

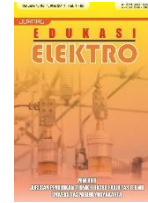


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## Developing Learning Media on Solar Power Generation to Enhance Practical Learning of Renewable Energy Competency for Undergraduate Students in The Electrical Engineering Education Study Program

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**Abstract**— The increasing demand for renewable energy expertise requires practical, competency-based education, particularly in electrical engineering programs. This study aimed to address the lack of effective learning media for solar power generation, which influences student preparedness and the overall quality of renewable energy education. Using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), instructional media were developed to enhance students' practical understanding of solar power generation. The study involved 29 sixth-semester undergraduate students enrolled in an electrical engineering education program. A quantitative approach was employed, utilizing pretests and posttests to measure learning outcomes, along with students' feedback. The results indicated a strong need for improved solar power generation tools and revealed significant competency gaps among students. The developed media included concept maps, diagrams, case studies, and interactive exercises, received very high feasibility ratings: 91.67% from media experts, 89.57% from material experts, and 91.40% from users. Following implementation, students demonstrated a significant improvement in understanding ( $p = 0.012$ ) with high test reliability (Cronbach's Alpha = 0.891). These findings demonstrate that the developed instructional media provide a validated, and practical solution to strengthen renewable energy education and support workforce readiness for the global energy transition.

**Keywords:** learning media, solar power generation, renewable energy, electrical engineering education, competency.

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## 1 Introduction

In recent years, the global urgency to shift from fossil fuel dependency toward sustainable and renewable energy solutions has intensified, driven by mounting environmental challenges such as

climate change and resource depletion. Among various renewable energy sources, solar energy has emerged as a leading alternative due to its affordability, scalability, and eco-friendliness [1][2]. Despite its high potential especially in equatorial nations like Indonesia solar energy adoption in the country remains marginal. According to Indonesia's Ministry of Energy and Mineral Resources [3], only a fraction of the nation's estimated 207.8 GW of solar energy potential has been tapped. The slow adoption is attributed not only to infrastructural and policy challenges but also to a significant gap in human capital readiness, particularly in the technical skills needed to implement, manage, and maintain solar power systems [4].

This deficiency is particularly pronounced at the undergraduate level in electrical engineering education, where curriculum implementation often remains theoretical and lacks adequate, interactive, and practice-oriented learning resources. Many institutions in Indonesia still employ outdated pedagogical models, focusing on rote learning rather than competency-based, hands-on instruction [5][6]. Consequently, graduates frequently enter the workforce ill-equipped for practical roles in the renewable energy sector. A mismatch between education outcomes and labor market needs persists, resulting in employability issues even as the demand for green-skilled professionals continues to rise [7].

One of the core barriers lies in the absence of accessible, modular, and pedagogically sound learning media for solar power generation. Existing educational tools are often imported, expensive, overly complex, or unsuited for Indonesia's specific socio-economic and geographical contexts [8]. In many institutions, instructors rely on static images, PowerPoint presentations, and outdated textbooks, which fail to provide the practical exposure necessary for understanding the intricacies of photovoltaic systems, charge controllers, inverters, and other key components of solar energy systems [9].

In response to this critical gap, this research proposes the development and implementation of innovative, interactive, and contextually relevant solar power learning media tailored for undergraduate electrical engineering education in Indonesia. Aligned with the Presidential Instruction No. 9 of 2016 and the national objective of reaching 23% renewable energy in the national energy mix by 2025, this initiative seeks to bridge the gap between theoretical education and practical application. The proposed learning media includes both printed learning modules and a hands-on training kit that integrates essential solar energy components such as solar panels, batteries, inverters, and charge controllers, structured according to didactic and modular principles.

The research is limited to the sixth-semester students of the Electrical Engineering Education Study Program at Universitas Negeri Yogyakarta and focuses specifically on solar power generation, excluding other renewable sources such as wind or biomass. The study adopts a development research approach that includes analysis, design, and development, implementation, and evaluation phases, targeting both cognitive and psychomotor competencies in accordance with the Indonesian National Work Competency Standards.

The ultimate goals of this research is to offers opportunities for deeper learning, higher engagement, and the acquisition of hands-on skills necessary for the green economy. By addressing both the pedagogical and technical dimensions of solar energy education, this study hopes to set a precedent for broader educational reforms in renewable energy training. The learning media developed through this research not only aligns with national priorities but also supports global sustainability objectives by fostering local capabilities in clean energy technologies.

