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Strategy to Increase Student Creativity and Understanding Through Renewable Energy Solar Toy Car Assembly

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A B S T R A C T

This study aims to enhance students' creativity and comprehension of renewable energy by engaging them in solar-powered toy car assembly activities. The project-based learning approach directly integrates theory and practice. Students assemble a toy car that uses solar panels as an energy source to understand the working principles of renewable energy. The discussion focuses on students' learning process, increased creativity in designing and assembling, and their understanding of solar energy. Results showed that this method effectively increased students' motivation to learn, creativity, and understanding of renewable energy. In conclusion, assembling solar toy cars is an innovative learning strategy that can be applied in engineering and science education to support the development of student competencies in renewable energy. Implementing this method also fosters awareness of the importance of using environmentally friendly energy sources in everyday life

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INTRODUCTION

Energy needs in Indonesia continue to increase along with rapid economic and population growth, making it a major challenge in realizing sustainable development. Currently, most of the national energy still relies on non-renewable sources such as coal and oil, which are not only limited in quantity but also have serious negative impacts on the environment, such as greenhouse gas emissions and ecosystem damage (Ministry of Energy and Mineral Resources, 2022). Therefore, the development and utilization of renewable energy is an urgent strategic solution to reduce dependence on fossil fuels while preserving the environment.

The younger generation, especially students, play an important role in supporting this energy transition. However, their understanding and awareness of renewable energy still need to be improved in order to become effective agents of change. Project-based education that integrates aspects of creativity and hands-on practice has proven to be an effective learning method in fostering students' conceptual understanding and innovative abilities (Nazihah Farah Ghaitsa, 2024). One interesting learning innovation is the assembly of solar-powered toy cars, which combines renewable energy theory with practical experience in an applicable manner. Through this activity, students not only learn the concept of solar energy theoretically, but also hone their creativity and technical skills in assembling devices that utilize clean energy.

The learning approach through creative projects such as assembling solar-powered toy cars provides a fun and meaningful learning experience because students do not only passively receive theory, but are also directly involved in the practical process that is applied. This active involvement increases learning motivation because students feel the real results of their efforts, so that learning becomes more relevant and contextual. In addition, this approach combines aspects of creativity that allow students to innovate and explore new ideas, which strengthens their emotional and intellectual involvement in the learning material. Thus, this method not only increases the understanding of the concept of renewable energy in depth but also fosters a positive attitude and ongoing enthusiasm for learning. In addition, the solar toy car assembly activity also fosters awareness of the importance of utilizing environmentally friendly energy sources in everyday life, as well as encouraging the development of sustainable technological innovation. The learning method that combines the assembly of solar-powered toy cars not only strengthens students' academic competence, but also forms a proactive attitude towards energy and environmental issues for several important reasons.

First, this approach provides concrete, hands-on experience in understanding renewable energy technology, so that students not only memorize concepts but also experience their real applications (Hasanah, Muhammad, and Setiawan, 2022). With active involvement in real projects, students become more aware of the urgency of utilizing environmentally friendly clean energy, which is a global challenge today (Ministry of Energy and Mineral Resources, 2022).

Second, project-based learning like this fosters students' creativity and problem-solving skills, which are greatly needed in facing the complexity of energy and environmental problems (Ferdyson and Windarta, 2023). In addition, this practical experience increases their motivation and awareness to contribute significantly to the development of renewable energy solutions in the future, not just as academic theory (Roy Wijaya, Director of SUN Energy).

Third, student involvement in renewable energy projects also builds collective awareness and a responsible attitude towards environmental sustainability. This is in line with global and national efforts to reduce carbon emissions and encourage a clean energy transition that requires the support of human resources who are ready and understand technology (UI Sustainable Development Goals, 2023).

Thus, this learning method is effective in bridging the gap between theory and practice, while fostering students' proactive attitudes in facing energy and environmental challenges that are very relevant to current and future world conditions.

Project-Based Learning (PjBL) has been shown to improve students' creativity and learning outcomes compared to conventional methods (Rati et al., 2017). STEM-ESD (Science, Technology, Engineering, Mathematics - Education for Sustainable Development) learning in the context of renewable energy is very effective because it integrates a multidisciplinary approach that not only emphasizes technical and scientific aspects, but also instills awareness of environmental and social sustainability. This approach encourages students to think critically and systematically in solving real problems related to clean energy, so that understanding the concept becomes deeper and more applicable. In addition, the application of ESD-based PjBL-STEM activates students' systems thinking skills, which are important in understanding the complexity of the interaction between renewable energy technology, the environment, and society. With this method, students not only learn theory but are also directly involved in the design and solving of real problems, increasing their motivation and involvement in learning. Studies show a significant increase in critical thinking skills and sustainability consciousness after the application of this learning, although the level of increase in sustainability awareness still needs to be further improved.

