Model of Educational Reconstruction Approach and Guided Inquiry to Correct Vocational Students' Misconceptions About Solar Cells

M. Raynaldo Sandita Powa, University of Bengkulu, Indonesia

The Asian Conference on Arts & Humanities 2025
Official Conference Proceedings

Abstract

Science learning in vocational high schools (SMK) should be directed to support vocational-character education that is contextual with a strong understanding of scientific concepts, particularly physics in the technical expertise field. However, the learning process often remains non-contextual, leading to misconceptions, especially regarding the principles of photovoltaic cell operation. This study aims to identify and reconstruct the misconceptions of tenth grade Computer and Network Engineering students regarding photovoltaic cells. Based on initial findings, 80% of students believed that electrical energy is generated from solar heat, while the correct concept involves the interaction of photons with semiconductors, which triggers electron movement. A study of the Science and Social Projects textbooks used in SMK revealed that photovoltaic cell material only covers theory and exercises without in-depth explanations, making it less relevant to vocational education, which emphasizes practical skills. This research employs the Model of Educational Reconstruction (MER) using Qualitative Content Analysis (QCA) method with guided inquiry learning, supported by YouTube videos as media showing solar cell simulations and experiments. The results indicate that this approach effectively corrected students' misconceptions and improved their understanding of the basic concepts of photovoltaic cells, with all students (100%) successfully comprehending the scientific principle of photovoltaics.

Keywords: photovoltaic cell, contextual learning, vocational school, misconception, model of educational reconstruction

Introduction

Science originates from the fundamental nature of humans to continuously ask questions, think creatively, and innovate to solve problems in their lives, moving from evidence to conclusions (McComas & Kampourakis, 2015). This can be seen in the awareness of the harmful effects of fossil fuel-based energy and the fact that fossil energy takes millions of years to regenerate, which drives human creativity to develop and utilize alternative energy sources as a complement to conventional fossil fuels—eventually replacing them entirely. This understanding needs to be disseminated through science education in schools as a step toward fostering environmentally conscious individuals in the future.

Learning in Vocational High Schools (*SMK*) adheres to the characteristics of vocational education, which emphasize "learning by doing" and "hands-on experience" (DITPSMK Kemendikbud, 2018). Technical and Vocational Education Training (TVET) requires vocational education to be relevant to the needs of the workforce, meaning that learning strategies should focus on developing skills and competencies based on industry demands while ensuring that they are practical, safe, accessible, and cost-effective (Sudira, 2016). Science education in SMK is integrated into the subject *Projek Ilmu Pengetahuan Alam dan Sosial* (IPAS) / Science and Social Project and is categorized within the vocational group under the *Kurikulum Merdeka*. Ideally, IPAS project-based learning in SMK should be contextual and aligned with the characteristics of vocational education. Contextual science learning means that concepts are connected to real-life situations. Scientific concepts do not stand alone but are interrelated with other concepts and interdisciplinary (Duit, 2007), thereby shaping students' knowledge (Lestari et al., 2015). The knowledge students construct is influenced by their daily life experiences and various factors such as environment, parents, and peers, which may not necessarily align with scientific facts and expert conceptions (Lestari et al., 2015). Ultimately, scientific knowledge that does not conform to scientific facts can lead to misconceptions in interpretation, application, and conceptual structure (Resbiantoro & Nugraha, 2017).

One of the physics topics included in the *Projek IPAS* (Science and Social Project) subject for the technical field in Vocational High Schools (*SMK*) is Renewable Energy, which is covered under the learning achievement standard Energy and Its Transformations. One key aspect discussed is Solar Cells, which require a comprehensive understanding of wave-particle duality (photovoltaic properties), semiconductors, and dynamic electricity. Moreover, this topic can be integrated with technology through the use of microcontrollers and sensors. Based on a literature analysis of the *Projek IPAS* textbook used in classroom learning, the *Solar Cell* material is presented with minimal theoretical explanation and only includes efficiency formulas. However, solar cell concepts could be delivered in a more engaging and contextual manner as an integration of science and technology, tailored to the conditions of each educational institution.

One of the instructional models that can be used is the guided inquiry learning model. Through guided inquiry in physics education, students are actively engaged in problem-solving using contextual problem scenarios, where they must integrate physics principles to find solutions (Nasir et al., 2022). Inquiry-based learning can be facilitated with the aid of instructional videos. The use of learning videos has been shown to enhance student learning outcomes and encourage active participation in the learning process (Hafizah, 2020). Implementing instructional videos can serve as a cost-effective alternative for delivering contextual learning, especially when compared to laboratory experiments that require substantial financial resources—such as solar cell experiments, which involve expensive.

