14 (1) (2025) 88-98

Unnes Science Education Journal
Accredited Sinta 2

https://journal.unnes.ac.id/journals/usej

Potential of STEAM-SDGs Integration in Physics Learning

Riska Ajibudiarta✉, Nur Khoiri, Siti Patonah, Muhammad Syaipul Hayat

DOI: http://dx.doi.org/10.15294/usej.v13i1.19326

Universitas Persatuan Guru Republik Indonesia Semarang, Indonesia

Article Info

Submitted 2025-01-05
Revised 2025-02-23
Accepted 2025-04-30

Keywords

Physiscs Learning; SDGs; STEAM

Abstract

This study analyzes the potential of integrating STEAM (Science, Technology, Engineering, Arts, and Mathematics) with the Sustainable Development Goals (SDGs) in physics learning within Grobogan District, Indonesia, aligning with the National Long-Term Development Plan (RPJPN) 2025-2045's focus on quality education. This descriptive qualitative research surveyed 23 physics teachers from the local MGMP (Subject Teacher Forum) using a questionnaire about STEAM-SDGs integration. Results revealed positive attitudes towards both STEAM (68% positive: 22% strongly agree, 46% agree) and SDGs (57% agree). However, understanding and application levels were low. 42% of teachers were undecided about STEAM, and 32% about SDGs. Regarding practical application, 37% were hesitant about STEAM implementation, and 29% about SDG integration. These findings highlight the need for comprehensive training to enhance teachers' understanding and preparedness for integrating STEAM and SDGs into physics instruction. This is crucial for improving physics education quality and equipping students to address 21st-century global challenges through innovative and sustainable learning.

How to Cite

Ajibudiarta, R., Khoiri, N., Patonah, S., & Hayat, S. M. (2025). Potential of STEAM-SDGs Integration in Physics Learning. *Unnes Science Education Journal*, 14(1), 88-98.

✉ Correspondence Author:
E-mail: riskaajibudiarta@gmail.com

p-ISSN 2252-6617
e-ISSN 2502-6232

INTRODUCTION

The vision of "Golden Indonesia 2045" aims to make Indonesia a developed country with superior quality human resources. To achieve this goal, collaboration between the government, society and the private sector is needed to improve the quality of education (Arini, 2024; Kirana et al., 2024; Muhammad Dimas Firmansyah, 2024). Investment in education and technological innovation is key to improving global competitiveness (Handyka, 2023; Kurniawan, 2023). By focusing efforts on developing quality human resources, Indonesia can capitalize on its demographic potential and achieve sustainable development growth.

The global challenges faced by the education system in Indonesia greatly affect the quality of education received by students (Susianita & Riani, 2024). One of the main challenges is the disparity in access to education between urban and rural areas, where many schools in remote areas still lack basic facilities and adequate resources (Edo & Yasin, 2024; Sari & Riansi, 2024). This leads to significant differences in the quality of education students receive, which in turn exacerbates social and economic disparities in different regions (Ayu et al., 2024). In addition, the rapid development of technology requires the education system to adapt quickly, but often the national education curriculum is unable to keep up with the changing needs of the world of work (Camelia, 2020). Therefore, it is important for the government and educational institutions to design learning approaches that can meet global challenges and improve the quality of education in Indonesia.

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning approach offers an innovative way to improve students' skills to think scientifically and utilize technology in the future (Martiani & Subali, 2024). The integration of art in science and technology learning can improve creativity and problem solving faced by students (Putra & Ellianawati, 2024; Widarti & Roshayanti, 2021). Research shows that the STEAM method can significantly increase students' learning motivation and academic results (Erwinsyah et al., 2022). Thus, STEAM equips students with the knowledge and skills needed to actively contribute to realizing a more sustainable world in accordance with the vision of the SDGs (Azzahra & Rahyasih, 2024).

Sustainable Development Goals (SDGs) is a global agenda that aims to achieve sustainable development until 2030. Indonesia is committed to integrating the SDGs in various sectors, including education, health and the environment (Kementerian PPN/Bappenas, 2020). Through quality education, it is expected that the younger generation can contribute to the achievement of SDGs in an innovative and sustainable way (Fadilah et al., 2024). Awareness of the importance of the SDGs must also be instilled from an early age so that children understand their role in creating a better world.

Conventional physics learning often focuses on delivering theoretical knowledge through lectures and routine exercises. This method can lead to students only playing the role of audience, so they are not actively involved in the learning process. In this context, students may have difficulty in relating physics concepts to real challenges facing society, such as climate change and renewable energy, which are important issues in the Sustainable Development agenda (Firmansyah & Jiwandono, 2022).

In addition, conventional approaches in physics education tend not to emphasize the essential skills needed in the 21st century. Students educated in this way are rarely given the opportunity to develop critical thinking and collaboration skills, which are key elements in solving today's complex problems (OECD, 2019). Without an emphasis on these skills, students may be less prepared to face global challenges that require innovative and sustainable solutions (Pahrijal et al., 2023).