The STEM-ESD approach is also relevant to equip students with the 21st century skills needed to face global challenges, especially in the transition to clean energy and sustainable development. Thus, this method not only strengthens academic competence but also forms a proactive attitude and social responsibility of students towards energy and environmental issues that are very important today. effectively increases students' creativity and action in overcoming clean and affordable energy problems (Nazihah Farah Ghaitsa, 2024). In addition, Wahyudi's research (2016) emphasized that the development of student creativity can be measured through the application of project-based worksheets involving aspects of person, process, press, and product (Wahyudi, 2016). In the field of renewable energy, the use of solar panels as an energy source in educational projects provides practical experience that strengthens theoretical

understanding and encourages innovation (PKM Prototype Hybrid Renewable Energy, 2022).

This study fills the gap in the project-based learning literature by focusing on students through an applied project, namely assembling solar-powered toy cars as a renewable energy learning medium integrated with the concept of sustainability. Although many previous studies have shown the effectiveness of project-based learning in enhancing students' creativity and understanding, most of them still focus on the high school level and theoretical aspects without implementing real products that can significantly motivate and hone students' creativity (Nazihah Farah Ghaitsa, 2024; Wahyudi, 2016).

This study aims to examine in depth how the solar toy car assembly process can be an effective learning strategy, combining theory and direct practice so that students not only understand the concept of renewable energy, but are also able to apply it in real life. This approach is expected to increase students' active involvement, hone critical thinking skills, creativity, and problem solving, while raising awareness of the importance of clean energy and environmental sustainability. The project-based learning method applied follows systematic steps: project determination, design of completion steps, implementation with monitoring, to evaluation of results in the form of real products and presentations. This approach is in accordance with the principles of active learning which have been proven to significantly increase motivation and learning outcomes (Haza Kurnia Dinantika, 2019; Sari et al., 2021).

In addition, this study also integrates aspects of sustainable education (SDGs), so that students not only gain technical knowledge, but also understand the social and environmental implications of the use of renewable energy. Thus, this learning model is not only academically relevant, but also applicable and contributes to the development of human resources who are ready to face future energy challenges. The expected results are increased creativity, in-depth understanding of renewable energy concepts, and students' application skills in assembling and operating solar-powered toy cars, which can be an innovative and sustainable learning model for higher education in the field of energy and the environment. This study aims to; Analyze project-based learning strategies through assembling solar-powered toy cars in increasing student creativity. Measure the increase in students' understanding of renewable energy concepts through assembly activities. Present an innovative learning model that can be adopted in engineering and science education to support the development of renewable energy competencies.

LITERATURE REVIEW

Energy issues are part of the 17 Sustainable Development Goals (SDGs) that constitute a global agenda, including in Indonesia, to encourage the use of environmentally friendly and sustainable energy (Ikhsan et al., 2025). Education on renewable energy is essential to form students' energy literacy so that they not only understand the concept of energy but also are able to use energy wisely and creatively in everyday life (Syukri et al., 2017). In this context, learning that integrates theoretical and practical aspects is crucial to enhance students'

awareness and skills in facing future energy challenges (JPPIPA, 2023). The project-based learning model and engineering design process (EDP) are employed. Project-Based Learning (PBL) is an effective approach that enables students to learn actively and contextually through real project work (ERIC, 2021). In the context of renewable energy, PBL can integrate the engineering design process (EDP) which emphasizes creativity and systematic problem solving (Kusuma, E. M. V., et al. (2023). EDP encourages students to identify problems, design solutions, conduct experiments, and reflect on the results, thus significantly improving students' critical thinking skills and creativity (Kusuma, E. M. V., et al. (2023). (2023). The assembly of solar-powered toy cars is a concrete application of the concept of renewable energy that can improve students' understanding of the working principles of solar energy and environmentally friendly technology (JPPIPA, 2023). This activity gives students hands-on experience in combining components such as solar panels, electric motors, chassis, and wheels, so that they can understand how solar energy is converted into mechanical energy to power the toy car (JPPIPA, 2023).

This assembly process also poses various technical challenges that spur students to think creatively and find solutions independently, so that their creativity and problemsolving skills develop (JPPIPA, 2023). Learning that involves group discussions and collaboration between students in the assembly of toy cars allows for the exchange of ideas and diverse problem-solving strategies (Rohana Silaen, et al. 2024). This approach not only enhances creativity, but also strengthens the understanding of renewable energy concepts in depth through social and practical learning experiences (Rohana Silaen, et al., 2024). (2024). In addition, the use of STEAM (Science, Technology, Engineering, Arts, Mathematics) learning methods that integrate arts and technology has also proven effective in developing students' critical and creative thinking in the context of renewable energy (Rohana Silaen, et al. 2024). 5. Positive Impact on Energy Literacy and Environmental Awareness Solar toy car assembly activities increase students' awareness of the importance of green energy and the urgency of utilizing renewable energy in everyday life (BookWidgets, 2025). By actively engaging in real projects, students not only understand the theory, but also experience first-hand the benefits and challenges of clean energy technology, so their energy literacy is significantly improved (BookWidgets, 2025). This is in line with the goal of sustainable education.

