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Training on Creating Simple Renewable Energy Projects Based on STEM -SDGs (Sustainable Development Goals) to Introduce SDG-Based Education

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Abstract

Energy is an important component in human life that is currently feared to be experiencing a shortage. This is because the main energy source used is fossil energy sources, which are limited and not environmentally friendly. This Community Service aims to introduce SDG-based education on the SDG's topic of using renewable energy sources to foster students' understanding and awareness of sustainable energy practices. This Community Service activity uses an Asset-Based Community Development (ABCD) approach, which focuses on identifying and utilizing the strengths and resources of the community and region, especially Samarinda, to support the integration of renewable energy education. This community service was carried out at State High School 4 Samarinda. The participants were all students from one of the classes who had or were taking subjects on renewable energy sources. The number of students who took part in this activity was 30 students. Data was obtained through project testing and questionnaires, which were distributed after the activities had been completed. The questionnaire consists of 10 questions, 8 of which are open questions. All groups succeeded in creating projects, and 86% of students responded positively to the SDGs. These results indicate that this educational activity has achieved its objectives regarding student understanding and awareness.

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INTRODUCTION

Energy is a crucial element needed by humans across various sectors and purposes. Humans use energy to survive, innovate, manage various activities, and maintain a comfortable life (Millward-Hopkins et al., 2020). The energy crisis has recently become an urgent national and global issue. Indonesia is predicted to face an energy crisis by 2051 (Wardana et al., 2022).

This energy crisis is caused by humans' dependency on non-renewable energy sources, particularly fossil fuels. Fossil energy has several advantages compared to other renewable and environmentally friendly energy sources, such as being practical, easy to obtain, and inexpensive (Cong, 2022). However, the dominance of fossil energy usage has led to an increased demand for energy, which in turn has rapidly escalated carbon dioxide emissions (Majid et al., 2018). Fossil energy usage contributes approximately 87% of carbon dioxide gas emissions produced by human activities (Zimon et al., 2023).

Scientists have developed many alternative energy sources suitable for use in Indonesia. Solar energy is one of the most promising sources (Nugraha, 2020). Solar energy is the most abundant renewable energy source, generating significantly lower CO_2 emissions (Neelakandan et al., 2021). However, society is still not accustomed to using solar energy daily (Askar & Imaduddin, 2023). Various training programs in the form of community service have introduced solar panel construction as an energy source, including those conducted by Rahayu (2019), Rahmawan et al. (2022), and Santoso et al. (2022).

One of the best steps to address this issue is to educate the public or future generations—students—so they become accustomed to using renewable energy sources. To educate students, they must understand the background of the problem they will face. Linking energy issues with the Sustainable Development Goals (SDGs) is highly relevant in this context.

SDGs, or Sustainable Development Goals, are a set of global objectives designed by the United Nations to achieve a better life on this planet (Setiadi et al., 2020). Energy issues relate to several SDG goals, including Affordable and Clean Energy, Climate Action, Quality Education, Industry, Innovation, and Infrastructure.

To educate students on the importance of using renewable and environmentally friendly energy sources, they must practice and actively participate in learning. Learning methods play a critical role in determining the effectiveness of the educational process (Hakim et al., 2023). One framework that is highly suitable for this purpose is the STEM (Science, Technology, Engineering, and Mathematics) framework.

The STEM framework in education allows students to study a problem from four perspectives: science, technology, engineering, and mathematics (Riyanto et al., 2021). This framework also enables students to learn and solve major challenges through small steps actively. Integrating all four components of STEM to address problems can raise students' awareness and provide opportunities for collaboration and teamwork (Mutmainah et al., 2022). In this case, project-based learning is an appropriate teaching method, where students are tasked with creating simple projects to address energy crisis issues. Integrating the STEM framework with project-based learning can enhance students' science process skills and their experience in understanding complex concepts (Lisa & Efwinda, 2024).

Based on discussions with the partners of the community service activity (PKM), namely physics teachers and students at SMA Negeri 4 Samarinda, it was identified that physics learning activities had not yet integrated SDG issues, such as SDG No. 7 on affordable and clean energy and SDG No. 13 on climate action. These two SDGs relate to global warming in the Grade 10 curriculum. An agreement with the PKM partners was then made to conduct Renewable Energy Education through Simple Project Training based on STEM-SDGs. Many PKM activities on STEM have been successfully carried out to achieve the desired goals, such as those conducted by (Ismail et al., 2023), (Sulaeman et al., 2023), dan (Efwinda et al., 2021).