A more active and interactive learning approach can help students improve their understanding of physics by linking theoretical knowledge with practical applications in the field. For example, collaborative projects related to environmental issues can provide a real context that makes learning more meaningful. The application of inclusive and participatory learning techniques can increase students' participation and foster their sense of responsibility towards global issues (Pahrijal et al., 2023).

Incorporating STEAM elements in physics learning allows students to develop innovations that support sustainability principles (Sukaesih, 2023). In the process, students are trained to think critically and creatively, which are essential skills in dealing with complex and dynamic problems in today's world (Nur & Nugraha, 2023). It can be said that physics learning that is focused on developing innovative solutions will better prepare students to contribute the achievement of SDGs.

Applying STEAM principles in physics learning can ultimately equip students with the skills needed to actively participate in their community and environment (Vioreza et al., 2023) . By using methods that encourage exploration and collaboration, students can more easily understand and internalize the material at hand (Mudaningrat et al., 2024; Tahmid et al., 2024). Therefore, STEAM-based physics education not only educates students in academic aspects, but also shapes them as individuals who are ready to face future challenges and are able to achieve sustainable development goals (Matitaputty et al., 2022; Meda, 2022) .

Previous research by Hayat et al. (2024) focused on innovations in physics learning methods, such as projectbased approaches, with the aim of increasing student engagement and teaching effectiveness of physics concepts. While offering significant contributions to active learning, these studies tend to be limited to the development of cognitive skills and less explicit in linking them to global issues or transdisciplinary approaches. In that context, this research has the novelty of integrating the STEAM-SDGs approach directly with the Sustainable Development Goals (SDGs), such as sustainability and renewable energy.

This research not only emphasizes the relevance of physics learning to global challenges but also provides a framework that engages students in collaborative projects to develop creative and transdisciplinary skills. Thus, this research fills a gap that exists in previous literature by uncovering the potential for physics learning to be more applicable and relevant to the needs of the times. It makes a new contribution to education by presenting a holistic approach to building environmental awareness and 21st century competencies.

Integration of physics learning with STEAM approach and Sustainable Development Goals (SDGs) can provide a more interesting and relevant learning experience (Syahrial, 2024). Through a combination of science, technology, engineering, art and math, students not only understand physics concepts, but are also invited to apply that knowledge in creating solutions to global challenges, such as climate change and social inequality (Lestari et al., 2024). This approach provides the practical context necessary for students to build awareness of important issues in society (Firdaus, 2024).

METHODS

This research used descriptive qualitative research by surveying the potential for STEAMSDGs integration in physics learning by giving questionnaires to 23 high school physics teachers in Grobogan Regency. Data collection techniques in this study through filling out questionnaire sheets. According to Sugiyono (2020) , a questionnaire is a tool used to collect data by giving a set of written questions to respondents to answer, which can be open or closed questions. Open questions give respondents the freedom to explain their opinions, while closed questions limit the answers to the options that have been provided (Sugiyono, 2023). The questionnaire comparising conventional physics learning and STEAM-SDGs integration to evaluate which method is more effective in achieving the goals of modern education, especially in the context of sustainability and student character development (Table 1).

Table 1. Comparison of conventional physics learning and STEAM-SDGs integration

Aspects	**Conventional Physics Learning** (Arends, 2019)	**STEAM-SDGs Physics Learning** (Bybee, 2013)
Approach	Theory-based and memorization	Project and application based
Student engagement	Passive, just listening	Active, engaged in projects
Skills taught	Focus on physical concepts	Creative, collaborative problem-solving skills
Relevance to everyday life	Limited to theory	Highly relevant to global issues such as climate change
Environmental awareness	Minim	Higher, through SDGs-related projects

One of the main advantages of using questionnaires is their ability to reach a wider population at a relatively low cost. Questionnaires can be distributed online, so researchers are not bound by geographical restrictions and can collect data from various locations quickly (Ardiansyah et al., 2023). In addition, questionnaires also provide time flexibility for respondents, allowing them to answer questions at their convenience. This has the potential to improve the quality of data obtained, as respondents may provide more honest and well thought out answers (Ardiansyah et al.

., 2023. The questionnaire consists of categories of attitude, understanding and application is an adaptation of research Sujarwanto et al., (2019) integrated STEAM-SDGS in physics learning. The question items in the attitude category are 3 questions, 4 questions for the understanding category and 13 questions for the application category in STEAM integration with a list of questions can be seen in Table 2.

