that innovative approaches are needed to apply physics concepts in the context of Society 5.0. This reflects the realisation that physics teaching methods should be more contextualised and problem-based, for example, through project-based learning or experiments relevant to sustainability issues. Research shows that integrating ESD in physics, for example, through solar cell experiments or renewable energy case studies, can foster students' deep understanding of energy processes and environmental awareness (Wang, 2024). Similarly, 35.83% of students agreed that technologies such as AI can improve the effectiveness of physics learning. This finding is consistent with the Society 5.0 concept, which integrates AI and information technology into everyday life (Jauhariyah et al., 2021). Advanced technologies, such as simulation and artificial intelligence, have the potential to enrich the physics learning experience; however, their use also demands infrastructure readiness and teacher training.

Critically, these data underscore some learning challenges and implications. The application of ESD and Society 5.0 principles in physics demands holistic and cross-cutting education. 21st-century education emphasises 4C skills (critical thinking, communication, collaboration, creativity) as well as digital literacy, which must be integrated into physics learning (Suprapto & Hidaayatullaah, 2023). A major challenge is the gap in technology access and educator readiness; without a paradigm shift, physics teachers may continue to teach in traditional ways, so that their students do not recognise the importance of local energy sources and their active role as sustainable global citizens (Malavoloneque & Costa, 2022). Consequently, the practical implications include the need for continuous professional training for teachers, curriculum development that incorporates environmental issues and the latest technologies, and learning evaluations that assess 21st-century competencies. Taking into account ESD theory and the demands of Society 5.0, physics education is expected to deliver not only scientific concepts but also instil sustainable values and critical skills to shape a future society that is technologically smart and environmentally aware (Rieckmann, Marco; Mindt, Lisa; Gardiner, 2017).

## CONCLUSION

This study shows that physics education students at Medan State University generally recognise the strategic relevance of physics to sustainable development, particularly in relation to global challenges such as climate change, energy transition, and technological innovation. However, their understanding remains conceptual rather than integrative. Students acknowledge the potential of the physics discipline for sustainability, yet they struggle to explicitly connect physics learning with the Sustainable Development Goals (SDGs) and the Education for Sustainable Development (ESD) framework. This indicates a gap between students' intuitive appreciation of physics-based problem-solving and their formal literacy regarding sustainability (Hariyono et al., 2023). When viewed through the lens of ESD theory and previous research on disciplinary literacy, these results suggest that the current physics learning environment has not yet positioned sustainability as a central pedagogical principle. This misalignment reflects broader structural challenges in higher education, including limited instructor capacity, insufficient contextual learning materials, and curricular constraints that hinder the integration of sustainability as a cross-disciplinary theme (Leiva-Brondo et al., 2022).

Strengthening SDG literacy in physics education requires more than simply adding content; it demands pedagogical transformation based on the principles of Education for Sustainable Development (ESD). Strategies such as targeted professional development for lecturers, the development of contextual learning resources, and stronger collaboration between universities, industry, and policymakers can support this shift. By fostering sustainability-oriented perspectives and competencies, physics education can prepare graduates to become scientifically knowledgeable and socially responsible contributors to sustainable development.

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## REFERENCES

Arntzen, M., Scheie, E., & Haug, B. (2025). Unveiling perceptions: how science teachers perceive sustainable development and their expectations of students' learning outcomes through environmental and sustainability education. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2025.2499215

Cachero, C., Grao-Gil, O., Pérez-del Hoyo, R., Ordóñez-García, M. C., Andújar-Montoya, M. D., Lillo-Ródenas, M. Á., & Torres, R. (2023). Perception of the Sustainable Development Goals among university students: A multidisciplinary perspective. *Journal of Cleaner Production*, 429(June), 139682. https://doi.org/10.1016/j.jclepro.2023.139682

Hák, T., Janoušková, S., & Moldan, B. (2016). Sustainable Development Goals: A need for relevant indicators. *Ecological Indicators*, 60, 565–573. https://doi.org/10.1016/j.ecolind.2015.08.003

Hariyono, E., Suprapto, N., Zakhiyah, I., & Ismail, M. H. (2023). Development of a Dye-Sensitised Solar Cells Steam Learning Prototype for Supporting Educational Initiatives in Sustainable Development. EUREKA, *Physics and Engineering*, 2023(5), 56–66. https://doi.org/10.21303/2461-4262.2023.002928

Hidaayatullaah, H. N., Hariyono, E., Hadiana, D., Fujii, H., & Satriawan, M. (2024). Exploring global dynamics of sustainable environmental sciences in climate change mitigation for sustainable development. *E3S Web of Conferences*, 513. https://doi.org/10.1051/e3sconf/202451303014

Hnatyuk, V., Pshenychna, N., Kara, S., Kolodii, V., & Yaroshchuk, L. (2024). Education's role in fostering environmental awareness and advancing sustainable development within a holistic framework. *In Multidisciplinary Reviews* (Vol. 7, Issue Special Issue). Malque Publishing. https://doi.org/10.31893/multirev.2024spe012

Jauhariyah, M. N. R., Prahani, B. K., Syahidi, K., Deta, U. A., Lestari, N. A., & Hariyono, E. (2021). ESD for physics: How to infuse education for sustainable development (ESD) to the physics curricula? *Journal of Physics: Conference Series*, 1747(1). https://doi.org/10.1088/1742-6596/1747/1/012032

John W Creswell; Vicky L Plano Clark. (2006). Designing and conducting mixed methods research. In Chapter 4.

