JPPIPA 9(12) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Engineering Design Process (EDP) Strategy Integrated PjBL-STEM in Learning Program: Need Analysis to Stimulate Numeracy Literacy Skills on Renewable Energy Topic

Sofhia Chairunnisya[1], Abdurrahman[1*], I Wayan Distrik[1], Kartini Herlina[1], Undang Rosidin[1], Ghani Fadhil Rabbani[1]

[1] Postgraduate Program, Master of Physics Education, University of Lampung, Lampung, Indonesia.

Received: October 8, 2023
Revised: November 12, 2023
Accepted: December 20, 2023
Published: December 31, 2023

Corresponding Author:
Abdurrahman
abeunila@gmail.com

DOI: 10.29303/jppipa.v9i12.6088

Abstract: This research constitutes a preliminary study aimed at determining the needs of teachers and students in the learning process, particularly in the context of physics subjects related to renewable energy. The chosen research method is a survey, conducted among 27 physics teachers and 59 high school students in MIPA field in Lampung Province using Google Forms. The collected data is then curated and analyzed to identify and address these educational needs. The results of the data analysis reveal a demand for learning programs that can enhance students' numeracy and literacy skills during the learning process. According to the survey, only 43% of teachers and 24% of high school students majoring in Mathematics and Natural Sciences are aware of the Sustainable Development Goals (SDGs). This aligns with the finding that only 40% of teachers have integrated PjBL-STEM into their learning programs. The worksheets lack activities that can stimulate students' numeracy and literacy skills, thereby impeding their active engagement in renewable energy learning. These findings are further corroborated by student questionnaires, which indicate that 55% of students feel they face limitations in understanding materials related to renewable energy. Additionally, 85% of physics teachers express concerns about students' difficulties in grasping the concept of renewable energy. Consequently, the development of an integrated renewable energy learning program incorporating PjBL-STEM becomes imperative.

Keywords: Engineering design process strategy; Learning program; Numeracy literacy skills; PjBL–STEM; Renewable energy

Introduction

Education is essential to equip students with the competence and global competitiveness required for adapting to the developments of the 21st century. Efforts aimed at fostering 21st-century skills include enhancing the quality of 21st-century learning, one of which involves the development of learning programs. In the 21st century, students are expected to possess the 4C skills, which comprise critical thinking, communication, creative thinking, and collaboration. These skills enhance tolerance for diversity, improve critical thinking abilities, foster creativity in problem-solving, and facilitate the application of theoretical knowledge to real-life situations (Jayadi et al., 2020; Marouli, 2021). These skills are not just about individual preparation but also about preparing society to face future challenges. Education that prioritizes the development of 21st-century skills helps create individuals who are not only academically competent but also ready to face the complexities of the modern world (Howard et al., 2019).

The 4C skills are closely related to numeracy literacy skills. Numeracy literacy refers to a person's ability to analyze and understand statements conveyed through the manipulation of symbols or language encountered in everyday life, as well as the ability to

How to Cite:
Chairunnisya, S., Abdurrahman, Distrik, I. W., Herlina, K., Rosidin, U., & Rabbani, G. F. (2023). Engineering Design Process (EDP) Strategy Integrated PjBL-STEM in Learning Program: Need Analysis to Stimulate Numeracy Literacy Skills on Renewable Energy Topic. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11197–11206. https://doi.org/10.29303/jppipa.v9i12.6088

express those statements in writing or text (Grahito Wicaksono, 2020; Zakiyah & Ramli, 2023). Numeracy literacy is demonstrated by the practical use of mathematical skills to meet the demands of life, as well as the appreciation and understanding of mathematically expressed information, such as graphs, charts, and tables. In the era of the Fourth Industrial Revolution, scientific literacy skills are crucial for prospective teacher students to master. Scientific literacy enhances one's way of thinking, fostering an understanding of science that enables individuals to address problems in various aspects of life (Lozano et al., 2022). Improving numeracy literacy skills is one of the primary learning objectives. Through literacy, students can analyze current scientific issues, including challenges faced by Indonesia in the energy sector, where the country still relies on non-renewable energy sources. This improvement is observed through indicators measuring scientific literacy in dimensions such as scientific context, scientific knowledge, and scientific compatibility (Kurent & Avsec, 2023; Paristiowati et al., 2022).

The integration of renewable energy materials into school curricula is an effort to address Indonesia's energy availability issues, aligned with the goals of Education for Sustainable Development (ESD). udESD can raise students' awareness. It is expected that students will find renewable energy concepts easier to grasp when connected to their immediate environment. This underscores the need for an appropriate learning model, and Project-Based Learning (PjBL) is a science learning model that can meet these requirements. This aligns with the findings of that PjBL provides students with opportunities to explore topics, issues, and problems without disciplinary barriers, making it applicable to all subjects (Wahdah et al., 2023).