Table 2. List of questions on STEAM integration in physics learning with the categories of attitude, understanding, and application (Sujarwanto et al., 2019)

NO	QUESTION
A	**Science, Technology, Engineering, Art, Mathematics (STEAM)**
	Attitude
1	I strongly agree to apply the STEAM approach in teaching Physics in the classroom
2	I believe students will benefit more if I integrate the STEAM approach in teaching Physics in the classroom.
3	I am very interested to know more about how to apply the STEAM approach simultaneously and correctly in teaching Physics in the classroom.
	Understanding
4	I know the term STEAM
5	I realize that STEAM in education is not a type of teaching method
6	I have sufficient knowledge about the disadvantages and advantages of STEAM integration.
7	I believe that STEAM is composed of the integration of science, technology, engineering, arts and math or composed of at least two of these disciplines.
	Application
8	I often teach Physics with various electronic devices
9	My students are actively engaged using simple technology or specific procedures
10	Sometimes, I teach by asking students to use the internet in class.
11	I use ready-made technology tools (not of my own making)
12	I always create questions or tasks according to students' ability to design and create prototypes or models in the form of project assignments.
13	In Physics lessons that generate data, I always direct students to analyze using simple statistics.
14	I often encourage students to think carefully with mathematical thinking to make decisions.
15	Sometimes, I design and make my own simple technology or use procedures to produce something that can be used in learning (e.g. designing and making levers, measuring tools, etc.).
16	In my classroom, I usually use technological tools to mathematically analyze data from observations (e.g. using calculators, computers, mobile phones, etc.).
17	I often encourage students to use all possible technologies to collect data in Physics class (e.g. using AVOmeter and using mathematical calculations to make decisions).
18	I often explain material about complicated calculations in Physics class and show it with Power Point or other learning technology.
19	I often ask students to use or recycle items around them to make them more useful and economically valuable, especially for the Physics learning process.
20	I often combine technology, engineering design, and mathematical approaches into one

SDGs integration also used a questionnaire adapted from research Sujarwanto et al., (2019) which also uses categories of attitude, understanding and application with details of 3 questions for the attitude category, 3 questions for the understanding category and 9 questions for the application category in SDGs integration with the list of questions can be seen in Table 3.

Table 3. List of questions on SDGs integration in physics learning with the categories of attitude, understanding, and application (Sujarwanto et al. ., 2019)

NO	QUESTION
B	**Sustainable Development Goals (SDGs)**
	Attitude
1	I strongly agree to apply the Sustainable Development Goals (SDGs) approach in teaching Physics in the classroom.
2	I believe students will benefit more if I integrate the SDGs approach in teaching Physics in the classroom.
3	I am very interested to know more about how to apply the SDGs approach to teaching Physics in the classroom.
	Understanding
4	I understand the basic concepts of SDGs
5	I believe that SDGs are important to be taught in Physics learning
6	I have integrated the SDGs principles in the Physics curriculum that I teach.
	Application
7	I have enough resources to teach the SDGs in my classroom
8	I feel comfortable using learning methods that support SDGs, such as project-based learning
9	I know how to evaluate students' understanding of SDGs in the context of Physics learning
10	I often look for the latest information on the SDGs to improve my teaching
11	I feel that the training on SDGs will be beneficial for my professional development as a Physics teacher
12	I have implemented outdoor activities related to SDGs in my learning
13	I believe that technology can be used to support the integration of SDGs in Physics learning
14	I feel that the current curriculum is sufficient to support the integration of SDGs in Physics learning
15	I would like to get more support and resources to integrate the SDGs in my teaching.

In scoring the answers, the authors use a Likert scale, namely: strongly agree (5), agree (4), doubt (3), disagree (2) strongly disagree (1). Using a Likert scale to measure respondents' attitudes, opinions, and perceptions of certain phenomena. This scale allows researchers to quantify responses and conduct statistical analysis to draw conclusions from the data collected (Noor, 2017) . The percentage score of each category is calculated using the ratio of the ideal score of the sum of each category with the following formula:

$$Percentage\ (\%) = \frac{Total\ Score}{Maximum\ Total\ Score}\ x\ 100\%$$

RESULTS AND DISCUSSION

STEAM approach

The results of the questionnaire that has been filled in by 23 high school physics teachers from MGMP physics in Grobogan District about attitudes, knowledge and application of STEAM in high school physics learning in Grobogan District can be seen in Figure 1.

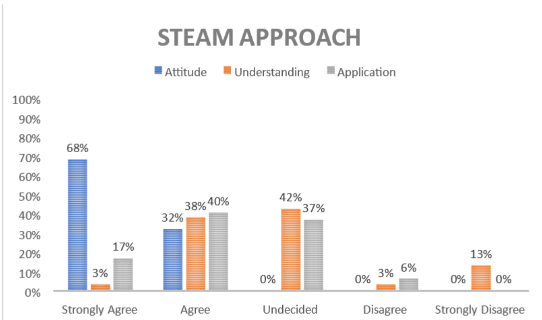

Figure 1. Results of teacher questionnaires on attitudes, knowledge and application of STEAM

From Figure 1, it can be seen that of the 23 high school physics teacher respondents in Grobogan Regency, in the attitude category shows a score percentage of 68% strongly agree, 32% agree and 0% for other criteria, while for understanding as many as 3% of physics teachers who strongly agree, 38% agree, 42% are undecided, 3% disagree and 13% strongly disagree. For the understanding category, a score of 17% strongly agreed, 40% agreed, 37% undecided, 6% disagreed and 0% strongly disagreed.