Therefore, by implementing Renewable Energy Education through Simple Project Training based on STEM-SDGs, students are expected to design solutions to energy crisis issues. Additionally, it is hoped that students will gain a better understanding and awareness of the importance of optimizing renewable and environmentally friendly energy sources.

METHODS

This training on simple project creation aims to introduce SDG-based education to students, preparing them to use renewable and environmentally friendly energy sources in

the future. These students are expected to grow into environmentally responsible individuals who can ensure sustainable life, particularly in the energy sector. The success of this training will be evaluated through the projects created by students and their responses to questionnaires distributed after the training. The projects are expected to demonstrate the ability to light an LED, store energy, and distribute it automatically, alongside students' positive responses to SDGs.

The community service activity (PKM) employs the ABCD method. The ABCD implementation begins with mapping community assets, including the potential for renewable energy in Samarinda and the potential of high school students as the future generation who play an essential role in achieving SDGs in their environment. After asset mapping, the activity proceeds with stakeholder collaboration involving schools, teachers, and students. Discussions among stakeholders agreed that students should be trained to create simple projects based on STEM-SDGs. The goal is to encourage active student participation in understanding and applying SDG concepts within the context of renewable energy. The final phase involves evaluation and follow-up activities to implement the training results in a broader community.

The training was attended by 30 students in one SMA Negeri 4 Samarinda class, comprising 18 male students and 12 female students. The selected class had already studied or was currently studying the Physics topic on renewable energy sources.

The training was conducted from May 8 to May 15, 2024, with direct mentoring from the PKM team provided during the initial and final sessions held at SMA Negeri 4 Samarinda.

In the Initial Session (May 8, 2024), the students were given an overview of the project and explanations about SDGs. Afterward, they were grouped to work on designs and initial components needed for the project. The students were given one week to continue their projects at home. Related to project duration, each group met outside of class approximately twice, each lasting 2 to 3 hours. In the final session (May 15, 2024), all groups had the opportunity to test and present their projects. The project's success criterion was to light an LED using a mini solar panel energy source.

The response questionnaire was distributed to students after the activity concluded. It consisted of 10 questions, two closed-ended and eight open-ended. These questions varied, covering topics such as students' familiarity with the SDGs (questions 1, 2, and 3), their interest in SDG-related topics (questions 4 and 5), the inclusion of SDG topics in school lessons (questions 6, 7, 8, and 9), and their curiosity about SDG topics (question 10).

Questions 1 and 4 were closed-ended. Question 1 asked whether students had previously heard about the SDGs, with response options being "Yes" or "No." Question 4 measured students' interest in learning about SDG topics, with response options ranging from "Not Interested," "Somewhat Interested," "Interested," to "Very Interested."

The data analysis technique calculated the percentage of student responses for each category. The data interpretation focused on identifying trends, analyzing the least and most frequently chosen answers, and drawing conclusions.

RESULTS AND DISCUSSION

The energy crisis has continuously driven humanity to seek renewable and environmentally friendly alternative energy sources. One such renewable energy source suitable for use in Indonesia is solar energy. However, Indonesian society is still unfamiliar with the application of solar energy in daily life. One solution to this issue is conducting educational training on simple projects based on STEM-SDGs.

The simple STEM-SDG-based project introduced during the training was a solar panel utilization project. This project aligns with SDG No. 7, focusing on clean and renewable energy. The components of Science, Technology, Engineering, and Mathematics (STEM) included in the project were:

1. Science: Related to the phenomena of global warming and the use of renewable energy.
2. Technology: Introducing students to the application of solar panel technology.
3. Engineering: Teaching students to design a simple project utilizing solar panels.
4. Mathematics: Teaching students to compare electricity cost estimates between fossil energy sources (PLN) and renewable energy sources (solar panels).

The training was attended by 30 students from an SMA Negeri 4 Samarinda class. The educational activity started on May 8, 2024, and included preparation, distribution of materials and tools, and construction of initial project frameworks. Experts in the field of SDGs led the preparation phase. Figure 1 presents one of the training documentation images.