The novelty of this research is that it involves the integrated development of contextualized and competency-based learning media in the generation of solar power, especially for undergraduate electrical engineering education in Indonesia. Unlike the more traditional instructional approaches that merely emphasize theoretical content and rely on imported laboratory tools, this study introduces the locally adapted and pedagogically anchored system of media for bridging the gap between conceptual understanding and practical skill acquisition. Utilizing the ADDIE model-a systematic approach for Analysis, Design, Development, Implementation, and Evaluation-the research product will not only include the development of multimedia instructional materials but also integrate hands-on training kits along with national competency standards or SKKNI. Thus, through this dual innovation, students understand not just the theory behind the photovoltaic systems but also develop

applied technical competencies through interactive engagement with real components: solar panels, batteries, inverters, and charge controllers.

## 2 Learning Media Development for Solar Power Generation Education

Effective learning media transforms these abstract theories into practical knowledge in higher education, especially regarding renewable energy [10]. The reason for the minimal utilization of 207.8 GW solar potential in Indonesia is not only because of the lack of practical training material to support it, but also because such materials are not widely used [3][4]. Such a Solar Power Generation (SPG) learning module offers printed guides, electronic media, and hands-on kits to improve cognitive and psychomotor competencies of students regarding photovoltaic systems [13][14]. ADDIE model (Analysis, Design, Development, Implementation, Evaluation) has been used for the development of learning media to be in line with objectives and usability [25]. Effectiveness and impact on society can be assessed by Kirkpatrick's Four Levels and Kaufman's Five Levels [17][18]. Practical feasibility, safety, cost-efficiency, and curricular relevance are essential in technical education [19]. SPG systems convert sunlight into electricity with the use of PV panels, inverters, and controllers [34][35]. Prior studies draw on the importance of usability, interactivity, and clarity of the learning media [17][20][21][22]. Over 85% content validity has been achieved by digital solar modules; there is improvement in the student outcomes. Innovation supporting this approach includes an AI-based SolarFlux Predictor [28][29]. This concept further aligns with Indonesia's Merdeka Belajar policy of strengthening the nation's renewable energy competencies to achieve sustainable workforce development [18][23][24].

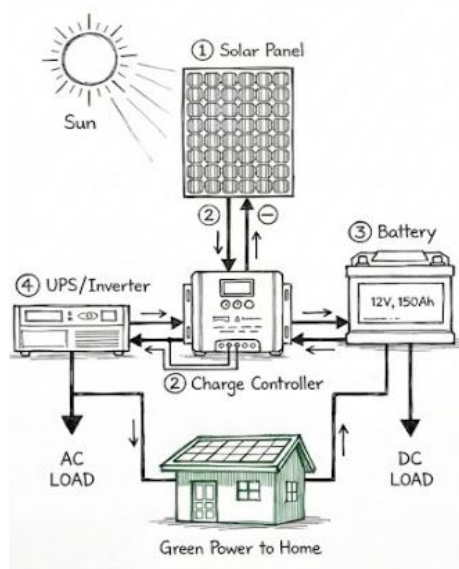


Figure 1. Solar power system [35]

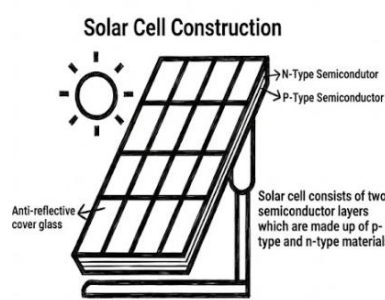


Figure 2. Solar cell [35]

## 3 Method

This study employs the ADDIE development model comprising Analysis, Design, Development, Implementation, and Evaluation to create and assess a solar power generation learning media for undergraduate students in the Electrical Engineering Education Study Program at Universitas Negeri Yogyakarta. The model is applied iteratively to allow flexibility in revising the learning media based on continuous feedback. The Development stage involved producing the media and supporting materials, including student worksheets and usage guides. The prototypes were validated by subject

matter experts. In the Implementation stage, the learning media were tested with 29 students. Observations were made on student engagement and interaction with the media.