Attitude toward STEAM

From the questionnaire results, 68% of teachers strongly agreed and 32% agreed with the application of STEAM in physics learning. This shows that the majority of teachers have a positive attitude towards the integration of this approach in the curriculum. This positive attitude is important because it can contribute to the success of STEAM integration in the classroom. Research Firdausi Nuzula & Budi Jatmiko (2023) conveyed that the application of STEAM can improve students' 21st century skills, such as critical and creative thinking, which are indispensable in physics learning.

Understanding of STEAM

In the understanding category, results show that only 3% of teachers strongly agree, while 38% agree, 42% are undecided, 3% disagree, and 13% strongly disagree. This shows that while there is support for STEAM implementation, there is still doubt and uncertainty among teachers regarding their understanding of this approach. This indicates the need for further training to improve teachers' understanding of STEAM concepts and applications in physics learning.

STEAM application

In terms of application, the results show 17% of teachers strongly agree, 40% agree, 37% are undecided, and 6% disagree. No respondents strongly disagreed. While the majority of teachers are willing to implement STEAM, the high level of hesitation (37%) suggests that they may feel unsure or underprepared to integrate this approach effectively. Other research emphasizes the importance of using innovative and engaging learning media to support STEAM applications, such as the use of information technology and gamification (Badryatusyahryah et al. ., 2022)

The results of this questionnaire reflect the positive attitude of high school physics teachers in Grobogan District towards the application of STEAM, but also indicate challenges in terms of understanding and application. To improve the effectiveness of STEAM integration, a comprehensive training program is needed for teachers so that they can better understand and apply this approach. Thus, it is expected that there will be an improvement in the quality of physics learning that is more interesting and relevant to students.

Analysis of Percentage Differences in Three Aspects: Attitude, Understanding, and STEAM Application

The differences in physics teachers' attitudes, understanding and application of STEAM can be explained by several key factors. Teachers generally show a very positive attitude towards STEAM due to their awareness of the importance of innovation in education, as described by research (Mu'minah, 2021) . However, the low understanding of STEAM concepts and applications is reflected in the high percentage of teachers who are undecided or disagree in this category. In addition, the lack of access to intensive training is a major cause of the low level of understanding and application, as revealed in the study Mulyani (2019) which emphasizes that comprehensive training is key to improving teachers' readiness to implement the STEAM approach. Another factor is the limited resources and infrastructure, such as technology, teaching materials, or time to design STEAM-based learning, which is a significant obstacle. This can be seen from the high number of doubts in the application of STEAM, as the results of research by Pramudyani & Indratno (2021) and (Suharni et al., 2024)

The integration of STEAM with Sustainable Development Goals (SDGs) in physics learning has great potential to provide significant added value. One effort that can be made is to organize thematic training that connects STEAM with SDGs issues, such as renewable energy, climate change, and environmentally friendly technology. This kind of training can increase the relevance of physics learning while motivating students to understand the relationship between science and global challenges, as expressed by (Vioreza et al., 2023) . In addition, collaboration with local industries and communities in STEAM-SDGs curriculum development can provide contextualized and applicable learning experiences. Community-based projects can also increase students' awareness of the importance of sustainability (Vioreza et al., 2023) . The use of interactive learning media, such as augmented reality (AR) based physics simulations or virtual reality (VR), can provide an engaging and immersive learning experience, as recommended by research (Mu'minah, 2021) .

SDGs Approach

The results of the questionnaire that has been filled in by 23 high school physics teachers from MGMP physics in Grobogan District about the attitude, knowledge and application of SDGs in high school physics learning in Grobogan

District can be seen in Figure 2.

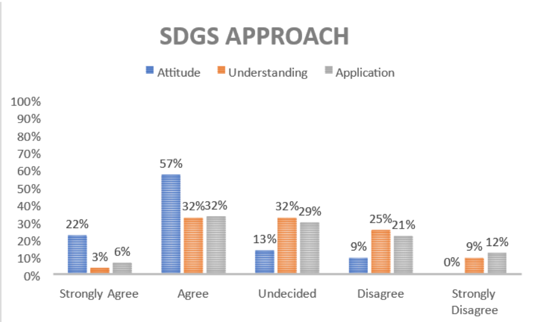

Figure 2. Teacher questionnaire results on attitudes, knowledge and application of SDGs

From Figure 2, it can be seen that of the 23 respondents of high school physics teachers in Grobogan Regency, in the attitude category obtained a percentage score of 22% strongly agree, 57% agree, 13% undecided, 9% disagree and 0% strongly disagree. For the understanding category, a percentage score of 3% strongly agreed, 32% agreed, 32% undecided, 25% disagreed, and 9% strongly disagreed. Meanwhile, for the application category, a percentage score of 6% strongly agreed, 32% agreed, 29% undecided, 21% disagreed and 12% strongly disagreed

