Vol. 5, No. 1, 2024, pp. 32-39
DOI: https://doi.org/10.29210/08jces479100

Contents lists available at Journal IICET

Journal of Counseling, Education and Society
ISSN: 2716-4896 (Print) , ISSN 2716-4888 (Electronic)

Journal homepage: https://jurnal.iicet.org/index.php/jces

Design and evaluation of solar power plant-based learning media for renewable energy education in high schools

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Article Info

Article history:

Received Aug 24th, 2024
Revised Sept 20th, 2024
Accepted Oct 25th, 2024

Keywords:

High school physics education
PLTS learning media
Student response to renewable energy

ABSTRACT

This research aims to develop renewable energy learning media in the form of a Solar Power Plant (PLTS), assess its feasibility, and analyze students' responses to the Renewable Energy Learning Media in the form of a Solar Power Plant (PLTS) in a high school in Bandung. This study is a type of developmental research that produces a product in the form of Renewable Energy Learning Media (Pane Surya). The research design adopts the Richey and Klein model with the stages of Design, Development, Implementation, and Decision Making. Data collection in this study was carried out using questionnaires. The results show that students' responses to the developed learning media indicate 80% for the attractiveness indicator, which falls under the high category; 81% for the usefulness indicator, categorized as high; and 79% for the ease-of-use indicator, also in the high category. Based on the research results, the renewable energy learning media in the form of a solar panel is deemed feasible to use and received positive responses from students during the renewable energy learning process in a high school in Bandung.

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Introduction

The technological advances that have developed today have had a significant impact on human life, including the field of education. The learning process in education has also adjusted to the needs and developments of the times, one of which is the development of learning media (Ismu Wahyudi et al., 2021). The use of learning media in the educational field has provided many new breakthroughs in increasing efficiency and effectiveness in the learning process. Teaching with the traditional method where the teacher delivers the content and students merely pay attention is no longer considered relevant in this advanced era (Saputra et al., 2020).

Teachers have the responsibility to provide knowledge to students that can be utilized in the future—not only to develop their own knowledge but also to innovate the learning process itself. One of the innovations in the learning process is using appropriate learning media that are suitable for the learning materials. The proper use of learning media will have an impact on achieving more effective learning outcomes (Lima et al., 2023). Learning media are tools or intermediaries, which in the context of education, can be interpreted as tools and materials used in the learning or teaching process (Arlen et al., 2020).

The use of learning media can be applied to all subjects, including physics (Haidir et al., 2021). Physics learning is still perceived as difficult to understand because some materials contain abstract concepts, making it challenging for students to connect them with daily life (Sanjaya et al., 2016). By using learning media, abstract materials can be more easily understood by students. Utilizing learning media also prevents boredom, thus encouraging students to be more enthusiastic about learning (Putra, 2021).

One type of learning media that can stimulate student interest is learning media based on instructional aids. Instructional aid-based learning media are learning tools that represent or depict the characteristics of the concepts being studied (Ashar, 2021).In physics subjects, instructional aids are often used as media during the learning process, and their availability can attract and encourage active participation from students. Learning media that incorporate instructional aids serve as essential tools to improve learning outcomes, particularly instructional aids related to renewable energy topics (Ali & Effendi, 2021).

Energy has become one of the primary or essential needs for living beings in daily life, from birth to death (Haryanto, 2017). Energy is divided into two types: renewable and non-renewable energy. Renewable energy is a source of energy that can be continuously utilized and is naturally available (Hasrul, 2021). Renewable energy can be replenished continuously and is abundantly available in nature. Along with the development of a more modern and sophisticated era, the need for energy has also increased for human necessities. One of these energy sources is electricity. The dependency on electricity is currently growing rapidly, but this increased demand for electricity is not in line with the existing availability, which is actually decreasing. Therefore, a way to anticipate this issue is to use renewable energy sources by utilizing solar energy through solar panels that can convert sunlight into electrical energy (Baharuddin, 2021).