The PjBL learning model can be integrated with the STEM Engineering Design Process strategy. Learner-centered STEM teaching not only enables investigative, action-adapted learning but also fosters independent learners who respond to their natural environment (Campbell & Speldewinde, 2022). The results of data analysis reveal a significant improvement in students' scientific literacy abilities after the learning process. Each indicator of students' scientific literacy was developed through a STEM approach (Lestari et al., 2021; Wahyu et al., 2023). Advancements in Science, Technology, Engineering, and Mathematics (STEM), and corresponding industries can be seen as vital for the success of achieving a majority of the sustainable development goals. Hence, the approaches taken to embed sustainability in learning and teaching in STEM higher education programs can be considered significant in many ways (Gamage et al., 2022). The use of PjBL in physics learning can foster the critical and creative development of students' problem-solving abilities through verbal and written communication (Mairizwan et al., 2022). Moreover, Students' participation in the project has made them aware of the community implications of maintaining the environment and generating benefits for the whole community (Martín-Sánchez et al., 2022).

PjBL-STEM combined with the engineering design process is described as an educational system that embeds mathematical knowledge in the context of design technology, creating a problem-solving learning environment in which students envision design solutions, gather information, and tackle real-world problems (Wahono et al., 2020). Other research results show that students who are taught using STEM-integrated PjBL learning are already environmentally literate, they can apply concepts or facts acquired from natural phenomena in their daily lives. Proficient environmental literacy skills indicate that students possess awareness and concern for the environment, leading them to place a greater emphasis on real-world problems encountered in everyday life. (Ginting et al., 2023; Rasmi et al., 2023).

This approach aligns with the research conducted by (Putra et al., 2023), indicating that EDP can engage students in real-world problem-solving activities designed in an engineering-like manner. Physics learning with STEM-PBL integrated EDP in the context of ESD has been shown to be effective in improving the systems thinking ability of high school students in renewable energy units (Abdurrahman et al., 2023). However, it's worth noting that the use of EDP in learning is not yet widely adopted in Indonesia, particularly in the context of renewable energy materials.

In light of the information above, and to meet the evolving needs of education, the author has conducted research on the development of a Renewable Energy Learning Program with an Integrated PjBL-STEM Engineering Design Process (EDP) Strategy to Enhance Numeracy Literacy Skills among learners.

Method

This study represents preliminary research with the aim of determining the needs of teachers and students in the learning process, particularly in the context of physics subjects related to renewable energy. The chosen research method involved a survey conducted among 27 physics teachers and 59 high school students in the Mathematics and Natural Sciences field in Lampung Province, using Google Forms. The collected data was then curated and analyzed to identify and address these educational needs. The results of the data analysis indicate a demand for learning programs that can enhance students' numeracy and literacy skills during the learning process. Two different questionnaires was used in this reasearch to investigate the how EDP strategy integrated PjBL-STEM in learning program stimulate creative problem solving skills. The questionnaire consists of 43 questions for teachers and 40 questions for students. It includes inquiries about personal background information, teaching aids, and learning processes within learning programs that utilize engineering design process (EDP) strategies to enhance students' numeracy and literacy skills. Additionally, the questionnaire aims to align learning objectives with the Sustainable Development Goals (SDGs). Each aspect contains open-ended question that allow diverse perspectives from respondents. Questionnaires were distributed randomly to high school physics teachers and high school students majoring in MIPA during specific time periods. The collected data is then curated and analyzed to identify and address these educational needs.

Result and Discussion

This preliminary study is a descriptive research aimed at determining the needs of teachers and students regarding learning programs on integrated renewable energy topics within the context of PjBL-STEM. The research was conducted by giving questionnaires to teachers and students using the Enginnering Design Process Strategy. This preliminary research presents an investigation into the needs and perceptions of renewable energy in learning program among 59 high school students and 27 physics teachers in Lampung Province.

The analysis we conducted aimed to determine the needs of teachers and students by examining the number of completed questionnaires. The information gathered from the questionnaires, relating to knowledge of the Sustainable Development Goals (SDG's) within the field of education, is presented in the diagram below.

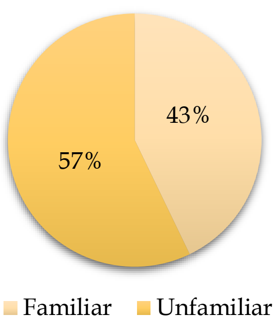

Figure 1. Diagram of the understanding of the SDG's objectives as gathered from teacher's questionnaire

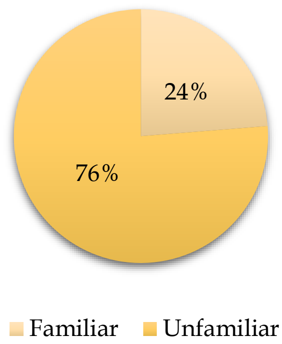

Figure 2. Diagram of the understanding of the SDG's objectives as gathered from student's questionnaire

Figure 1 illustrates that 57% of teachers were unfamiliar with the existence of the SDG's. Similarly, Figure 2 also reveals that 76% students lack awareness of the Sustainable Development Goals (SDGs) related to the education sector. Through surveys with respondents, it became evident that a significant portion of the respondent population is not well informed with these global goals. The information gathered from the questionnaires, relating to the use of PjBL in the learning process, is presented in the diagram below.