Figure 1 preparation by experts

The distribution of tools and materials, as well as the training for project creation, was conducted by the experts and their assistants. During this process, students were tasked with designing a model or miniature solar panel system capable of generating electricity, storing it, and distributing it automatically using the provided tools and materials. The creation of the miniatures was left entirely to the student's creativity, while the assembly of the solar panel circuits was supervised to prevent any unwanted accidents. Documentation of the project-making activity by participants is presented in Figure 2.

Figure 2 project creation by participants

The first day of training concluded with varying progress among the groups. The project was given a one-week deadline, allowing students to continue working on it at home. At the final meeting, each group collected, tested collectively, and presented the projects. Figure 3 documents the project testing process.

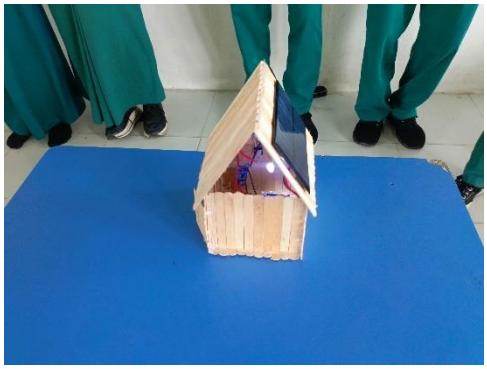

Figure 3 Project testing

The results of the project testing showed that all groups successfully created functional models or miniatures that met the success criteria. The LED lights worked in dark environments, and the solar panels could charge rechargeable batteries.

After the project testing phase, students were asked to present the projects they had created with their respective groups. Figure 4 documents a group presentation activity.

Figure 4 Group presentations

The group presentations proceeded smoothly, with all members collaborating effectively on the project creation and the presentation. Students showed varying enthusiasm during the presentations; the majority were interested, while a minority showed less interest in presenting their projects.

After completing the activities, students were given a response questionnaire. The purpose of the questionnaire was to determine their interest in SDG-related topics.

The questionnaire comprised 10 questions, including two closed-ended and 8 open-ended questions. The first question was closed-ended, asking whether students had heard of the term SDGs before. The results of the student's responses to this question are presented in Table 1.

Table 1 Percentage of student responses to question 1

Response	Number of Students
Yes	38%
No	62%

Table 1 shows that 38% of students had previously heard of the term SDGs, while 62% had never heard of it. This indicates that SDG education has not yet been evenly disseminated at the high school level.

The second closed-ended question, Question 4, asked whether students were interested in learning about SDG-related topics. Table 2 presents the students' responses to this question.

Table 2 Percentage of students' answers to question 4

Response	Number of Students
Not Interested	14%
Somewhat Interested	45%
Interested	34%
Very Interested	7%

Table 2 shows that 14% of students are not interested in learning about SDGs topics, 45% are somewhat interested, 34% are interested, and 7% are very interested. The main reason students lack interest in learning about SDGs topics is their perception that these topics are difficult to understand since they have never encountered them before. On the other hand, students' interest in learning about SDGs is mainly due to their relevance to everyday life, making it enjoyable to connect learning materials with real-life situations or phenomena.

The first open-ended question, Question 2, asked what students know about SDGs. Based on the responses, most students were unaware of SDGs. However, some students were able to answer the question. One example is the response from CG-9: *"Sustainable Development Goals (SDGs) are 17 global goals formulated by the United Nations in 2015 to be achieved by 2030. These goals focus on sustainable development."*
Question 3 is another open-ended question that asked where students gained knowledge about SDGs. The responses to Question 3 are shown in Table 3:

Table 3 Percentage of students' answers to question 3

Source	Number of Students
Social Media	31%
School Environment	31%
Never Heard of SDGs	28%
Others	10%

Table 3 indicates that 31% of students gained knowledge about SDGs through social media, another 31% from their school environment, 28% had never heard of SDGs, and 10% obtained knowledge through other sources, such as the Internet.

These results show that schools are not yet the primary source for students to gain knowledge about SDG-based education. Therefore, teachers' knowledge of SDGs should be applied in school learning activities to educate students about sustainability.

Question 5 asked about the reasons for students' interest in learning about SDG topics, which relates to the previous question (Question 4). This open-ended question allowed students to provide their answers. Some interested students responded in detail, such as CG-20.
"Because it helps me understand current global challenges and provides better information to users about efforts to achieve them."