In a study of 1200 American high school students, only 32% were able to correctly explain the basic concepts of renewable energy and the difference between renewable and non-renewable energy sources. This suggests that while renewable energy is becoming increasingly important in the context of climate change and sustainability, student understanding is still low (Mason, 2023).

Solar panels are systems capable of converting energy from sunlight into electrical energy through the photovoltaic effect principle. When the surface of the photovoltaic cell is exposed to sunlight, the upper part of the cell will generate negative charges that accumulate in the phosphorus layer, while the bottom part of the photovoltaic cell will generate positive charges in the boron layer. These two surfaces will generate their respective charges if the photovoltaic cell is exposed to sunlight, resulting in a potential difference or electrical voltage between the two sides of the photovoltaic cell (Usman, 2020).

In the needs analysis conducted by the researcher, several obstacles were found during the practical implementation of renewable energy materials, specifically solar panel energy. The teaching of renewable energy materials still relies on videos without any instructional aids. Additionally, there is a lack of adequate practical tools to achieve the learning objectives of the renewable energy material (Al-Shahri et al., 2021).

Educational environments face several challenges when it comes to technology integration, including lack of student engagement, limited access to quality learning resources, and lack of technology skills. If the teaching methods used are traditional and uninteresting, many students feel less engaged in the learning process. In addition, in some areas, access to online learning resources is still limited, which can impact on students' ability to obtain the information and knowledge they need (Werang & Leba, 2022).

Therefore, there is an increasing need to develop more interactive and accessible learning solutions. To overcome these problems, it is effective to utilize project-based learning media and learning technology system "PLTS". The integration of PLTS provides students with a more interactive and applicable learning experience thus increasing motivation. These media not only help students better understand the material, but also provide wider access to useful learning resources (Dziubata et al., 2021). In addition, PLTS is designed to enhance students' technological skills, which are essential for success in an increasingly digital world. Therefore, the use of PLTS-based learning media directly addresses the challenges facing education today and guarantees a more effective and enjoyable learning experience.

The problem with current photovoltaic education methods in this field is often the limited practical understanding and inability to apply the technology directly in a learning environment. Although the concept of solar energy is becoming more widely recognized in theory, many educational institutions still do not provide their students with opportunities to engage directly in simulations and practices related to solar power generation technology. In addition, there is a gap in access to learning facilities and tools that support project-based learning, where most educational institutions still rely on traditional methods such as lectures and the use of textbooks. As a result, students lack the technical skills and practical experience to operate or understand solar power plant components and systems. There is still a significant gap between the industry's need for work readiness and the skills that graduates acquire from the current learning process. Therefore, a more innovative educational approach that focuses on problem solving and hands-on application in practice is required.

Based on these initial observations, there is a need for an effort to develop renewable energy learning media in the form of a Solar Power Plant (PLTS) that can enhance the effectiveness of learning activities and explore new innovations to maximize students' abilities. By using appropriate and varied media, it can spark students' enthusiasm for learning and encourage them to improve their thinking abilities, which is expected to lead to improved learning outcomes.

Method

Research Design and Procedure

This developmental research method aims to create and develop a product in the form of learning media. The learning media developed in this research is a renewable energy learning media in the form of a solar panel. The sample size of this study consisted of 30 students of class X SMA / MA in Bandung City who participated in learning activities of renewable energy-based learning media (PLTS) using LKPD and response questionnaire.The research design adopted the model of Richey and Klein (2007) with the stages of Design, Development, Implementation, and Decision Making. The detailed treatment at each stage of the research is illustrated in Figure 1.