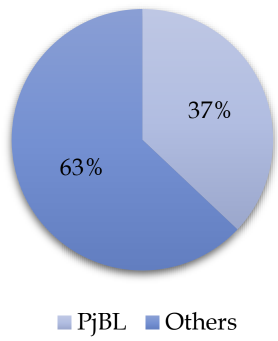

Figure 3. Diagram of the use of PjBL in the learning program as gathered from teacher's questionnaire

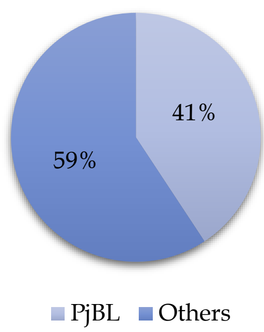

Figure 4. Diagram of the use of PjBL in the learning program as gathered from student's questionnaire

Unfortunately, the data shown in Figure 3 shows that only 37% of teachers use the PjBL learning model in the learning process. The same thing is shown in Figure 4. Students stated that only 41% of their teachers used the PjBL learning model in teaching renewable energy material. The low use of the PJBL learning model is due to limited school facilities, such as teaching aids and internet networks. Additionally, it is attributed to the challenges in creating engaging teaching materials that can atively involve students in the learning process. Student worksheets are among the teaching materials that can be employed. Data regarding the use of worksheets is presented in the diagram below.

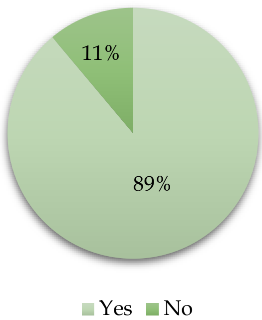

Figure 5. Diagram of the use of worksheet in the learning process as gathered from teacher's questionnaire

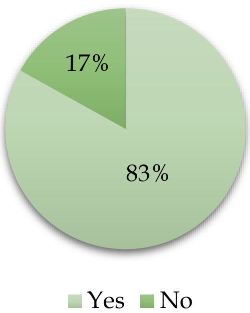

Figure 6. Diagram of the use of worksheet in the learning process as gathered from student's questionnaire

Figure 5 and Figure 6 show that the majority of physics teacher have used worksheets in the learning process to teach renewable energy material. However, the important consideration is the effectivity of using these workshehets in meeting student's needs and achieving learning goals.

Renewable energy materials often require a conceptual understanding, which frequently involves numerical calculations related to data on energy availability, energy demand, and energy efficiency. By being numerate, students can better grasp and apply these concepts, enabling them to actively engage in creating solutions to energy problems. Therefore, it is important to create worksheets that can stimulate students' numeracy literacy skills when teaching renewable energy concepts. Data regarding the use of worksheets that can stimulate students' numeracy literacy skills is presented in the diagram below.

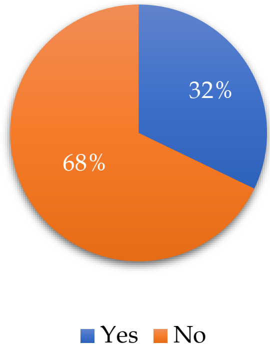

Figure 7. Diagram of the effectiveness of worksheets in learning program to stimulate students' numeracy literacy skills as gathered from student's questionnaire

Figure 7 shows that the worksheets used by teachers in teaching renewable energy materials have not successfully stimulated students' numeracy literacy skills.

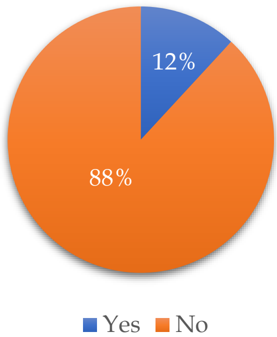

Figure 8. Diagram of the effectiveness of worksheets in learning program to stimulate students' numeracy literacy skills as gathered from student's questionnaire

The same result is demonstrated in Figure 8, where 88% of students feel that they cannot perform numeracy literacy well after using the provided worksheets. Students' numeracy and literacy skills are assessed based on their ability to apply various mathematical symbols and numerical concepts to solve problems related to energy availability. This includes the capacity to analyze information presented in formats such as charts, graphs, and tables and then interpret the results of the analysis to make predictions and informed decisions. The following data shows students' responses in understanding the concept as shown in the graph below.

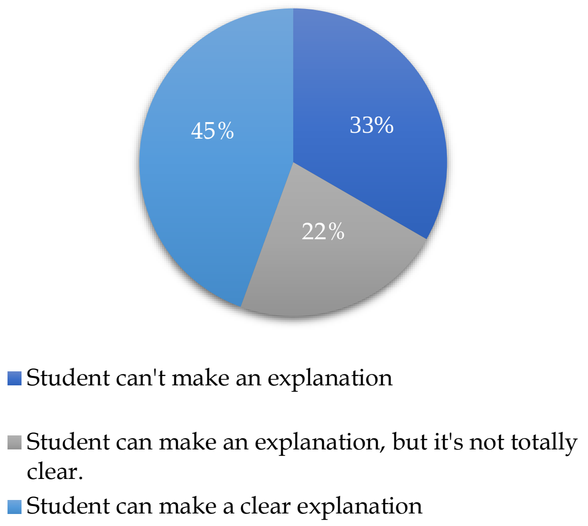

Figure 9. Diagram of understanding the renewable energy concept as gathered from teacher's questionnaire