Attitude towards SDGs

From the questionnaire results, 22% of teachers strongly agreed, 57% agreed, 13% were undecided, 9% disagreed, and none strongly disagreed towards the implementation of SDGs in physics learning. The high percentage for the agree category indicates that the majority of teachers have a positive attitude towards the integration of SDGs in physics learning. This attitude is important because a positive attitude can influence teachers' motivation to integrate this approach in their learning. Hartati & Hariyono (2020) stated that integrating SDGs in education can increase students' awareness of global and environmental issues, and foster a sense of social responsibility.

Understanding of the SDGs

In the understanding category, results show that only 3% of teachers strongly agree, while 32% agree, 32% are undecided, 25% disagree, and 9% strongly disagree. This low level of understanding reflects the urgent need to improve teachers' knowledge of the SDGs and how the principles can be integrated into physics learning. This is in line with the findings of Kiswanda et al.,(2021) that many educators still lack an in-depth understanding of the SDGs concept, which may hinder the effectiveness of integration in the classroom.

Application of SDGs

In the application category, results show that 6% of teachers strongly agree, 32% agree, 29% are undecided, 21% disagree, and 12% strongly disagree. While there is support for the application of the SDGs, the high level of doubt and disagreement suggests that many teachers feel less confident or prepared to integrate these principles in learning practices. Rahmania & Hudri, (2024) pointed out that the successful integration of the SDGs in education relies heavily on adequate training and support for educators.

The results of this questionnaire indicate a positive attitude of high school physics teachers in Grobogan Regency towards the implementation of the SDGs, but also significant challenges in terms of understanding and application. To improve the effectiveness of SDGs integration in physics learning, there needs to be a comprehensive training program for teachers so that they can better understand and apply the principles. . Thus, it is expected to create more relevant and impactful learning for students, and support the achievement of sustainable development goals more effectively.

Analysis of Percentage Differences in Three Aspects: Attitude, Understanding, and Application of SDGs

The questionnaire results revealed striking differences between the three aspects studied, namely teachers' attitudes, understanding and application of the integration of Sustainable Development Goals (SDGs) in learning. The majority of teachers (79%) showed a positive attitude, characterized by agreeing or strongly agreeing, indicating a desire to integrate the SDGs into the learning process. However, lower percentages in the understanding and application aspects suggest a gap between positive attitudes and the knowledge and practical skills needed for effective implementation.

This high positive attitude is likely influenced by the increasing global awareness of sustainability issues and the crucial role of education in achieving the SDGs. Exposure through mass media, seminars and various trainings that have been organized are thought to have strongly contributed to the formation of teachers' positive perceptions of the urgency of the SDGs. In contrast, the lower percentage in the understanding aspect (35% agree/strongly agree) shows that although teachers have a supportive view, their in-depth knowledge of the SDGs concept, especially in the context of physics materials, is still limited.

The biggest challenge lies in the application aspect, with the lowest percentage (38% agree/strongly agree). This shows the difficulty of teachers in translating the conceptual understanding of the SDGs into classroom practices. Some factors contributing to this difficulty include: the lack of concrete examples and practical guidance on the integration of SDGs into lesson plans and physics learning activities; teachers' concerns related to measuring and evaluating the achievement of SDGs goals in learning; limited time and resources to develop SDGs-oriented learning materials and activities; and teachers' tendency to maintain established conventional teaching methods. The significant percentage difference between these three aspects emphasizes the importance of focusing on improving teachers' understanding and ability to apply the SDGs, and not only focusing on cultivating positive attitudes.

To effectively raise awareness and implement STEAM-SDGs in physics learning, a series of integrated and sustainable efforts are needed. First, comprehensive training programs and workshops play a crucial role in equipping teachers with knowledge, skills and practical strategies. This training ideally includes an in-depth understanding of the SDGs concept and its relevance to physics, provision of concrete examples and case studies of STEAM-SDGs application in the context of physics learning, development of STEAM-SDGs based lesson plans and teaching materials, and appropriate assessment and evaluation strategies. Second, the availability of relevant and easily accessible resources and teaching materials, such as modules, books, videos, and online platforms, is essential to support teachers' implementation of STEAM-SDGs. Third, the establishment of a community of physics teacher practitioners who implement STEAM-SDGs can facilitate the exchange of experiences, share good practices and provide valuable peer support. Fourth, collaboration with related parties, such as universities, research institutes and non-governmental organizations working on education and sustainability, can enrich training programs and resource development. Finally, encouraging teachers to conduct classroom action research can help test the effectiveness of various STEAM-SDGs implementation strategies in their own learning contexts and contribute to the development of best practices.