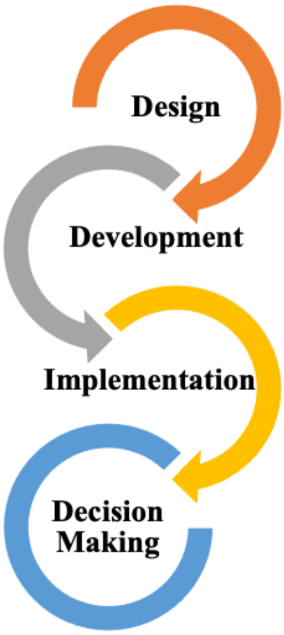


Figure 1 <Stages of Developmental Research (adopted from Richey and Klein, 2007)>

The product development procedure consists of four stages: design, development, implementation, and decision making (Anderson et al., 2024). The design stage includes needs analysis and planning. During the needs analysis phase, CP analysis and journal reviews were conducted. Next, CP analysis was carried out on the subject matter to ensure that the development of learning media aligns with the CP (Curriculum Principles) that are developed according to the demands of the curriculum. In the planning stage, the design of the learning media to be used is created.

Design: At this stage, researchers formulate learning objectives and needs and design a conceptual framework that will serve as the basis for product development. The aim is to identify the target group, analyze the learning situation, and develop the specifications of the desired product. Careful design is an important basis for ensuring that the learning products produced are relevant and appropriate to the needs of students (Bringle et al., 2023).

Development: After the design is completed, the researcher proceeds to the development stage, where the learning product is designed and built based on the given specifications. At this stage the necessary learning materials, tools and media are developed. This process also includes initial testing to ensure the product functions properly and meets the expected quality standards (Burkhardt & Schoenfeld, 2021).

Implementation: Once the product is developed, the next step is implementation. Learning products are used in real-life situations, both in the classroom and in other learning environments . It is important to monitor and evaluate the implementation process to identify any challenges that may arise and assess student response to the product in use (Morze et al., 2021).

Decision Making: The final stage of the model is decision-making, where the researcher analyzes the data obtained during the implementation process (Bousdekis et al., 2021). The development stage involves the production process, where the learning media is constructed according to the previously established design components. After the production process is completed, the next step is to validate the learning media. This validation involves physics subject matter experts to ensure it meets the design components. The following are the results of the development of renewable energy learning media in the form of a Solar Power Plant (PLTS) instructional aid.

Figure 2 <Renewable Energy Instructional Aid Product in the Form of a Solar Power Plant (PLTS)>

The implementation stage involves small-scale group trials to gather feedback from prospective users and to assess the effectiveness of the developed media in the learning process. The results are then evaluated thoroughly and meticulously. The final stage of this research is a comprehensive interpretation of the collected data to determine the next step, whether to conduct a revision or proceed with large-scale testing. Thus, it can be concluded that this study resulted in the development of a learning media.

Research Area and Subjects

This research was conducted in Bandung, involving product validators, namely experts in the fields of media and physics. The small-scale group trial involved 10th-grade students at one of senior high school in Bandung.

Instruments and Data Analysis

The instruments used in this research include LKPD (Student Worksheets) and response questionnaires given to students. The LKPD was provided to students participating in learning activities using the renewable energy learning media (Solar Panel). The student response questionnaire was given to students who had engaged in learning using the media. The LKPD and the response questionnaire were administered to assess the students' responses to the use of renewable energy learning media (Solar Panel). The questionnaire utilized a Likert scale adopted from Ratumanan & Laurent (2011). The validity scores of the developed product are shown in Table 1.