However, some students not interested in learning about SDG topics responded briefly, expressing indifference.

Question 6 was an open-ended question regarding students' opinions on the subjects and topics they had studied in elementary, junior high, and high school that discussed SDG-related topics. Student responses to this question varied, with some of the subjects mentioned being science, physics, biology, chemistry, mathematics, civics, economics, sociology, geography, social studies, and Indonesian language. There were also responses where students did not mention specific subjects but referred to activities conducted in

schools implementing the "Merdeka Curriculum," such as the "Strengthening Pancasila Student Profile" project (P5).

Question 7 was another open-ended question about students' opinions on appropriate learning methods for teaching SDG topics. Responses to this question were also diverse, with most students favouring learning through practice or projects, as stated by CG-10:
"Involving students in real-life projects related to the Sustainable Development Goals (SDGs) allows them to understand the concepts more deeply and experience the impact directly."

Other students preferred learning using engaging media, such as instructional videos or PowerPoint presentations. Some students, however, desired simple learning methods where teachers explain the material clearly with examples.

Question 8 was an open-ended question about students' opinions on the advantages of integrating SDGs into science/physics/biology/chemistry lessons. Responses varied, but 34% of students did not know the advantages of integrating SDGs into these lessons. On the other hand, some students provided detailed responses, such as CG-29:
"1. Integration Across Subjects: Integrating SDGs into science/physics/chemistry/biology lessons allows students to see connections between various aspects of sustainability, such as the environment, natural resources, energy, and health. This helps students understand the complexity of global challenges holistically.
2. Development of Critical Thinking Skills: Through learning about SDGs in the context of science/physics/chemistry/biology, students are encouraged to develop critical and analytical thinking skills in exploring solutions for complex global problems."

Question 9 was an open-ended question about students' opinions on the drawbacks of integrating SDGs into science/physics/chemistry/biology lessons. As with Question 8, some students did not know the drawbacks of this integration; however, the percentage of such students was higher at around 45%. On the other hand, some students provided complex answers, such as CG-21:
"In my opinion, the drawbacks are that it takes a very long time because nature cannot regenerate instantly, which can be exploited by irresponsible individuals. It requires high awareness and action from the community to be implemented effectively. Unequal education results in some people not knowing how to implement SDGs properly or even being unaware of what SDGs are."

Question 10 was an open-ended question about what students wanted to learn more deeply regarding SDG-based education. A small number of students did not know what they wanted to learn about SDGs. In contrast, other students gave varied responses, ranging from the benefits of studying SDGs, effective methods, integration with the curriculum, global news on SDGs, and more.

From the overall responses provided by all students, this activity successfully increased students' knowledge and interest in energy crisis issues and SDGs. This is evident from the 86% of students who showed interest in learning about SDG topics.

Community service activities that train students to actively explore knowledge by creating projects need to be continuously encouraged, as they receive positive feedback from students. This applies not only to this particular community service activity but also to other examples, such as those conducted by Dewi et al. (2023), which trained students in creating science learning media from recycled materials, and by Efwinda et al, (2022), which trained students in creating digital posters on the theme of global warming.

After obtaining the results of the PKM (Community Service Program) activities, an evaluation of the PKM activities was conducted. The evaluation showed that the PKM activities successfully achieved the goal of introducing the concept of SDGs to students, particularly on the topic of renewable energy. A majority of the students expressed

interest in learning about SDG topics. This training activity also successfully equipped students with the skills to create simple projects using solar panels. Most groups successfully created projects where LED lights were powered by solar energy.

The limitation of the PKM activities was that the training was conducted with a limited number of students. Thus, similar training activities, including STEM-SDGs training for teachers, especially science teachers, need to be implemented more widely in the future.

CONCLUSION

Based on the results and discussion, this educational activity successfully achieved its goals of introducing SDG-based education to students regarding the use of renewable energy. This success can be seen in the ability of all groups to create relevant projects and in the increased awareness among students about the importance of using renewable energy sources, as reflected in their expressed interest in SDGs.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

"Conceptualization, SE, MS, and AH; methodology, M and YO; formal analysis, M and SE; writing—preparation of the original draft, M; Reviewed and edited the manuscript, providing significant input to enhance clarity and precision: SE, MS, and AH; All authors have reviewed and approved the final version of the manuscript.

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