Kioupi, V., & Voulvoulis, N. (2019). Education for sustainable development: A systemic framework for connecting the SDGs to educational outcomes. *Sustainability (Switzerland),* 11(21). https://doi.org/10.3390/su11216104

Leal, S., Nascimento, J., Piki, A., Tekerek, A., Güzel, A., Loureiro, A., Gonçalves, C., Messias, I., Simons, J., Teunen, L., Barradas, L. C. S., Palmer, N., Mongelli, T. L., Nedelko, Z., & Oliveira, S. (2024). Exploring sustainable development perceptions among higher education students: An empirical study on knowledge, attitudes, and behaviours. *Cleaner and Responsible Consumption*, 14. https://doi.org/10.1016/j.clrc.2024.100223

Leiva-brondo, M., Lajara-camilleri, N., Vidal-mel, A., Atar, A., & Lull, C. (2022*). Spanish University Students' Awareness and Perception of Sustainable Development Goals and Sustainability Literacy*. 1–26.

Malavoloneque, G., & Costa, N. (2022). Physics Education and Sustainable Development: A Study of Energy in a Glocal Perspective in an Angolan Initial Teacher Education School. *Frontiers in Education*, 6. https://doi.org/10.3389/feduc.2021.639388

Ministry of Finance and Economic Development. (2016). *United Nations Sustainable Development Goals-the 2030 Agenda for Sustainable Development, Ministry of Finance and Economic Development, Government of Sierra Leone, Advanced Draft Report on Adaptation of the Goals in Sierra Leone* (Issue July).

Miqdad, M., Anugerah, E. G., Sulistiyo, A. B., & Wardhaningrum, O. A. (2020). An assessment of the faculty sustainability reporting guideline (FRSP): Indonesia's sustainable development goals for higher education. *International Journal of Research in Business and Social Science*, 9(1), 94–105. http://ssbfnet.com/ojs/index.php/ijrbs/article/view/578

Mitarlis, Azizah, U., & Yonata, B. (2023). The Integration of Green Chemistry Principles in Basic Chemistry Learning to Support Achievement of Sustainable Development Goals (SDGs) Through Education. *Journal of Technology and Science Education*, 13(1), 233–254. https://doi.org/10.3926/jotse.1892

Rieckmann, Marco; Mindt, Lisa; Gardiner, S. (2017). Education for Sustainable Development Goals: learning objectives. In Education for Sustainable Development Goals: learning objectives. UNESCO. https://doi.org/10.54675/cgba9153

Saphira, H. V., Prahani, B. K., Hariyono, E., Wibowo, F. C., Bunyamin, M. A. H., & Wahono, S. (2023). The pathway of digital learning environments in advancing Sustainable Development Goals (SDGs): A Bibliometric analysis covering three decades of research. *E3S Web of Conferences*, 450. https://doi.org/10.1051/e3sconf/202345001005

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualisation and operationalisation. *Quality and Quantity*, 52(4), 1893–1907. https://doi.org/10.1007/s11135-017-0574-8

Suprapto, N., & Hidaayatullaah, H. N. (2023). University Students' Perspectives on Physics Education in Sustainable Development Goals. *Journal of Physics: Conference Series,* 2623(1). https://doi.org/10.1088/1742-6596/2623/1/012001

Utama, Y. J., Ambariyanto, A., Zainuri, M., Darsono, D., Setyono, B., Widowati, & Putro, S. P. (2018). Sustainable development goals form the basis of university management in pursuit of global competitiveness. *Journal of Physics: Conference Series*, 1025(1). https://doi.org/10.1088/1742-6596/1025/1/012094

Vioreza, N., Hilyati, W., & Lasminingsih, M. (2023). Education for Sustainable Development: Bagaimana Urgensi dan Peluang Penerapannya pada Kurikulum Merdeka? *PUSAKA: Journal of Educational Review*, 1(1), 34–48. https://doi.org/10.56773/pjer.v1i1.11

Wang, L. (2024). Exploring the integration of physics education and sustainable development education: resource utilisation and environmental awareness cultivation. *Region - Educational Research and Reviews,* 6(5), 99. https://doi.org/10.32629/rerr.v6i5.2148

Widya. (2024). Challenges And Needs in Integrating Sustainable Development Goals (SDGs) Into High School Physics Curriculum: A Study in Lhokseumawe, Indonesia. Proceedings of Malikussaleh *International Conference on Multidisciplinary Studies (MICoMS),* 4, 00036. https://doi.org/10.29103/micoms.v4i.959