A one-group pretest-posttest design was used to assess learning gains. Data was collected using questionnaires (Likert scale), and test instruments. Validity and reliability of the questionnaires were tested using Pearson's product moment and Cronbach's alpha, respectively. SPSS was used in this study to analyze the data and determine how effective the developed solar power generation learning media were. This, therefore, involved comparing the pretest–posttest scores of students using a paired sample t-test.

#### 4 Results and Discussion

Results of the initial development of the Solar Power Generation Module using the ADDIE instructional design model. This process was aimed at enhancing the practical competencies of undergraduate students in the Electrical Engineering Education Study Program, particularly in the area of renewable energy.

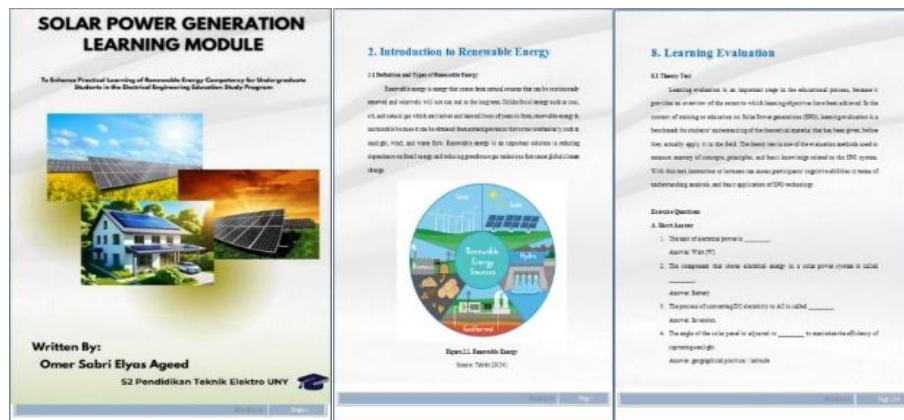


Figure 3. Learning module cover

##### 4.1 Development Stage, Implementation Stage, and Evaluation Stage

The Development, Implementation, and Evaluation stages of the study highlight the structured approach taken to produce and test a solar power generation learning module for undergraduate students. During the Development stage, the module was created in both printed and interactive PDF formats, incorporating design improvements such as color-coded sections and clickable contents. Validation was conducted by two solar energy experts and two instructional designers, whose feedback led to revisions in technical clarity, diagram accuracy, font sizing, and visual consistency. As a result, Version 1.0 of the module was completed with high confidence in its educational and technical quality. In the Implementation stage, the module was piloted with 29 students through weekly 90-minute lab sessions. Student perceptions of the module were collected through questionnaires measuring clarity, usefulness, and enjoyment.

##### 4.2 Product Trial Results

The overall feasibility for a media validity test, as presented in Table 1, with a percentage of 91.67%, puts the learning media into the very feasible category. All assessment indicators are above 83%, which confirms that both the instructional content and technical aspects are appropriate to include in the Electrical Engineering Education curriculum. The Clarity of Material indicator achieved a score of 100%, revealing that the media is clearly and well-structured in terms of instructional design, thus being accessible for students at different levels of prior knowledge. Other indicators, such as Suitability of Material (93.33%) and Benefits for Practical Learning (96.67%), confirm the relevance of the media with regard to linking theoretical knowledge with hands-on applications. Media Display Design and User Involvement received slightly lower scores (86.67% and 83.33%, respectively), indicating where improvements might be needed regarding interactivity and

visual engagement in the future. The Technical Feasibility score was 90%, which means that the media functions reliably and is suitable for classroom or laboratory use regarding its pedagogical soundness and operational robustness.

**Table 1.** Results of the validity assessment of solar power generation learning media

Assessment Indicator	Media		Materials		Category
	Total Score	Percentage	Total Score	Percentage	
Suitability of Material	28	93.33%	30	93.75%	Very Feasible
Clarity of Material	30	100%	28	87.50%	Very Feasible
Media Display Design	26	86.67%	27	84.38%	Very Feasible
User Involvement	25	83.33%	29	90.63%	Very Feasible
Technical Feasibility	27	90.00%	26	81.25%	Very Feasible
Benefits for Practical Learning	29	96.67%	31	96.88%	Very Feasible