This study, while providing valuable insights, has some limitations that need to be acknowledged. First, the relatively small sample size (23 teachers) limits the generalizability of the findings to a wider population of teachers, so the results of the study may not be fully representative to describe the condition of all physics teachers in Grobogan district or similar areas. Second, this study focused on teachers' perceptions and understanding of STEAM-SDGs without measuring the direct impact of implementing this approach on student learning outcomes. As a result, the effectiveness of STEAM-SDGs in improving physics concept understanding, 21st century skills (such as critical thinking, problem solving, collaboration, and communication), and student learning motivation cannot be evaluated comprehensively and empirically. Third, the use of questionnaires as the only method of data collection limits the depth of exploration of the reasons behind teachers' attitudes, understanding and application of STEAM-SDGs. Questionnaires tend to provide quantitative data measuring levels of agreement or frequency, but are less able to explore teachers' subjective contexts, experiences or interpretations in depth.

Based on these limitations, several recommendations are proposed for future research. First, future research is suggested to involve a larger and more representative sample, so that the research findings can be generalized more validly to a wider population. Second, the use of more diverse data collection methods, such as in-depth interviews, classroom observations, document analysis (e.g., lesson plans, student worksheets), and case studies, can provide a more comprehensive and in-depth understanding of the implementation of STEAM-SDGs. Interviews can explore teachers' perspectives and experiences in more detail, classroom observations can provide a direct picture of learning practices in the classroom, and document analysis can provide concrete evidence of lesson planning and implementation. Third, classroom action research is highly recommended to test the effectiveness of various STEAM-SDGs implementation strategies in real learning contexts and to directly measure the impact of these interventions on student learning outcomes. PTK allows researchers and teachers to collaborate in designing, implementing, evaluating and revising learning interventions in a cyclical manner, resulting in continuous improvement. Fourth, future research needs to consider contextual factors that may influence STEAM-SDGs implementation, such as school policies, support from principals and peers, availability of resources (e.g. facilities, equipment and teaching materials), and school climate and culture.

Understanding how these factors interact with STEAM-SDGs implementation can provide more holistic insights and assist in designing more effective implementation strategies. Longitudinal studies are also needed to track the development of teachers' attitudes, understanding and skills in implementing STEAM over time, especially after participation in training programs or professional interventions. Future research could also explore the effectiveness of different STEAM implementation strategies, such as projectbased learning (PjBL), problem-based learning (PBL), guided inquiry and cross-disciplinary collaboration, to identify best practices and optimize the impact of STEAM in the physics learning context. Most importantly, future research should directly measure the impact of STEAM integration on student learning outcomes in physics, including motivation, critical thinking skills and academic achievement. A mixed methods approach that combines quantitative data (e.g., achievement tests, surveys) and qualitative data (e.g., classroom observations, student interviews) can provide a deeper and more comprehensive understanding of the effectiveness of STEAM approaches in the context of physics education.

CONCLUSION

The results of a questionnaire to 23 high school physics teachers in Grobogan District showed a significant positive attitude towards the application of STEAM and SDGs in physics learning with the majority of teachers supporting the integration of the two approaches. However, the main challenge lies in the teachers' low understanding and readiness to apply these concepts effectively, as seen from the high level of doubt and uncertainty expressed in the questionnaire. Therefore, a comprehensive training program that focuses on improving understanding and practical strategies for STEAM and SDGs integration, as well as systemic support from schools and educational institutions are needed. With these measures, it is expected that the quality of physics learning can improve, while preparing students to face global challenges through innovative and sustainable approaches.

REFERENCES

Ardiansyah, R., Jailani, M. S., & Risnita. (2023). Data Collection Techniques and Educational Scientific Research Instruments in Qualitative and Quantitative Approaches. *IHSAN: Journal of Islamic Education*, 1(2), 1–9.

Arends, R. I. (2019). *Learning to Teach. In McGraw-Hill (9th ed., Vol. 11, Issue 1).* McGraw-Hill.

Arini, F. (2024). Encouraging Collaboration between Private Sector, Government, and Community through Crowdfuding to Improve Education Quality. *Educatus: Journal of Education*, 2(1), 1–6.

Ayu, R. S., Dewi, A., & Febrina, N. (2024). An Analysis of the Government's Role in Overcoming Education Disparities in the Special Region of Jakarta. *Educatus: Journal of Education,* 2, 1–14.

Azzahra, S. F., & Rahyasih, Y. (2024). Strategies for Improving the Quality of Human Resources through Digital Literacy Programs in Schools. *Pendekar: Journal of Character Education*,7 (2), pp. 64-70.

Badryatusyahryah, N.F., Winarsih, M., Kustandi, C., & Putro, P. A. (2022). Application of Gamification in Physics Education: A Systematic Literature Study. Kwangsan: *Journal of Educational Technology*,10 (2), 283. https://doi.org/10.31800/jtp.kw.v10n2.p283--301

Bybee, R. W. (2013). The Case for Education: STEM Challenges and Opportunities. *NSTA (National Science Teachers Assocation)*, 33-40. www.nsta.org/permissions.