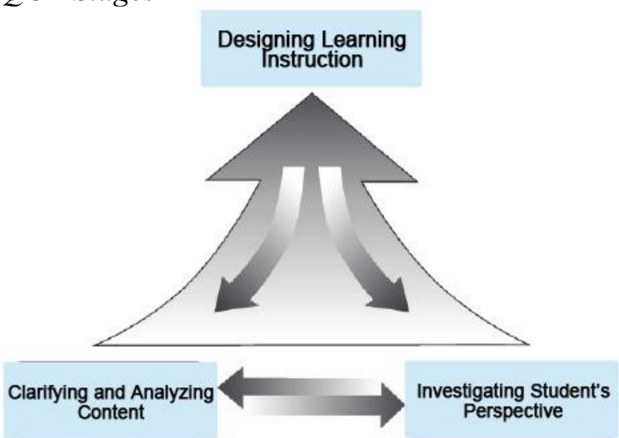
One approach that is expected to address scientific misconceptions in learning is the Model of Educational Reconstruction (MER). The restructuring of learning through this model can make scientific perspectives easier to understand and more meaningful (Sam et al., 2016). The components of MER include: (1) Analysis of content/learning structure, (2) Research on teaching and learning, and (3) Development and evaluation of learning (Duit, 2007). Research conducted by Niebert and Gropengießer (2014) and Sam et al. (2016) has shown that the MER approach can guide students' misconceptions toward scientifically accurate understandings.

Based on the description above, this study aims to reconstruct science learning by aligning students' conceptions with scientific conceptions using the Inquiry learning model. This approach is expected to correct students' misconceptions about the working principles of solar cells. Therefore, this study is titled “Model of Educational Reconstruction Approach and Guided Inquiry to Correct Vocational Students' Misconceptions About Solar Cells”.

Methodology

This study is based on the Model of Educational Reconstruction (MER) and employs the Qualitative Content Analysis (QCA) method with two research questions: (1) What conceptions do students in the technical field have regarding solar cells?; (2) What instructional approach can be used to integrate students' conceptions with scientific conceptions in the implementation of solar cell learning?. The QCA stages to be conducted include: (1) Investigating students' perspectives; (2) Clarifying and analyzing content, and; (3) Designing learning instruction. The learning process will then be carried out based on the MER results using the guided inquiry model supported by instructional videos. The research instrument consists of written interview questions on the topic of Solar Cells, and the study sample includes 25 tenth-grade students from the Computer and Network Engineering program at a Vocational High School.

Figure 1
QCA Stages



Results and Discussion

Results

Student's Conception Analysis

At this stage, students' conceptions about how solar cells work were assessed through 3 written questions: (1) Sunlight can be converted into electricity using a device called a solar cell. In your opinion, how does a solar cell convert sunlight energy into electrical energy?; (2) Do you think a solar cell can continuously generate electricity? Explain your answer., and; (3) How can a solar cell continue to generate electricity when sunlight is minimal or absent?. All students answered these questions within 20 minutes.

For the first question, 20 students responded that "solar cells obtain electrical energy from the sun's heat", and 5 students responded "absorb energy by exposing them to the sun". For the second question, all students stated that solar cells only work during the day using sunlight and cannot generate energy at night. For the third question, 21 students answered that "solar cells store the generated energy in a battery", and 4 students answered that "energy has been previously stored". From the students' responses, three key misconceptions were identified: (1) Electrical energy is obtained from the sun's heat.; (2) Solar cells only work due to sunlight., and; (3) Batteries can store electrical energy for later use.