The material validity test resulted in an overall feasibility percentage of 89.57%, which also falls into the very feasible category. Benefits for Practical Learning received the highest score, at 96.88%, indicating the learning media appropriately helped to enhance the students' practical abilities in managing a solar energy system. Suitability of Material and Clarity of Material Presentation received scores of 93.75% and 87.50%, respectively, confirming the accuracy and coherence of the contents and how interesting they were to the learners. Although Media Display Design and Technical Feasibility scored relatively low, at 84.38% and 81.25%, respectively, they are still within the feasible levels and confirm that only minor improvements on the visuals and ergonomic aspects would be required. The material validity results confirm that the developed learning media is conceptually sound, instructionally effective, and aligns with the curricular standards for renewable energy education.

### 4.3 Product Revision

After the validation stages, several product revisions were made based on expert and user recommendations. Table 2 show the suggestions and implemented revisions of learning media in its final form, therefore, the Solar Power Generation Learning Module (Fig. 4) represents a carefully validated educational innovation whose systematic refinement has integrated theory, practice, and assessment to develop students' competencies in renewable energy. The findings of the product trial provide very strong support for the module's effectiveness and its potential for wider adoption in engineering education programs in sustainable technologies.

**Table 2.** Suggestions and recommendations for improvement of learning media

No	Suggestions and Recommendations	Implementation of Revision
1	Addition of Content Map at the beginning of the module to make the learning flow clearer	Content Map has been added to the Introduction Chapter
2	Addition of illustrative images to the explanation of components and system diagrams to clarify the material	Images have been added
3	The number of evaluation questions is still lacking, it should be increased to 20 questions to measure learning achievement	Evaluation questions are increased to 20 questions
4	Include feedback on passing grade so that participants can find out the minimum passing limit	Passing grade feedback is added to the evaluation section

### 4.4 Final Product Review

Validity and reliability tests on the learning media of solar power generation from the perspective of student users indicated that the developed product met the necessary psychometric standards for it to be both valid and reliable as a learning tool. Testing for validity and reliability found that the Solar Power Generation Learning Module met robust psychometric standards. From Table 3, all 36 items represent six key indicators-Suitability of Material (SM), Clarity of Material Presentation (CMP), Media Display Design (MDD), User Involvement (UI), Technical Feasibility (TF), and Benefits for Practical Learning (BPL)-have an r-count above or very close to the r-table value of 0.355. The strongest coefficients were in TF1 = 0.625, TF3 = 0.642, and UI4 = 0.588, indicating strong correlations between each item with their respective constructs. This confirms that the instrument is

valid, and the intended variables have been measured. The students' perception of the learning media as conceptually coherent, pedagogically sound, and visually engaging is consistent with a principle of instructional design emphasizing clarity, relevance, and interactivity. The reliability testing had a Cronbach's Alpha of 0.891, which is higher than the threshold limit 0.70 recommended for good internal consistency, as shown in Table 3. That is to say, the students responded coherently and dependably for all the indicators.

**Table 3.** Product trial results validity and reliability test results by user (student)

Indicators	Range of r-count	r-table	Cronbach's Alpha	Interpretation
Suitability of Material (SM)	0.352 – 0.802	0.355	0.891	Valid and Reliable
Clarity of Material Presentation (CMP)	0.362 – 0.519			Valid and Reliable
Media Display Design (MDD)	0.364 – 0.492			Valid and Reliable
User Involvement (UI)	0.340 – 0.588			Valid and Reliable
Technical Feasibility (TF)	0.419 – 0.642			Valid and Reliable
Benefits for Practical Learning (BPL)	0.367 – 0.499			Valid and Reliable

The validity test of the practical competency instrument (Table 4) revealed that all 14 indicators had r-count values greater than 0.355, showing their statistical validity. The indicators Usefulness (U1–U2), Ease of Use (EOU1–EOU4), Attitude Toward Use (A1–A2), Compatibility (C1–C2), Habit (H1–H2), and Actual Effectiveness (AE1–AE2) correspond to the TAM and UTAUT frameworks. Among them, H1 reached 0.614, and AE2 reached 0.550, which means that besides getting benefits from media, students have developed familiarity and their technical performance has improved. In this regard, ADDIE-based development ensured that the design was user-centered and accessible, which directly supported learning effectiveness. It means that an instrument to measure students' practical competencies is valid and reliable, while learning media effectively enhances the students' practical and cognitive mastery in solar power systems.