Camelia, F. (2020). Analysis of the Foundations of Science and Technology in Curriculum Development. *SAP (Education Article Structure)*,5 (1). https://doi.org/10.30998/sap.v5i1.6474

Edo, A., & Yasin, M. (2024). The Impact of Educational Access Gaps and Family Economic Factors on Social Mobility. *Journal of Education & Social Sciences*, 2(3), 317–326.

Erwinsyah, A., Yusuf, F. M., & Gintulangi, S. (2022). Innovation in Natural Science Learning (Narrative Lirerature Review). *IRFANI: Journal of Islamic Education*,19 (2), 140-161. https://journal.iaingorontalo.ac.id/index.php/ir/article/view/2149

Fadilah, A. D., Adinda, N. T., & Rahman, I. F. (2024). Realizing Inclusive and Sustainable Education with Digital Literacy: The Role of Technology in the Era of Sdgs 2030. *Multidisciplinary Scientific Journal*, 1(5), 106–121.

Firdaus, F. A. (2024). Building Environmental Awareness Through Islamic Education Curriculum Contribution to SDGs. *TarbiyahMu Journal*, 4, 13–21.

Firdausi Nuzula, & Budi Jatmiko. (2023). Physics Learning with STEM-Based PBL Model to Improve Critical Thinking Skills of High School Students. *Student Scientific Creativity Journal*,1 (5), 311-323. https://doi.org/10.55606/sscj-amik.v1i5.2044

Firmansyah, A., & Jiwandono, N. R. (2022). Teachers' Tendency in Applying Student Center Learning and Teacher Center Learning Approaches in Learning. *Indonesian Teacher Journal*,2 (1), 33-39. https://doi.org/10.51817/jgi.v2i1.229

Handyka, M. A. (2023). Education Transformation: Innovative Strategies in Increasing Social Participation to Build an Inclusive and Competitive Society. *JECTH: Journal Economy, Technolo-*

gy, Social and Humanities Vol.1 No.1, May 2023, Vol.1 No.1(1), 1-9. https://jetch.id/index.php/jetch/article/view/11/10

Hartati, M., & Hariyono, E. (2020). Effectiveness of Physics Learning Integrated with Climate Action on Sustainable Development Goals Principles in Increasing Environmental Care Character. *IPF: Physics Education Innovation*,9 (3), 349-355. https://doi.org/10.26740/ipf.v9n3.p349-355

Hayat, M. S., Rita, E., & Dewi, S. (2024). Students' Creative Thinking Skills with STEAM-SDGs Approach to Energy Concept: Rasch Model Analysis. *Educatus: Journal of Education,* 10(12), 11152–11161. https://doi.org/10.29303/jppipa.v10i12.9532

Ministry of National Development Planning/Bappenas. (2020). *Technical Guidelines for Preparing Action Plans for Sustainable Development Goals (SDGs)*. Bappenas,53 (9), 21-25. http://www.elsevier.com/locate/scp

Kirana, A. N., Lestari, E. P., & Rachman, I. F. (2024). Improving Digital Literacy Through Government, Private Sector, and Community Collaboration: Contribution to the Achievement of SDGS 2030 in Education. *MERDEKA: Multidisciplinary Scientific Journal*, 1(5), 1–8.

Kiswanda, V., Aswirna, P., & Nurhasnah. (2021). Development of Stem-Based Physics E-Modules with Sustainable Development Principles for Science Literacy of Grade Xi Students. *Journal Cerdas Mahasiswa*, 62–75.

Kurniawan, Z. (2023). Competitiveness of Human Resources in the Era of Digitalization. *EBI Journal*,5 (2), 83-88. https://doi.org/10.52061/ebi.v5i2.182

Lestari, N. A., Jatmiko, B., Hariyono, E., & Prahani, B. K. (2024). STEAM in Physics Learning and Sustainable Development (U. A. Deta (ed.)).

Martiani, N. P., & Subali, B. (2024). Literature Review of STEM-Based E-LKPD Research Trend in Physics 2019-2024 in Indonesia. *Unnes Physics Education Journal*, 13(2).

Matitaputty, J. K., Ufie, A., Ima, W., & Pattipeilohy, P. (2022). Implementation of Education for Sustainable Development (Esd) through Ecopedagogy in Learning at Smp Negeri 8 Ambon. *Budimas: Journal of Community Service*,4 (1), 1-8. https://doi.org/10.29040/budimas.v4i1.3532

Meda, T. (2022). Potential Analysis of Education for Sustainable Development lesson plans in High School Physics Subject. *Ideguru: Journal of Teacher Scientific Work,*7(3), 344–352. https://doi.org/10.51169/ideguru.v7i3.446

Mu'minah, I. H. (2021). Literature Study: 21st Century Learning Through the Steam Approach (Science, Technology, Engineering, Art, and Mathematics) in Welcoming the Era of Society 5.0. *Proceedings of the National Seminar on Education*, 3, 584–594.

