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**ANALYSIS OF CONCEPTUAL UNDERSTANDING IMPROVEMENT THROUGH SOLAR CELL EXPERIMENTS IN SCIENTIFIC-BASED PHYSICS LEARNING**

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**Abstract**

*The global energy transition toward renewable sources has increased the urgency of integrating solar energy concepts into physics education. This study analyzes the effectiveness and characteristics of solar cell experiments in supporting scientific-based learning at the senior high school level. The research employed a quantitative pre-experimental design using a one-group pretest–posttest approach. The participants were 32 twelfth-grade students in Pontianak, Indonesia. Research instruments included a conceptual understanding test, scientific activity observation sheets, student response questionnaires, and inquiry-based experiment worksheets. Data were analyzed using mean scores, N-gain calculations, and percentage-based descriptive analysis. The results indicate a significant improvement in students' conceptual understanding, with the average score increasing from 58 to 82 and an N-gain value of 0.57 in the moderate category. The highest improvement was observed in students' understanding of the effect of light intensity on electrical power output. The implementation of scientific learning stages showed high percentages across all phases, particularly in the experimenting phase (94%). These findings suggest that solar cell experiments effectively enhance both conceptual understanding and science process skills. The study concludes that simple, measurable, and contextual solar cell experiments can integrate empirical measurement, data analysis, and scientific communication into a coherent learning sequence. The integration of photovoltaic experiments is recommended to strengthen energy literacy and scientific literacy in secondary physics education.*

**Keywords:** Solar cell; renewable energy; scientific-based learning; conceptual understanding; science process skills.

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**INTRODUCTION**

The global energy transition has become a strategic international agenda in response to the climate crisis, which demands an accelerated shift from fossil-based energy systems to renewable sources. Reports from the International Energy Agency emphasize that accelerating clean energy development is essential to achieving net zero emission targets (Herrera et al., 2015; Prihatiningtyas & Putra, 2018). Over the past decade, global solar energy capacity has increased significantly, reinforcing the economic and technical relevance of photovoltaic (PV) technology as a major component of modern energy portfolios (Chien et al., 2018; Guo et al., 2021). This trend indicates



that photovoltaic technology is not only an environmental solution but also increasingly cost-competitive and technologically mature (Zimny et al., 2018).

Indonesia possesses strong geographical potential for solar energy development. Located along the equator, the country receives relatively stable and high-intensity solar radiation throughout the year, creating substantial photovoltaic potential. Despite this advantage, solar energy concepts have not been fully integrated into physics education at the senior high school level. Physics instruction remains predominantly lecture-based and textbook-oriented, with limited authentic experimental experiences that enable students to scientifically understand the operational mechanisms and performance characteristics of solar cells (Salasati et al., 2022). Preliminary observations in several high schools indicate that laboratory activities are still constrained by limited equipment and insufficient experimental design. This condition contributes to low levels of science process skills, particularly in measurement, data analysis, and evidence-based reasoning. Physics learning therefore requires systematic integration of conceptual understanding, experimentation, and quantitative reasoning (Salasati et al., 2022).

Scientific-based learning emphasizes five essential stages: observing, questioning, experimenting, reasoning, and communicating. These stages align with the nature of physics as an experimental science. Photovoltaic experiments provide opportunities for students to measure voltage, current, and electrical power while manipulating variables such as light intensity and panel inclination angle. Through these activities, students can strengthen their understanding of cause-and-effect relationships and develop data interpretation skills (Salasati et al., 2022).

Constructivist theory provides the theoretical foundation for integrating experimentation into learning, as knowledge is actively constructed through direct experience. Photovoltaic experiments not only reinforce concepts related to the photoelectric effect and energy conversion but also foster energy literacy and environmental awareness among students (Salasati et al., 2022). Furthermore, the implementation of photovoltaic experiments supports the development of scientific literacy, science process skills, and critical thinking abilities. Previous studies have demonstrated that integrating mini photovoltaic laboratory experiments and investigation-based worksheets can significantly improve conceptual understanding and science process skills (Chien et al., 2018; Salasati et al., 2022). Based on these considerations, this study aims to examine the characteristics of solar cell experiments as renewable energy technology that effectively support scientific-based learning in enhancing students' conceptual understanding and science process skills.

## **METHOD**

This study employed a quantitative pre-experimental design using a one-group pretest–posttest approach to analyze the effectiveness of solar cell experiments in supporting scientific-based physics learning. The participants were 32 twelfth-grade students from a senior high school in Pontianak, Indonesia, selected purposively because they had previously studied dynamic electricity and energy conversion. The research was conducted in the school physics laboratory equipped with basic facilities, including small photovoltaic panels, multimeters, and adjustable light sources.