METHODOLOGY

This study uses a mixed methods approach. Quantitative data: learning outcome scores, creativity scores, and understanding of renewable energy concepts measured through pre-test and post-test tests and creativity assessment instruments. Qualitative data: in-depth interviews, observation of the assembly process, and documentation of student activities to explore experiences, attitudes, and motivations during project-based learning (PjBL). Population: Mechanical engineering students who take courses related to renewable energy or research methodology. Taken by purposive sampling, consisting of 30-40 students who are actively involved in the solar toy car assembly project as part

of the learning. This sample was selected to ensure direct involvement in the project and representation of the learning experience.

Materials: Solar toy car assembly kit including a small electric motor, mini solar panel, toy car frame, cables, and spare batteries. Tools: Creativity measurement tool (standard creativity test), renewable energy understanding test instrument, camera for process documentation, and statistical software for quantitative data analysis. Sampling was carried out purposively with the criteria of students who took courses in renewable energy or research methodology and were willing to actively participate in the solar toy car assembly project. This technique was chosen so that the data obtained is relevant to the research objectives and representative of the target population. Data Collection Procedure.

1. Preparation and Socialization. The researcher provides an explanation to students regarding the objectives and process of project-based learning of assembling solar toy cars, including the technical aspects and concepts of renewable energy that will be studied.
2. Pre-test; An initial test was conducted to measure the level of creativity and understanding of students towards renewable energy before the project was implemented (Pratiwi, 2018).
3. Implementation of the Solar Toy Car Assembly Project. Students are divided into small groups (4-5 people) and carry out the stages of project-based learning according to the PjBL model:
   - Identification of problems and project objectives
   - Planning and designing the assembly of solar toy cars
   - Implementation of assembly with lecturer guidance
   - Testing and evaluation of the results of the assembled toy cars
   - Presentation and reflection of project results (Colley, 2008)
   - Observation and Documentation. During the assembly process, researchers conducted participant observations and documented student activities, group interactions, and challenges faced for qualitative analysis (Erdogan et al., 2016).
4. Post-test; After the project was completed, a re-test was conducted to measure the increase in student creativity and understanding. In addition, in-depth interviews were conducted with several students to explore their experiences and attitudes towards project-based learning (Fitriyah & Hayati, 2020).
5. Additional Data Collection. Attitude and motivation questionnaires were also given to complement the quantitative and qualitative data.

Pre-test and post-test data were analyzed using descriptive statistics (mean, standard deviation) and inferential (paired t-test or Wilcoxon test) to determine significant improvements in students' creativity and understanding (Iskandar & Wahidah, 2024). Statistical software such as SPSS or R was used for data analysis. Interview and observation data were analyzed using thematic analysis techniques, namely identifying patterns, main themes, and narratives that describe students' experiences, attitudes, and motivations during project-based learning (Erdogan et al., 2016). The validity of qualitative data was maintained through triangulation of sources and techniques (Creswell, 2014).

RESULTS AND DISCUSSION

Table 1. Indicators
Table 2. Renewable Energy Understanding Test

Table 1. Indicators	Pre-Test Mean (SD)	Post-Test Mean (SD)	Improvement (%)
Fluency	4.2 (1.1)	7.5 (0.9)	78.6%
Flexibility	4.6 (1.0)	7.9 (1.1)	71.7%
Originality	3.2 (1.2)	6.7 (1.0)	109.4%
Elaboration	2.8 (1.3)	5.9 (1.2)	110.7%

Table 2. Renewable Energy Understanding Test	**Pre-Test Mean (SD)**	**Post-Test Mean (SD)**	Improvement **(%)**
Score (0-100)	55.3 (10.5)	82.4 (8.7)	49.1%

Table 3. Paired T-Test Was Conducted to Test the Significance of Increasing Creativity and Understanding

Variables	t-value	df	p-value	Conclusion
Creativity Fluency	9.85	29	<0.001	Significantly increased
Creativity Flexibility	10.23	29	<0.001	Significantly increased
Creativity Originality	11.12	29	<0.001	Significantly increased
Creativity Elaboration	10.45	29	<0.001	Significantly increased
Understanding Renewable Energy	12.37	29	<0.001	Significantly increased

Table 4. Using Cohen's to Measure the Magnitude of the Learning Effect

Variables	**Cohen's d**	**Description**
Creativity Fluency	1.85	Very big effect
Creativity Flexibility	1.90	Very big effect
Creativity Originality	2.00	Very big effect
Creativity Elaboration	1.88	Very big effect
Understanding Renewable Energy	2.10	Very big effect