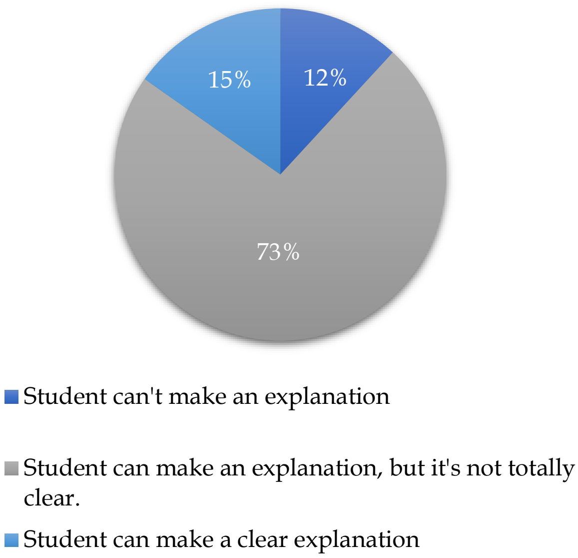

Figure 10. Diagram of understanding the renewable energy concept as gathered from student's questionnaire

After progressing through various learning stages in the alternative energy program provided by the teacher, Figure 9 reveals that 55% of students encountered difficulties in explaining the renewable energy material they were studying. The teacher's assessment, illustrated in Figure 10, concurs with this finding, indicating that 85% of students struggle to grasp the concept effectively. In addition, the following data shows student's ability in formulating solutions as shown in the graph below.

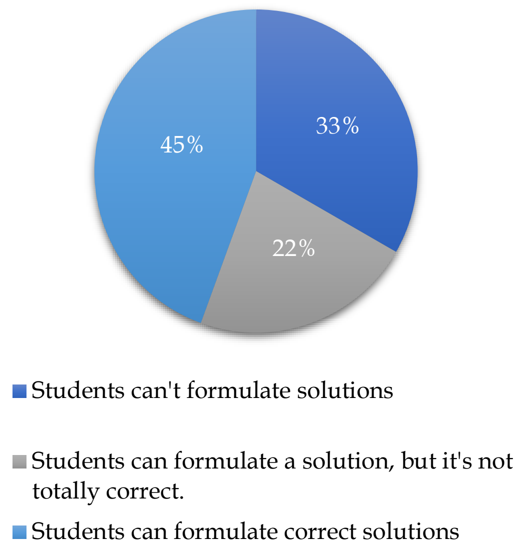

Figure 11. Diagram of formulating solutions as gathered from teacher's questionnaire.

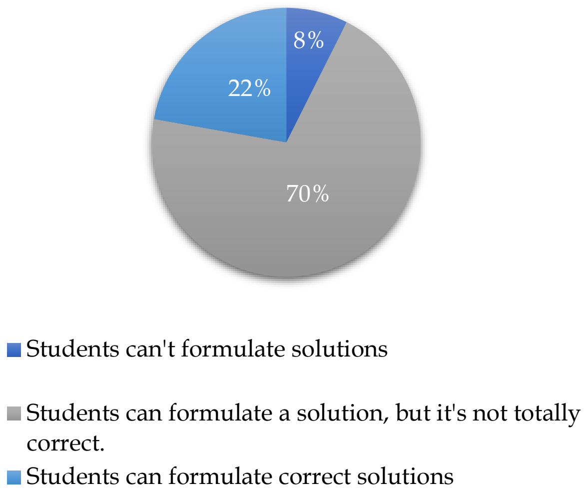

Figure 12. Diagram of formulating solutions as gathered from student's questionnaire

Figure 11 depicts that only 45% of students successfully formulated solutions to address energy needs using renewable energy materials, while another 22% attempted to formulate solutions but encountered errors. Similarly, Figure 12 also reveals that only 22% of students successfully formulated solutions, while another 78% encountered difficulties in formulating correct solutions. These findings are consistent, emphasizing that a majority of students have not yet mastered the correct formulation of solutions. After formulating a solution, students are expected to implement it. The graph below illustrates data on students' ability to put their formulated solutions into practice.

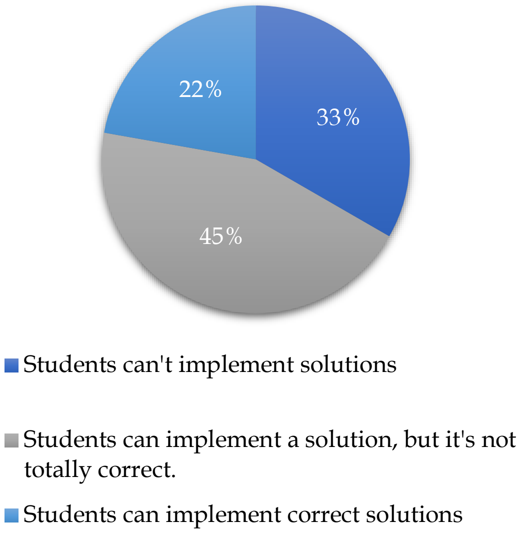

Figure 13. Diagram of implementing solutions as gathered from teacher's questionnaire.