Data were collected using four instruments: a conceptual understanding test consisting of multiple-choice and short-answer items, a scientific activity observation sheet assessing the stages of observing, questioning, experimenting, reasoning, and communicating, a student response questionnaire, and an inquiry-based experiment worksheet guiding students through measurement and data analysis. All instruments were validated by two physics education lecturers and one physics teacher to ensure content validity. The intervention was implemented in two instructional sessions, during which students measured voltage and current under varying light intensities and panel inclination angles, analyzed the relationship between light intensity and power output, interpreted graphical data, and presented their findings. Data were analyzed using mean scores and normalized

gain (N-gain) to determine conceptual improvement, while observational and questionnaire data were analyzed descriptively using percentages.

## RESULTS AND DISCUSSION

### Improvement of Conceptual Understanding

The analysis of pretest and posttest scores demonstrates an improvement in students' conceptual understanding following the implementation of the solar cell experiment. The results are presented in Table 1.

**Table 1. Pretest, Posttest, and N-Gain Results**

Measured Aspect	Pretest	Posttest	N-Gain	Category
Overall Mean Score	58	82	0.57	Moderate
I-V Curve	55	80	0.56	Moderate
Electrical Power	60	85	0.63	Moderate
Efficiency	52	78	0.54	Moderate
Effect of Light Intensity	65	88	0.66	Moderate

As shown in Table 1, the average score increased by 24 points, with a normalized gain of 0.57 in the moderate category. Improvement occurred across all conceptual indicators. The highest gain was observed in the "effect of light intensity" indicator, suggesting that direct manipulation of physical variables strengthened students' understanding of cause-and-effect relationships between light input and electrical output.

These findings align with previous research indicating that experiment-based learning involving direct measurement and data analysis significantly enhances science achievement (Atar & Atar, 2012; Dai et al., 2011; Mohammed & Amponsah, 2021; Yuniarti, 2023). Studies on photovoltaic laboratory integration also confirm that measuring voltage and current and analyzing I-V characteristics contribute to deeper conceptual understanding and science literacy (Chien et al., 2018; Salasati et al., 2022).

### Implementation of Scientific-Based Learning

The implementation of scientific learning stages was observed during the instructional sessions. The results are summarized in Table 2.

**Table 2. Percentage of Scientific Learning Stage Implementation**

Scientific Stage	Percentage (%)
Observing	90
Questioning	82
Experimenting	94
Reasoning	85
Communicating	80

Table 2 indicates that the experimenting stage obtained the highest percentage (94%), reflecting active student engagement in hands-on measurement activities. The reasoning and communicating stages also showed strong implementation, indicating that students not only conducted measurements but also analyzed and presented their findings.

The high level of implementation across scientific stages supports the constructivist principle that knowledge is built through direct experience and empirical investigation (Ayob et al., 2022;

Salasati et al., 2022; Yuliati & Saputra, 2019). By integrating observation, experimentation, and communication, the solar cell experiment strengthened science process skills such as measurement, data interpretation, and evidence-based reasoning (Chien et al., 2018; Darmaji et al., 2019).

The moderate N-gain value (0.57) indicates that the solar cell experiment was effective in improving conceptual understanding of renewable energy topics. The contextual nature of photovoltaic experiments, combined with measurable variables and graphical analysis, provided meaningful learning experiences. This finding is consistent with research highlighting the effectiveness of simple photovoltaic laboratory setups in enhancing quantitative reasoning skills (Chien et al., 2018; Crabtree et al., 2011; Zimny et al., 2018).

Furthermore, integrating photovoltaic experiments into physics education is relevant to the global energy transition agenda, which emphasizes the increasing technical and economic significance of solar technology (Guo et al., 2021; Herrera et al., 2015; Prihatiningtyas & Putra, 2018). Embedding renewable energy contexts within scientific-based learning not only improves academic performance but also strengthens students' energy literacy and environmental awareness. Overall, the combination of improved conceptual scores and high implementation of scientific learning stages suggests that solar cell experiments represent an effective instructional approach for renewable energy education at the secondary school level.