Mudaningrat, A., Marianti, A., Ellianawati, E., & Parmin, P. (2024). Development of STEAM-Based Belawa Tortoise Conservation E- Supplement to Improve Higher Order Thinking Skills in High School Ecosystem Material. *Unnes Science Education Journal*, 13(1), 39–47.

Muhammad Dimas Firmansyah. (2024). Transformation of Education Through Government, Private, and Community Collaboration for Digital Literacy for Sustainable Development 2030. *Multidisciplinary Scientific*, 1(4), 317–327.

Mulyani, T. (2019). STEM Learning Approach to face the Industry 4.0 Revolution. *National Postgraduate Seminar 2019*,7 (1), 455-460. https://proceeding.unnes.ac.id/index.php/snpasca/article/download/325/351

Noor, J. (2017). *Research methodology: thesis (Doctoral dissertation, thesis, dissertation, and scientific work) (7th ed.)*. KENCANA.

Nur, N., & Nugraha, M. S. (2023). Implementation of STEAM Learning Model in Improving the Creativity of Learners in RA Al-Manshuriyah Sukabumi City. *Arjuna Journal: Publication of Education, Language and Mathematics Sciences*,1 (5), 73-93. https://doi.org/10.61132/arjuna.v1i5.158

OECD. (2019). *PISA 2018 Results (Volume I) WHAT STUDENTS KNOW AND CAN DO. PISA*, OECD Publishing, Paris. https://doi.org/10.1787/5f07c754-en

Pahrijal, R., Priyana, Y., & Sukini. (2023). Essential Skills in the 21st Century: Education and Professional Success. *West Science Education Journal*, 01(09), 583–589.

Pramudyani, A. V. R., & Indratno, T. K. (2021). Improving teachers' professional competence in implementing STEAM in PAUD. *Proceedings of the National Seminar on Community Service Results UAD*, 1073–1081.

Putra, B. R., & Ellianawati. (2024). Development of STEAM-Based E-Modules (Science, Technology, Engineering, Art, and Mathematics) on Energy Source Materials to Support Participants' Character Development. *Unnes Physics Education Journal*, 3(3), 77–83.

Rahmania, R., & Hudri, M. (2024). Enhancing Student Engagement through Educational Technology: A Systematic Review. 4, 1–13.

Sari, F., & Riansi, E. S. (2024). The Role of Stakeholders in Overcoming Education Inequality in Remote Areas: Challenges and Solutions. P*endas: Scientific Journal of Basic Education*, .09

Sugiyono. (2020). *Quantitative, Qualitative, and Combination Research Methods (Mixed Methods).* Bandung : Alfabeta.

Sugiyono. (2023). *Quantitative, Qualitative, and R&D Research Methods*. Bandung Alfabeta.

Suharni, Sulistiawati, I., & Irawan, N. (2024). Analysis of STEAM Learning Model as a Strategy for Developing Algebraic Numeration in Junior High School. *Bima Journal of Elementary Education*, 2(1), 7–15.

Sujarwanto, E., Madlazim, & Ibrahim, M. (2019). Attitude, Knowledge, and Application of STEM

Owned by Science Teachers. *Journal of Physics: Conference Series*, 1417 (1). https://doi.org/10.1088/1742-6596/1417/1/012096

Sukaesih, S. (2023). Realizing a Smart, Competitive and Characterful Generation in the 21st Century through Biology Education and Sustainable Research Innovation. *Proceedings of the XI National Biology Seminar*, 11, 16–22.

Susianita, R. A., & Riani, L. P. (2024). Education as the Main Key in Preparing the Young Generation to the World of Work in the Era of Globalization. *Proceedings of Economic Education,* 1–12.

Syahrial, A. (2024). Analysis of Steam-Integrated Physics Learning to Train Students' 21st Century Skills and Science Process Skills in the Implementation of the Merdeka Curriculum. *A Review*. 6(4).

Tahmid, Syaiful, M., & Nurkhoiri. (2024). Improving Science Literacy and Critical Thinking through ESD at SMPN 2 Bojong. *Diklabio: Journal of Biology Education and Learning*, 8(2), 235–245.

Vioreza, N., Hilyati, W., & Lasminingsih, M. (2023). Education for Sustainable Development: What is the Urgency and Opportunities for Implementation in the Independent Curriculum? *EUREKA: Journal of Educational Research and Practice,*1 (1), 34-47. https://doi.org/10.56773/eureka.v1i1.

Widarti, R., & Roshayanti, F. (2021). Potential Implementation of STEAM (Science, Technology, Engineering, Art and Mathematic) oriented ESD (Education for Sustainable Development) in Fluid Learning. *Unnes Physics Education Journal*, 10(3), 291–295.