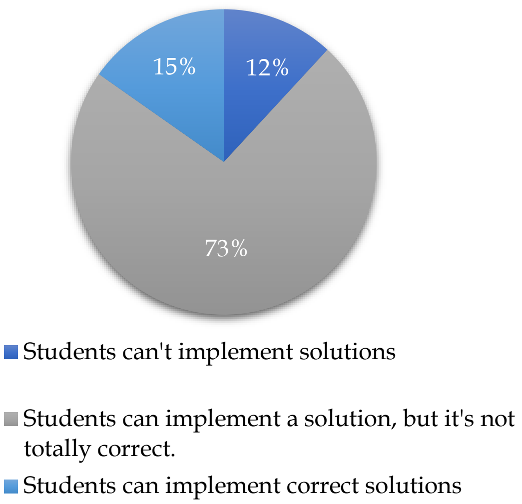

Figure 14. Diagram of implementing solutions as gathered from student's questionnaire.

Figure 13 illustrates that only 22% of students were able to successfully implement the solution derived from their previously formulated solutions. This may occur due to the inapplicability of the created solution formulation or its complexity, leaving students feeling unsure about the implementation process due to a lack of understanding. Similarly, Figure 14 reveals that only 15% of students managed to correctly implement the solution. Following the implementation, a crucial step is to review the solution, analyzing its advantages and disadvantages. This process allows for improvements to be made, enhancing the overall quality of the solution. The data from the review of the created solutions is presented in the graph below.

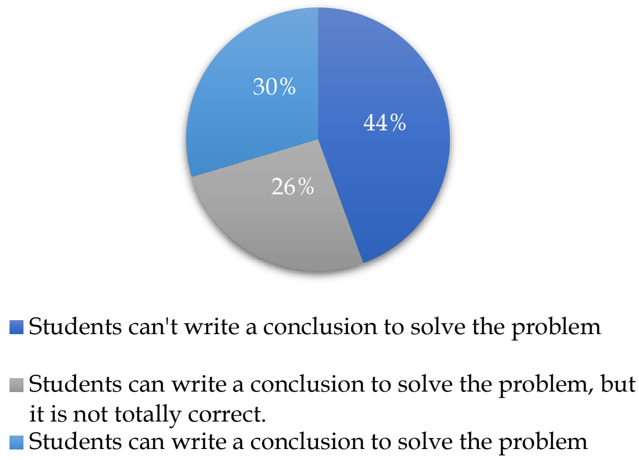

Figure 15. Diagram of reviewing solutions as gathered from teacher's questionnaire

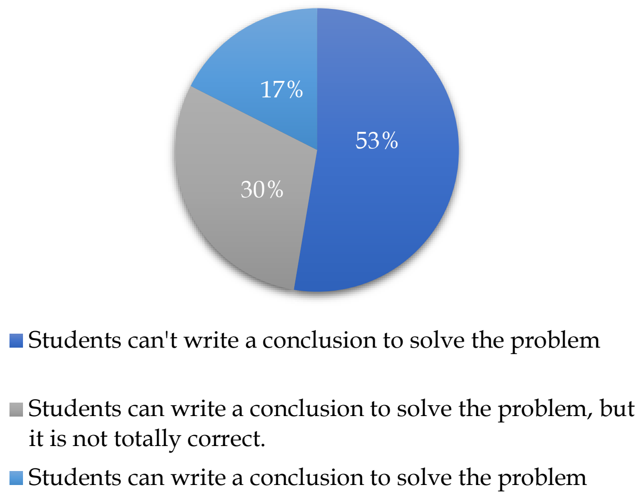

Figure 16. Diagram of reviewing solutions as gathered from student's questionnaire

Figure 15 shows that 44% of students could not formulate conclusions to address energy demand problems in renewable energy material. Similarly, Figure 16 reveals that 53% of students struggle to comprehend renewable energy material as a whole. Questionnaire results revealed that the primary reason for their lack of knowledge was a limited understanding of its significance. Addressing these challenges requires a comprehensive approach that involves curriculum reform, innovative teaching strategies, integrating technology judiciously, fostering a positive attitude towards mathematics, emphasizing real-world applications, and ensuring adequate resources and support. By addressing these factors, educators and policymakers can contribute to reversing the trend and promoting a culture of numeracy literacy proficiency among students. Numeracy literacy acquired through learning programs will provide students with the ability to actively participate in renewable energy projects, design sustainable policies, and contribute to increasing resource efficiency. (Ningrum et al., 2023; Rahmah et al., 2022). Renewable energy material often involves complex mathematical concepts, such as energy efficiency calculations, data analysis, and mathematical modeling. The learning program will equip learners with these skills to overcome complex challenges in the field of renewable energy (Bellini et al., 2019; Nurjumiati et al., 2022; Sonnenschein et al., 2022). Furthermore, respondents were unaware that Renewable Energy is included in the Sustainable Development Goals (SDGs) as a component of physics education. Interestingly, additional data indicates that the majority of students find the subject of renewable energy both fascinating and appealing for further study. Teachers are encouraged to involve students in discussions about inquiry and thought processes, enabling them to assess the effectiveness of their learning strategies and explore alternative approaches (Lee et al., 2019; Shvartsman & Shaul, 2023). The integration of renewable energy material into school curricula is undertaken to address the issue of energy availability in Indonesia. This initiative aligns with the objectives of Education for Sustainable Development (ESD).