Table 1 <Validity Test Questionnaire Scale>

Pilihan Jawaban	**Skor**
Sangat setuju	4
Setuju	3
Tidak Setuju	2
Sangat tidak setuju	1

The data analysis technique used in this research implements a quantitative descriptive analysis technique. Data is analyzed using the following formula:

$$\%x = \frac{\sum Earned\ score}{\sum Maximum\ score} \times 100\%$$

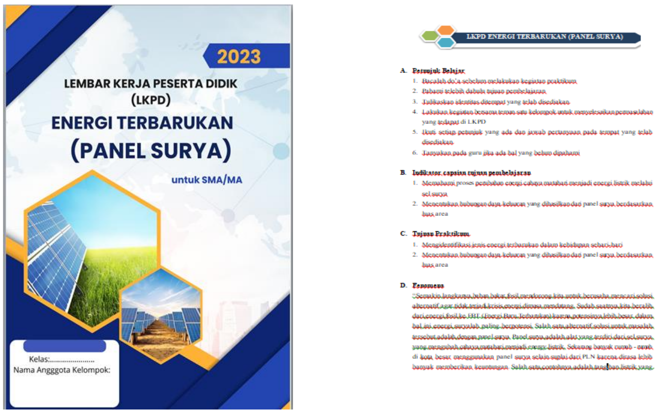
The resulting percentage is then converted using the criteria shown in Table 2.

Table 2 <Product Validity Score Criteria (Adapted from Ratumanan & Laurent, 2011)>

Percentage (%)	Criteria
0.00 - 20.00	Low
20.10 – 40.00	Fair
40.10 – 60.00	Moderate
60.10 – 80.00	High
80.10 – 100.00	Very High

Results and Discussions

The product developed from this research is a renewable energy learning media in the form of a Solar Power Plant (PLTS) for learning Physics in 10th-grade high school (SMA/MA). The development of this media began with a preliminary study to gather information related to Physics learning with a focus on Renewable Energy, specifically addressing the need for physics learning that involves practical activities to train students in discovering concepts, interpreting graphs, and enhancing multiple representation skills. This was followed by an analysis of the learning outcomes (CP and ATP) of the Physics content to be developed in the LKPD (Student Worksheets).



(a) (b)

Figure 3 <(a) & (b) Student Worksheets (LKPD)>

Based on the results of trials conducted on the development of renewable energy learning media in the form of a Solar Power Plant (PLTS) with 10th-grade high school students in Bandung, the LKPD assessment data obtained is as follows.

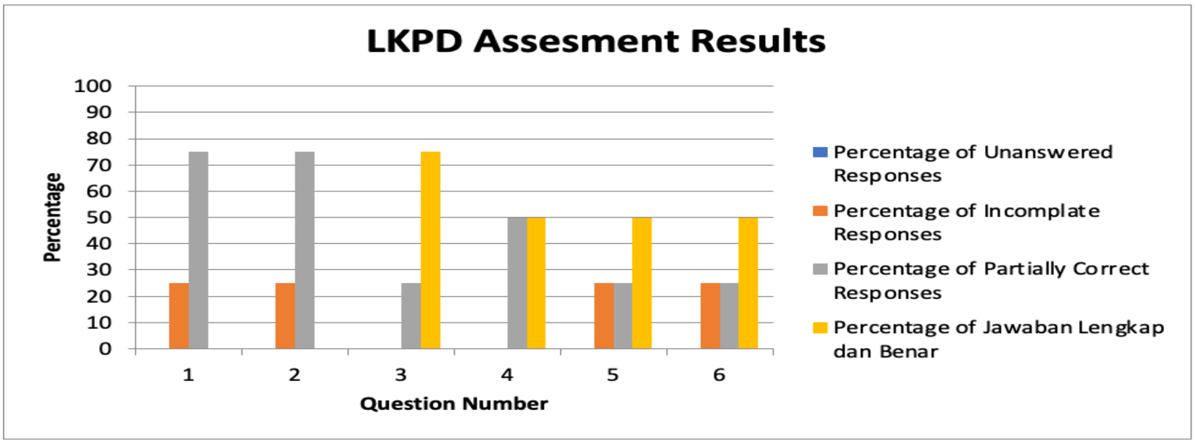


Figure 4 <Graph of LKPD Assessment Results>

The image above explains that for item one, 25% of students answered with incomplete responses, and 75% of students answered with partially complete responses. For item two, 25% of students answered with incomplete responses, and 75% of students answered with partially complete responses. For item three, 25% of students answered with partially complete responses, while 75% of students answered with complete and correct responses. For item four, 50% of students answered with partially complete responses, and 50% of students answered with complete and correct responses. For item five, 25% of students answered with incomplete responses, 25% of students answered with partially complete responses, and 50% of students answered with complete and correct responses. For item six, 25% of students answered with incomplete responses, 25% of students answered with partially complete responses, and 50% of students answered with complete and correct responses.