## **CONCLUSION**

This study aimed to examine the characteristics and effectiveness of solar cell experiments as renewable energy technology in supporting scientific-based learning at the senior high school level. The findings demonstrate that a simple, measurable, and contextual solar cell experimental design is feasible for classroom implementation and effectively integrates empirical measurement with conceptual analysis. The experiment enabled students to measure voltage, current, and power while analyzing the relationship between light intensity, panel inclination angle, and electrical output in an evidence-based manner. The implementation of the solar cell experiment significantly improved students' conceptual understanding, as reflected by the increase in the average score from 58 to 82 and a normalized gain of 0.57 in the moderate category. Improvement was observed across all conceptual indicators, with the highest gain in understanding the effect of light intensity on power output. This result indicates that direct manipulation of variables strengthens students' comprehension of causal relationships in physics concepts.

Furthermore, the experiment successfully activated all stages of scientific-based learning, including observing, questioning, experimenting, reasoning, and communicating. Students were actively engaged not only in conducting measurements but also in interpreting data and presenting their findings scientifically. These outcomes suggest that solar cell experiments are effective in enhancing both conceptual understanding and science process skills. Pedagogically, integrating solar cell experiments supports data-driven physics instruction and reinforces students' energy literacy within the context of the global energy transition. Practically, the modular and simplified experimental design allows implementation in schools with limited laboratory facilities. Renewable energy learning through experimentation therefore represents a relevant and strategic approach to strengthening scientific literacy and preparing students to address future sustainability challenges.

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## REFERENCES

- Atar, H., & Atar, B. (2012). Investigating the multilevel effects of several variables on Turkish students' science achievements on TIMSS. *Journal of Baltic Science Education*, 11(2), 115–126. <https://doi.org/10.33225/jbse/12.11.115>
- Ayob, S. M., Tan, C. W., Ayop, R., & Daud, M. F. (2022). Implementation of photovoltaic academic service learning at school and its impact on student schools and student facilitators. *ASEAN Journal of Engineering Education*, 6(2), 26–30. <https://doi.org/10.11113/ajee2022.6n2.103>
- Chien, S., Su, C., Chou, C., & Li, W. (2018). Visual observation and practical application of dye-sensitized solar cells in high school energy education. *Journal of Chemical Education*, 95(7), 1167–1172. <https://doi.org/10.1021/acs.jchemed.7b00484>
- Dai, D., Gerbino, K., & Daley, M. (2011). Inquiry-based learning in China: Do teachers practice what they preach, and why? *Frontiers of Education in China*, 6(1), 139–157. <https://doi.org/10.1007/s11516-011-0125-3>
- Guo, L., Vengalil, M., Abdul, N. M. M., & Wang, K. (2021). Design and implementation of virtual laboratory for a microgrid with renewable energy sources. *Computer Applications in Engineering Education*, 30(2), 349–361. <https://doi.org/10.1002/cae.22459>
- Herrera, R. S., Márquez, M., Mejías, A., Morueta, R. T., & Andújar, J. M. (2015). Exploring the usability of a remote laboratory for photovoltaic systems. *IFAC-PapersOnLine*, 48(29), 7–12. <https://doi.org/10.1016/j.ifacol.2015.11.205>
- Mohammed, S., & Amponsah, K. (2021). Teachers' and educational administrators' conceptions of inquiry: Do they promote or constrain inquiry-based science teaching in junior high schools? *Journal of Curriculum and Teaching*, 10(3), 58. <https://doi.org/10.5430/jct.v10n3p58>
- Prihatiningtyas, S., & Putra, I. A. (2018). Efektivitas penggunaan alat peraga sederhana berbasis pendekatan sains teknologi masyarakat pada materi fluida statis. *Jurnal Riset dan Kajian Pendidikan Fisika*, 5(2), 102. <https://doi.org/10.12928/jrkpf.v5i2.10988>
- Salasati, I. L., Suryatna, A., & Suhandi, H. (2022). Analisis indikator keterampilan proses sains yang dapat dikembangkan melalui LKS praktikum berbasis inkuiri terbimbing pada topik titrasi asam-basa. *Jurnal Riset dan Praktik Pendidikan Kimia*, 10(1), 62–70. <https://doi.org/10.17509/jrppk.v10i1.52153>
- Yuliati, Y., & Saputra, D. S. (2019). Urgensi pendidikan STEM terhadap literasi sains mahasiswa calon guru sekolah dasar. *Proceedings of the ICECRS*, 2(1), 321–326. <https://doi.org/10.21070/picecrs.v2i1.2420>
- Yuniarti, L. (2023). Differentiating instruction in inquiry-based learning to assess science process skills. <https://doi.org/10.46529/socioint.202330>
- Zimny, J., Bielik, S., Michalak, P., & Bojko, M. (2018). The laboratory stand for measurements and analysis of photovoltaic modules. *International Journal of Electrical Engineering Education*, 55(2), 142–154. <https://doi.org/10.1177/0020720917750954>