The questionnaire results revealed that the primary reason for their lack of knowledge was a limited understanding of its significance. Furthermore, respondents were unaware that Renewable Energy is included in the Sustainable Development Goals (SDGs) as a component of physics education. Interestingly, additional data indicates that the majority of students find the subject of renewable energy both fascinating and appealing for further study. The integration of renewable energy material into school curricula is undertaken to address the issue of energy availability in Indonesia. This initiative aligns with the objectives of Education for Sustainable Development (ESD).

Education for Sustainable Development (ESD) is a crucial instrument aligned with the United Nations' Sustainable Development Goals. It underscores the necessity for individuals to acquire the knowledge and skills required to address the challenges of building a more sustainable world while the implementation of ESD training among secondary school teachers is still low, 42% of science teachers agree that renewable energy is a pertinent subject in ESD and represents the seventh global development goal (Ssossé et al., 2021). Education for Sustainable Development (ESD) can enhance student's awareness. ESD incorporates sustainability issues into the curriculum, addressing concerns like climate change, biodiversity, and inequality. It facilitates learners' understanding of the global impact of both individual and societal actions. Beyond imparting knowledge, ESD plays a crucial role in shaping attitudes and values that prioritize environmental and societal well-being. Through ESD, students learn to embrace a global citizenship perspective, becoming responsible individuals who actively care about sustainability. (Fredriksson et al., 2020; Kalla et al., 2022; Weng et al., 2020). However, the questionnaire results indicate that most teachers have not integrated the PjBL learning model into their programs for teaching renewable energy material. The absence of active student engagement in renewable energy learning, such as through experiments or real projects, diminishes their interest in the subject.

The questionnaire data for both teachers and students reveals that the learning process for renewable energy material is not yet effective. This situation highlights the need for a comprehensive learning program that includes lesson plans, worksheets, and various learning resources. This aligns with the results of using STEM approach-based worksheets, which have been designed, are proven to foster scientific literacy skills. The average score achieved is 86.3%, with 19 students completing them and receiving a "Very Practical" assessment. These results meet the criteria for effectiveness in improving science literacy skills (Safitri & Tanjung, 2023).

This approach aims to empower students to overcome challenges in their numeracy and literacy skills, fostering critical, logical, and systematic thinking. (Astuti et al., 2019). Project-Based Learning (PjBL) can be implemented with an integrated STEM (Science, Technology, Engineering, and Mathematics) Engineering Design Process strategy. The combination of PjBL-STEM and the engineering design process is employed to create a problem-solving learning environment in which students envision solutions, gather information, and address real-world problems (Wahono et al., 2020). The results of the descriptive analysis of students' scientific literacy after engaging in science learning through the STEM-based PjBL model showed a significant increase in the average score. This improvement placed the scores in the 'very good' category when compared to those obtained through conventional learning methods (Asri et al., 2021; Hasibuan et al., 2022). This aligns with the findings of research conducted by (Putra et al., 2023), which indicate that the Engineering Design Process (EDP) can engage students in solving real-world problems through activities designed to mimic the work of engineers. The EDP stages utilized in this research are by Abdurrahman et al. (2023) which represented in several stages: ask, imagine, plan, create, test, and improve. These stages are suitable for involving students in the learning process, thereby stimulating their numeracy and literacy skills, especially in renewable energy materials.

Conclusion

The research that has been conducted illustrates that based on survey results, According to the survey results, only 43% of teachers and 24% of high school students majoring in Mathematics and Natural Sciences are aware of the Sustainable Development Goals (SDGs). This aligns with the finding that only 40% of teachers have integrated PjBL-STEM into their learning programs. The worksheets lack activities that can stimulate students' numeracy and literacy skills, hindering their active engagement in renewable energy learning. These findings are further supported by student questionnaires, revealing that 55% of students feel they have limitations in understanding renewable energy material. Additionally, 85% of physics teachers express concerns about students' inability to grasp the concept of renewable energy. A well-designed learning program can offer a profound understanding of numeracy concepts associated with renewable energy. This encompasses the utilization of numbers, data, and other mathematical skills to analyze, interpret, and make decisions pertaining to renewable energy. Consequently, the development of a PjBL-STEM integrated renewable energy learning program becomes imperative.

Acknowledgments

The author would like to express gratitude to the supervisors who provided guidance throughout the preparation and implementation of the research. Special thanks also go to fellow researchers who assisted in the implementation and data analysis process. The researchers extend their appreciation to the respondents, which include 27 high school physics teachers and 59 high school students in MIPA field in Lampung Province, for their valuable contributions to this survey.