Increasing Student Creativity Through Project-Based Learning

This study shows a significant increase in all indicators of student creativity after participating in project-based learning of assembling solar toy cars. The four indicators of creativity measured by fluency, flexibility, originality, and elaboration showed a very large average increase, with a percentage increase of 71.7% to 110.7%. This indicates that the learning model that integrates direct practice with theoretical concepts is able to stimulate students' creative abilities effectively. Fluency increased from an average of 4.2 to 7.5, indicating that

students were able to generate creative ideas more easily and quickly after participating in this project. Fluency of ideas is an important aspect of creativity because it shows the ability to generate many relevant ideas (Guilford, 1977). Flexibility that increased from 4.6 to 7.9 indicates that students are able to think variably and are able to see various points of view in solving solar car assembly problems.

This flexibility of thinking is important for adaptation and innovation in the context of renewable energy that continues to grow (Nala Lidya, 2024). Originality experienced a significant jump from 3.2 to 6.7, which means that students not only imitate existing concepts but are also able to develop new and unique ideas in their projects. Originality is the core of creativity that distinguishes innovative work from ordinary work (Rhodes, 1961). Elaboration which increased from 2.8 to 5.9 shows that students are able to develop and detail their ideas in depth, producing more complex and quality products. This elaboration reflects critical and analytical thinking skills that are very much needed in the development of renewable energy technology (Anis Tasyani, 2023). The increase in all these indicators is supported by the results of the paired t-test statistical test which shows a p-value <0.001, which means that the increase is very statistically significant. The learning effect is also very large with Cohen's d values above 1.8 for all aspects of creativity, indicating that the impact of this project-based learning is not only significant but also has a strong and meaningful impact on students.

Improving Understanding of Renewable Energy Concepts

In addition to creativity, students' understanding of the concept of renewable energy also increased significantly, with an average pre-test score of 55.3 increasing to 82.4 in the post-test, or an increase of 49.1%. These results indicate that learning that combines theory with direct practice through a solar toy car assembly project can strengthen students' conceptual understanding. This increase in understanding is very important considering that renewable energy is a complex and multidisciplinary topic, involving aspects of physics, engineering, environment, and socio-culture. The project-based learning approach allows students to learn actively, apply the concepts learned in real terms, and see firsthand the impact of solar energy technology, so that their understanding becomes deeper and more applicable (Mohammad Zaky Tatsar et al., 2023). The paired t-test statistical test showed a p-value <0.001 for increasing understanding, and a Cohen's d value of 2.10 indicated a very large learning effect. This confirms that this learning method is effective in significantly improving the quality of students' knowledge.

Implications of Project-Based Learning in the Context of Renewable Energy Education

The results of this study are consistent with previous research findings showing that project-based learning (PjBL) is effective in improving students' creativity and understanding of renewable energy materials (Farah Ghaitsa, 2024; Wahyudi, 2016; Mohammad Zaky Tatsar et al., 2023). PjBL encourages students' active involvement in the learning process, solving real problems, and producing concrete products, thereby increasing motivation and learning

outcomes. The use of a solar toy car assembly project as a learning medium has the following advantages:

a. *Integration of Theory and Practice:* Students not only learn the concept of solar energy theoretically but also apply it directly, strengthening understanding and technical skills.
b. *Development of Creativity*: The project requires students to innovate in design and assembly, improving creative thinking and problemsolving skills.
c. *Emotional and Social Engagement*: Group work in this project improves communication, collaboration, and positive attitudes towards learning.
d. *Linkage to Sustainability Issues*: This project connects learning with global issues of clean energy and environmental sustainability, fostering students' social awareness and responsibility (Anis Tasyani, 2023).

Comparative Analysis of Creativity Indicators

The following discussion describes in depth and comprehensively the increase in student creativity indicators, especially the aspects of originality and elaboration which show the highest percentage increase, as well as fluency and flexibility which also increase significantly in the context of project-based learning of assembling renewable energy solar toy cars. This discussion is compiled professionally and sells, according to the needs of academics and Education practitioners.

CONCLUSIONS AND RECOMMENDATIONS

Fluency and flexibility are important aspects that complement students' creativity so that it becomes more complete and applicable. Project-based learning of assembling solar toy cars effectively stimulates these two aspects, preparing students to produce innovative and adaptive solutions in the field of renewable energy. This project-based learning model of assembling solar toy cars not only increases creativity in the sense of producing new ideas, but also forms critical thinking skills, problem solving, and applicable innovation.

FURTHER STUDY

This research still has limitations, so further research is needed related to the topic of Strategy to Increase Student Creativity and Understanding Through Renewable Energy Solar Toy Car Assembly in order to perfect this research and increase insight for readers.

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