For questions 1, 2, 3, 4, 5, and 6, there were no unanswered questions. All groups managed to respond to every question in the LKPD. However, in items 1 and 2, none of the students answered with a complete and correct response. To further investigate, interviews were conducted with some students. Based on the interviews, the students expressed that they could not clearly understand the questions in the LKPD and were unfamiliar with the specifications of the fan used in the experiment.

For question 4, the percentage of correct and complete responses and partially correct responses were both 50%, indicating that 50% of the students did not fully comprehend question 4 in the LKPD. Interviews revealed that this was due to students' lack of attention during the experiment. Additionally, the incorrect placement of the equipment under direct sunlight affected the students' responses to question 4.

For questions 5 and 6, some students provided incomplete and partially correct responses. Interviews revealed that while the use of the learning media helped students understand the concept of renewable energy, particularly solar panels, they still struggled to draw accurate conclusions. The students were unable to see the internal processes occurring within the solar panel that cause the fan to move. This issue arose because the learning tool was only designed to demonstrate how sunlight is converted into electrical energy, without illustrating the internal processes occurring within the solar panel.

Overall, the analysis of LKPD results indicates that while students were able to answer all the questions, some of their responses were incomplete. This may have occurred because the students did not fully grasp the material and answered based on assumptions without a solid understanding of the concepts. Additionally, many students provided incorrect responses due to misconceptions influenced by their everyday experiences (Susilawati et al., 2020).

At the end of the lesson, students were asked to fill out a response questionnaire related to the development of the renewable energy learning media in the form of the Solar Power Plant (PLTS) used in the lesson. The following section presents the students' responses to the developed learning media.

Table 5 <Student Responses to the Developed Learning Media>

Category	Score	Persentage (%)	Criteria
Attractiveness	64	80	High
Usefulnes	65	81	High
Ease to Use	63	79	High