Author Contributions

Research design, S. C. and A.; Data collection, S. C., A., G. F. R.; Data curration and analysis, S. C. and A.; Validation, A., I. W. D., K. H., U. R.; Writing Article, S. C.; Review and Editing, S. C. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

Abdurrahman, A., Maulina, H., Nurulsari, N., Sukamto, I., Umam, A. N., & Mulyana, K. M. (2023). Impacts of integrating engineering design process into STEM makerspace on renewable energy unit to foster students' system thinking skills. *Heliyon*, e15100. https://doi.org/10.1016/j.heliyon.2023.e15100

Asri, Y. N., Mursyidah, D. S., & Rizqi, V. (2021). Application of Project-Based Learning Through a STEM Approach to Improve Learning Outcomes During a Pandemic. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 719–722. https://doi.org/10.29303/jppipa.v7i4.819

Astuti, I. D., Toto, T., & Yulisma, L. (2019). Model Project Based Learning (PjBL) Terintegrasi STEM untuk Meningkatkan Penguasaan Konsep dan Aktivitas Belajar Siswa. *Quagga: Jurnal Pendidikan Dan Biologi*, *11*(2), 93. https://doi.org/10.25134/quagga.v11i2.1915

Bellini, D., Crescentini, A., Zanolla, G., Cubico, S., Favretto, G., Faccincani, L., Ardolino, P., & Gianesini, G. (2019). Mathematical Competence Scale (MCS) for primary school: The psychometric properties and the validation of an instrument to enhance the sustainability of talents development through the numeracy skills assessment. *Sustainability (Switzerland)*, *11*(9). https://doi.org/10.3390/su11092569

Campbell, C., & Speldewinde, C. (2022). Early Childhood STEM Education for Sustainable Development. *Sustainability (Switzerland)*, *14*(6). https://doi.org/10.3390/su14063524

Fredriksson, U., Kusanagi, K. N., Gougoulakis, P., Matsuda, Y., & Kitamura, Y. (2020). A comparative study of curriculums for Education for Sustainable Development (ESD) in Sweden and Japan. *Sustainability (Switzerland)*, *12*(3). https://doi.org/10.3390/su12031123

Gamage, K. A. A., Ekanayake, S. Y., & Dehideniya, S. C. P. (2022). Embedding Sustainability in Learning and Teaching: Lessons Learned and Moving Forward-Approaches in STEM Higher Education Programmes. *Education Sciences*, *12*(3). https://doi.org/10.3390/educsci12030225

Ginting, F. W., Mellyzar, M., & Lukman, I. R. (2023). Analysis of Student Environmental Literacy: PjBL-Based Learning that is Integrated STEM. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 242–248. https://doi.org/10.29303/jppipa.v9i1.2599

Grahito Wicaksono, A. (2020). Penyelenggaraan Pembelajaran IPA Berbasis Pendekatan STEM dalam Menyongsong Era Revolusi Industri 4.0

LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *10*(1), 54–62. https://doi.org/10.24929/lensa.v10i1.98

Hasibuan, M. P., Sari, R. P., Syahputra, R. A., & Nahadi, N. (2022). Application of Integrated Project-based and STEM-based E-learning Tools to Improve Students' Creative Thinking and Self-Regulation Skills. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 51–56. https://doi.org/10.29303/jppipa.v8i1.1050

Howard, P., O'Brien, C., Kay, B., & O'Rourke, K. (2019). Leading educational change in the 21st century: Creating living schools through shared vision and transformative governance. *Sustainability (Switzerland)*, *11*(15). https://doi.org/10.3390/su11154109

Jayadi, A., Putri, D. H., & Johan, H. (2020). Identifikasi Pembelakalan Keterampilan Abad 21 pada Aspek Keterampilan Pemecahan Masalah Siswa SMA Kota Bengkulu dalam Mata Pelajaran Fisika. *Jurnal Kumparan Fisika*, *3*(1), 25–32. https://doi.org/10.33369/jkf.3.1.25-32

Kalla, M., Jerowsky, M., Howes, B., & Borda, A. (2022). Expanding Formal School Curricula to Foster Action Competence in Sustainable Development: A Proposed Free-Choice Project-Based Learning Curriculum. *Sustainability (Switzerland)*, *14*(23). https://doi.org/10.3390/su142316315

Kurent, B., & Avsec, S. (2023). Systems Thinking Skills and the ICT Self-Concept in Preschool Teachers for Sustainable Curriculum Transformation. *Sustainability*, *15*(20), 15131. https://doi.org/10.3390/su152015131

Lee, S., Kwon, B. C., Yang, J., Lee, B. C., & Kim, S. H. (2019). The correlation between users' cognitive characteristics and visualization literacy. *Applied Sciences (Switzerland)*, *9*(3). https://doi.org/10.3390/app9030488

Lestari, H., Rahmawati, I., Siskandar, R., & Dafenta, H. (2021). Implementation of Blended Learning with A STEM Approach to Improve Student Scientific Literacy Skills During The Covid-19 Pandemic. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 224. https://doi.org/10.29303/jppipa.v7i2.654

Lozano, A., López, R., Pereira, F. J., & Blanco Fontao, C. (2022). Impact of Cooperative Learning and Project-Based Learning through Emotional Intelligence: A Comparison of Methodologies for Implementing SDGs. *International Journal of Environmental Research and Public Health*, *19*(24). https://doi.org/10.3390/ijerph192416977

Mairizwan, M., Hidayati, H., Dewi, W. S., Afrizon, R., & Jarlis, R. (2022). Increasing the Competence of Physics Teachers in Designing PjBL-Based Teaching Aids for the Implementation of the Merdeka Curriculum. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2948–2953. https://doi.org/10.29303/jppipa.v8i6.2585