**Table 4.** Product trial results validity test results by students' practical competency

Indicators	Range of r-count	r-table	Cronbach's Alpha	Interpretation
Usefulness (U1–U2)	0.385 – 0.515	0.355	0.761	Valid and Reliable
Ease of Use (EOU1–EOU4)	0.361 – 0.449			Valid and Reliable
Attitude Toward Use (A1–A2)	0.370 – 0.397			Valid and Reliable
Compatibility (C1–C2)	0.422 – 0.512			Valid and Reliable
Habit (H1–H2)	0.365 – 0.614			Valid and Reliable
Actual Effectiveness (AE1–AE2)	0.410 – 0.550			Valid and Reliable

The results summarized in Table 5 indicate a clear improvement in students' understanding and skills following the implementation of the Solar Power Generation Learning Module. During the pretest, students achieved a total score of 1,544, corresponding to a mean score of 53.24 with a score range of 4–96, which reflects a moderate to low baseline level of knowledge. This suggests that before the intervention, students had uneven conceptual and practical understanding related to solar power generation systems.

**Table 5.** Summary of pretest and posttest results

Assessment	Total Score	Mean Score	Score Range	Interpretation
Pretest	1544	53.24	4 – 96	Moderate–Low Baseline
Posttest	2116	72.97	20 – 100	Significant Improvement

After taking the module, the posttest results revealed a total score of 2,116 and an average score of 72.97 with scores ranging from 20 to 100. This represents a significant improvement in overall performance, suggesting that most of the students performed at a higher level of mastery. The mean shift upwards and score distribution indicates improvement of cognitive and practical competencies through the module, further reinforcing its pedagogical value for use as an instructional tool in renewable energy education.

In addition, a quantitative measure of the efficacy of the learning module can be estimated by the normalized gain (N-Gain) score. An N-Gain of 0.42 falls in the range of moderate gain, showing that the learning module functioned decently in improving the understanding of the solar generation systems.

$$N - Gain = \frac{Posttest\ Mean - Pretest\ mean}{100 - Pretest\ Mean} \tag{1}$$

$$N - Gain = \frac{72.97 - 53.24}{100 - 53.24} = 0.42 \tag{2}$$

The paired samples t-test showed that there was a statistically significant increase in students' understanding after going through the developed learning module (Table 6). Precisely, there was an increase of 19.72 points in the mean score from the pretest to the posttest, revealing a very good gain in learning outcomes. The calculated t-value of -2.670 with a p-value of 0.012, that is,  $p < 0.05$ , proves that the difference is real and not by chance, hence really showing an increase in student learning. The negative value of 't' has no meaning other than that it simply reflects the direction of subtraction; it simply shows here that posttest scores were higher.

**Table 6.** T-Test Results

		Paired Samples Test							
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-19,72414	39,78415	7,38773	-34,85722	-4,59106	-2,670	28	0,012

This statistical evidence presents support for the effectiveness of module-based learning media in knowledge acquisition and comprehension related to renewable energy, particularly for concepts of solar power generation systems. The findings agree with previous research that points out the importance of interactive context-based instructional modules in significantly enhancing learners' conceptual understanding and interest in technical subjects [32]. Therefore, the established module succeeded in ensuring meaningful learning took place and laid a strong foundation for similar integrations in energy education and other related STEM fields.

**4.5 Discussion**

Learning media based on the module provides a number of educational advantages that facilitate effective learning. Modules provide a guided and flexible learning process, enabling students to learn the educational content on their own and according to their own pace. The systematic order of the knowledge, facilitated by the concept map and evaluation activities with feedback, ensures a comprehensive learning process focused on developing competencies and skills [36].

In the area of solar power generation, a relatively new area of renewable energy issues that some students find less familiar, the developed module serves as a great link between conceptual and practical understanding. The educational material provided helps students to understand the working of photovoltaic schemes, to identify major components of these schemes, as well as to understand their applications. Secondly, the use of exercises and cases helps to engage students actively with the material and to apply conceptual solutions to practical issues. In other words, from a pedagogical viewpoint, a competency-based approach to learning with a focus on measuring conceptual understanding and developing practical skills can be argued to be appropriate in such a case [37].