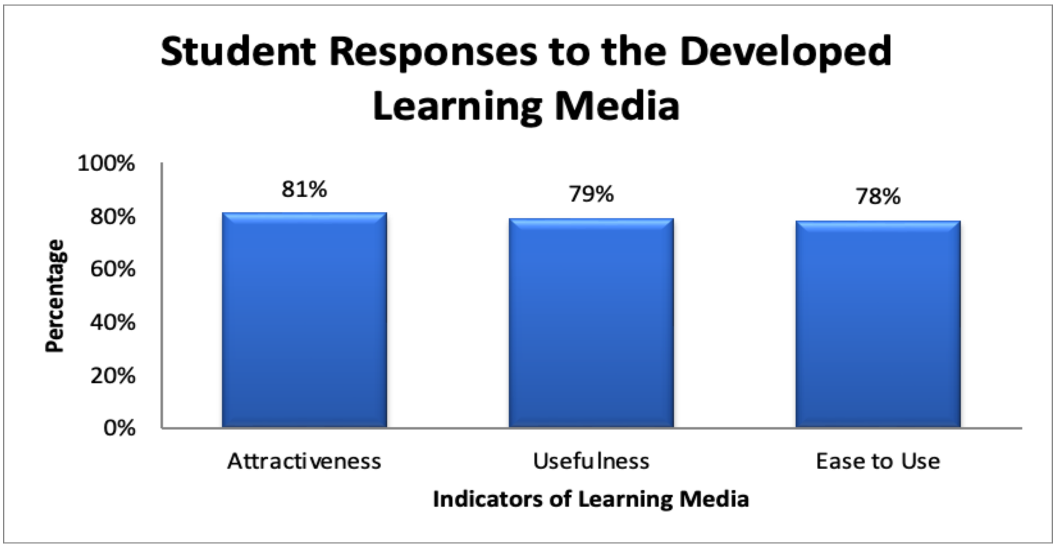


Figure 5 <Student Responses to the Developed Learning Media>

The image above shows that the percentage of student responses to the developed learning media for the usefulness category, with indicators stating that the learning media is very beneficial and that the media makes the material easy to remember, has the highest percentage at 81%, followed by the attractiveness category, where the indicators indicate that the learning media used is very engaging and makes students interested in studying the material at 80%, and the ease of use category, with indicators stating that the learning media is easy to use and the worksheets (LKPD) used are very clear at 79%.

In terms of student responses to the learning media used, the indicators of attractiveness fall into the high criteria. This indicates that the renewable energy learning media in the form of solar panels is engaging for the students. In the learning process, students require innovative, attractive, and user-friendly media to understand the learning material effectively and to visualize the material taught, thereby enhancing students' understanding (Hermawan, 2021)

The usefulness indicator also falls into the high criteria, meaning that the learning media used provides benefits to the students in the learning process. Based on the responses from students on the usefulness indicator, the learning media fosters collaboration among students in groups, facilitates understanding of the material, and enhances students' independence in learning, especially concerning the renewable energy material in the form of solar power systems (PLTS).

Furthermore, the ease of use indicator is also classified as high, indicating that the learning media used is easy for students to operate during the learning process. The components of the learning media are user-friendly. The measuring tools used are digital, allowing students to accurately read their measurement results. The renewable energy learning media in the form of solar panels is portable, easily movable, and its components are accessible.

Although the results showed that three main indicators were rated highly by students: attractiveness, ease of use, and ease of use, a detailed analysis of the relationship between the three indicators could not be determined. Attractive media is not necessarily easy to use. Visual stimulation can increase motivation, but an unclear interface can hinder use. Even if the media is easy to use, without relevant content, students' understanding of the concepts taught may be impaired. Therefore, it is important to examine the relationship between these indicators, as engaging media can increase engagement, whereas difficult-to-use media can demotivate students. Further research investigating the dynamic relationship between these three metrics will lead to a deeper understanding of learning media effectiveness and recommend more appropriate designs.

Based on the analysis of the LKPD assessment data and student responses, it shows that the results of the LKPD align with student responses. This can be seen from the varied LKPD answers in accordance with the student responses, indicating that the renewable energy learning media is beneficial for the learning process and easy to use.

Conclusions

A detailed analysis of the results of the research on the development of photovoltaic power system (PLTS)-based learning media showed significant differences in student responses. The media was considered interesting, useful and user-friendly, but it also had some limitations that could not be ignored. Some students reported difficulty understanding the content provided through the media. This shows that although the media is well designed, not all students have the same background knowledge. This suggests the need to differentiate the delivery of learning materials to achieve different levels of student understanding. In addition, the results showed that some students successfully answered the questions on the Student Worksheet (LKPD),

Specific recommendations for further development include using simpler language and adding visual explanations to support understanding of complex concepts, depending on the needs of different students. In the broader context of education, it is also important to train teachers how to use the media to facilitate learning more effectively. Critically examining the challenges of implementing media in different educational environments reveals that factors such as uneven technological infrastructure, differences in teacher skills and differences in student characteristics can affect the effectiveness of using learning media.

Suggestions for future research include testing the media in different educational settings and with different student populations to find out how these variables affect learning outcomes. Further research can also investigate aspects such as student motivation and the impact of media use on students' long-term understanding of renewable energy concepts. Therefore, the results of this study can serve as a foundation for the development of learning media that are more adaptive and responsive to the needs of students in different educational environments.

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