Marouli, C. (2021). Sustainability education for the future? Challenges and implications for education and pedagogy in the 21st century. *Sustainability (Switzerland)*, *13*(5), 1–15. https://doi.org/10.3390/su13052901

Martín-Sánchez, A., González-Gómez, D., & Jeong, J. S. (2022). Service Learning as an Education for Sustainable Development (ESD) Teaching Strategy: Design, Implementation, and Evaluation in a STEM University Course. *Sustainability (Switzerland)*, *14*(12). https://doi.org/10.3390/su14126965

Ningrum, M. C., Juwono, B., & Sucahyo, I. (n.d.). Implementasi Pendekatan TaRL untuk Meningkatkan Motivasi Belajar Peserta Didik pada Pembelajaran Fisika. *PENDIPA Journal of Science Education*, *2023*(7), 94–99. https://doi.org/10.33369/pendipa.7.2.94-99

Nurjumiati, N., Syahriani Yulianci, & Asriyadin, A. (2022). Pengaruh Model Inquiry Berbasis Literasi Numerasi Terhadap kemampuan Pemodelan Matematis dan Bahasa Simbolik Fisika. *Jurnal Pendidikan MIPA*, *12*(3), 945–948. https://doi.org/10.37630/jpm.v12i3.714

Paristiowati, M., Rahmawati, Y., Fitriani, E., Satrio, J. A., & Hasibuan, N. A. P. (2022). Developing Preservice Chemistry Teachers' Engagement with Sustainability Education through an Online, Project-Based Learning Summer Course Program. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031783

Putra, P. D. A., Sulaeman, N. F., Supeno, & Wahyuni, S. (2023). Exploring Students' Critical Thinking Skills Using the Engineering Design Process in a Physics Classroom. *Asia-Pacific Education Researcher*, *32*(1), 141–149. https://doi.org/10.1007/s40299-021-00640-3

Rahmah, S., Dalila, A. A., Liliawati, W., & Setiawan, A. (2022). Pendekatan Pembelajaran Diferensiasi dalam Model Inkuiri terhadap Kemampuan Numerasi Siswa. *Jurnal Imiah Pendidikan Dan Pembelajaran*, *6*(2), 393–401. https://doi.org/10.23887/jipp.v6i2.50838

Rasmi, D. P., Hendri, M., & Azriyanti, R. (2023). Analysis of the Need for Development of Teaching Materials in the Form of STEM-Based Electronic Modules. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4135–4141. https://doi.org/10.29303/jppipa.v9i6.2683

Safitri, N., & Tanjung, I. F. (2023). Development of STEM-Based Student Worksheets on Virus Material to Improve Student Science Literacy.

Jurnal Penelitian Pendidikan IPA, *9*(3), 1457–1464. https://doi.org/10.29303/jppipa.v9i3.3288

Shvartsman, M., & Shaul, S. (2023). The Role of Working Memory in Early Literacy and Numeracy Skills in Kindergarten and First Grade. *Children*, *10*(8). https://doi.org/10.3390/children10081285

Sonnenschein, S., Susperreguy, M. I., Lira, C. J., & Lefevre, J.-A. (2022). *Cross-Cultural Comparisons of Home Numeracy and Literacy Environments: Canada, Mexico, and Chile*. https://doi.org/10.3390/educsci

Ssossé, Q., Wagner, J., & Hopper, C. (2021). Assessing the impact of ESD: Methods, challenges, results. In *Sustainability (Switzerland)* (Vol. 13, Issue 5, pp. 1–26). MDPI. https://doi.org/10.3390/su13052854.

Wahdah, N., Nugroho, K. A., & Jumadi, J. (2023). Enhance Critical Thinking Skills in Application of PjBL-STEM on Fluids Dynamics: A Literature Study. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 89–94. https://doi.org/10.29303/jppipa.v9i6.2743

Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. In *International Journal of STEM Education* (Vol. 7, Issue 1). Springer. https://doi.org/10.1186/s40594-020-00236-1

Wahyu, Y., Edu, A. L., & Helmon, A. (2023). STEM-based PjBL Learning Model with Manggaraians Indigenous Science Content to Improve Science Literacy: is it Effective? *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8263–8273. https://doi.org/10.29303/jppipa.v9i10.4963

Weng, S. S., Liu, Y., Dai, J., & Chuang, Y. C. (2020). A novel improvement strategy of competency for education for sustainable development (ESD) of university teachers based on data mining. *Sustainability (Switzerland)*, *12*(7). https://doi.org/10.3390/su12072679

Zakiyah, N., & Ramli, Y. (2023). Pengaruh Pembelajaran PBL Terintegrasi STEM terhadap Keterampilan Berpikir Kritis Siswa The Effect of STEM-integrated PBL Learning on Students' Critical Thinking Skills. *Jurnal Jeumpa*, *10*(2), 269–277. https://doi.org/10.33059/jj.v10i2.8479

Zubaidah, S. (2019). Pendidikan Karakter Terintegrasi Keterampilan Abad Ke-21. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *3*(2). https://doi.org/10.36312/e-saintika.v3i2.125