Despite the relatively favorable learning outcomes, some reflection on the feedback suggests that there was slightly weaker performance with respect to the visual presentation and engagement element of the learning routine. This could be due to several reasons. Firstly, the learning routine placed more emphasis on accuracy and understanding, which meant that the presentation that was delivered was possibly less engaging and interactive. Another reason for this could be that the online learning platform that was employed did not facilitate highly interactive multimedia components like animation, simulation, or visual interactive tools, which are known to facilitate high engagement within learning platforms for technical education. Therefore, although there was successful transfer of

learning, the experience did not necessarily satisfy the requirements of visual interactivity associated with modern online learning platforms [38].

Despite this, the module embodies a profound aspect of contextual learning, especially in the realm of engineering fields, whereby there is an integration of theoretical knowledge with real-life applications as per the demands of the industry related to the field of renewable energy sources. Analysis of the findings shows that the module not only refines their cognitive learning but also enables the learners to be better prepared for the solution of real-life problems related to the industry concerned, such as the energy industry. Module-learning media can be considered the most appropriate learning tool for enhancing the competency levels of the learners in the field of Electrical Engineering Education [38].

The successful execution of the module using the online learning environment further strengthens the fact that vocational and technology learning can be successfully accomplished in virtual settings with well-designed learning. Despite the absence of the contact presence, the employment of graphics, explanations, and problem-solving tasks enabled the learners to conceptualize the solar cell and the power conversion process that would otherwise be hard to directly experience. Furthermore, the asynchronous nature of the online learning environment enabled the learners to return to the difficult concepts as often as they wanted to learn at their own pace [39].

The module development process followed the ADDIE model, which helped improve the module continuously through feedback from students and faculty members. The involvement of the users in the evaluation process helped improve the relevance and applicability of the module, ensuring that it was meaningful in the academic field and not just academic in nature [40]. The module was competent in meeting the goals and requirements it had set out to achieve, and it was fit for the users it was directed at. The module was well-designed in that it was appropriate to the target audience and was based on the requirements of the users in the academic field that it was suited for [40].

#### 4.6 Research Limitations

This study was conducted with the aim of developing and evaluating learning media on solar power generation to improve the practical understanding of renewable energy competencies among undergraduate students. While the research provides meaningful insights and demonstrates the potential effectiveness of the developed module, several limitations must be acknowledged:

- a. The research was conducted among a small population consisting of 29 undergraduate students from the Electrical Engineering Education Program at Universitas Negeri Yogyakarta; therefore, the findings may not be readily generalized to other populations.
- b. The study employed a one-group pretest-posttest design without a control group. As a result, it is difficult to attribute all observed learning gains exclusively intervention. The lack of a control group means that nothing could be done to eliminate extraneous variables that could be operating outside this study to affect student performance.
- c. This study concentrated on the learning outcomes acquired through the learning program. It did not assess the long-term retention of the knowledge gained, the application of the skills learned in real-world situations, and the long-term effect of the learning program on learning performance.
- d. The data on perceptions was collected from students through a self-reported Likert scale questionnaire. The methodology of such a study can never be objective. The responses to the study can be influenced by bias. The students can rate the module highly based on their perceptions and not based on whether the module met its intended goals.

## 5 Conclusion

Based on the results of the analysis, this study concludes that the development of learning media for solar power generation successfully addressed the identified gaps in renewable energy education. The initial needs analysis, conducted through input from instructors and students, revealed a clear lack of understanding among students in both theoretical and practical aspects of solar energy systems. These findings formed the foundation for designing targeted instructional materials. The design process followed a systematic approach based on the ADDIE model, resulting in a module that integrated concept maps, supporting diagrams, feedback-oriented evaluations, and case study-based exercises, all aimed at developing renewable energy competencies progressively and thematically.

When applied in an online learning environment, the module successfully facilitated interactive, experiential, and situational learning, increasing student engagement despite the absence of direct laboratory practice. Furthermore, the evaluation results showed a statistically significant improvement in students' renewable energy competencies ( $p = 0.012 < 0.05$ ), supported by a high reliability coefficient (Cronbach's Alpha = 0.891). The study confirms that the developed instructional media is a valid and effective tool for enhancing practical and theoretical understanding in solar power education.

## 6 Acknowledgment

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