Content Analysis: Scientist's Conception

At this stage, a scientific content analysis was conducted using scientific articles to explain the working principles of solar cells and address students' misconceptions. The results of the scientific content analysis were then compared with the analysis of students' conceptions, as presented in the following table:

Table 1
Student's and Scientist's Conception Analysis

No.	Scientist's Conception	Student's Conception	Conclusion
1.	"*Kenaikan temperatur permukaan sel surya menyebabkan sistem kerja solar cell terganggu*". (Pido et al., 2019, p. 29) [The increase in the surface temperature of the solar cell causes the working system of the solar cell to be disrupted] "*Batas titik efisiensi panel surya adalah pada suhu 65°C (149°F). Di atas suhu ini, efisiensi kinerja solar system dapat terganggu karena turunnya tegangan yang dihasilkan.*" (Simanullang et al., 2024) [The limit point of solar panel efficiency is at 65°C (149°F). Above this temperature, the efficient performance of the solar system may be compromised due to a drop in the voltage produced.]	Solar cells obtain energy from the sun's heat	Misconceptions

2.	Light trapping is the **capturing of as many photons as possible from an impinging electro-magnetic (E-M) wave** with the objective of generating heat or charge carriers, excitons, or both (Fonash, 2015)	Solar cells obtain energy from the sun's heat	Misconceptions
3.	Photovoltaic devices can be designed to be effective for electromagnetic spectra **other than sunlight** (Fonash, 2010, p. 2) ... "light" being trapped may lie **anywhere** in that part of the E-M spectrum **extending from the infrared to the ultraviolet** (Fonash, 2015, p. 1) The performance of solar cells is essentially governed by the **light absorption** characteristics of semiconducting light absorbers incorporated into solar cells and the understanding of the **absorber optical properties**... (Fujiwara & Collins, 2018, p 1)	Solar cells only work due to sunlight	Misconceptions
4.	The components used are a solar charger controller, **battery**, Arduino ... (Mayub, 2024, p. 994) The solar cell **power-bank** shows students the phenomenon of changing solar energy into electrical energy, **storing the electrical energy produced** ... (Mayub, 2024, p. 994)	Batteries can be used to store electrical energy from solar cells	Correct Concept

Learning Design and Evaluation

Based on the analysis of students' conceptions and scientific content, an inquiry-based learning design supported by instructional videos was developed. Instructional videos were chosen as an alternative since conducting a solar cell experiment was not feasible. The required experimental equipment (*solar panels, batteries, cables, multimeters, and sensors*) would incur high costs. The learning syntax is as follows:

Table 2
Inquiry Learning Syntax

No	Syntax	Activity
1.	Problem Orientation	Providing a trigger question: • How does sunlight become electricity? • Can solar cells generate electricity without sunlight?
2.	Formulate the question	• What is photovoltaics? • Do solar cells only work with sunlight?
3.	Collecting the data	Observation of learning videos. • https://www.youtube.com/watch?v=fmKlzxLp7Vc • https://www.youtube.com/shorts/X3Sw3pMChCs
4.	Analyzing the data	Discuss from the video that has been shown related to how solar cells work and the rays that affect the performance of solar cells.
5.	Conveying the results	• Conclude the results of observations and video observations. • Deliver the conclusion orally.

Discussions

Regarding students' conception in the first question (*solar cells obtain energy from the sun's heat*), this misconception was corrected by Pido et al. (2019), who stated that the heat from the sun, which increases the temperature of solar cells, can actually disrupt their performance. Therefore, it is incorrect to assume that solar cells convert heat into electricity. Simanullang et al. (2024) further explained that excessive temperatures (*above 65°C*) can reduce the voltage output of a solar cell. From an energy source perspective, Fonash (2015) clarified that solar cells operate by absorbing as many photons of electromagnetic waves as possible. Based on the scientific concept analysis, it can be concluded that the energy generated by solar cells does not come from heat but from photons emitted by sunlight. Moreover, excessive heat can even decrease the efficiency of solar cells. Following this analysis, students were given treatment in the form of an instructional video about how solar cells work. After watching the video and gathering data and facts, students presented their observations orally. As a result, all students correctly answered that solar cells obtain energy from sunlight, where photons collide with the semiconductor material in the solar cell.

Regarding students' conception in the second question (*solar cells only work with sunlight*), this misconception was corrected by Fonash (2010), who stated that solar cells, as photovoltaic devices, can operate beyond just sunlight. Additionally, in another statement, Fonash (2015) explained that light can be captured from any electromagnetic wave, not specifically from sunlight. Fujiwara and Collins (2018) also confirmed that the operation of solar cells is fundamentally determined by the light absorption characteristics of semiconductor light absorbers, with no restrictions on the type of light used, including but not limited to sunlight. Based on this analysis, students were given treatment in the form of observing a YouTube Shorts video titled *"Sunflower Solar Tracker."* In the video, solar cells arranged in a sunflower-like structure were illuminated using a smartphone flashlight, and the solar cells moved following the flashlight's motion. After watching the video and gathering data and facts, students presented their observations orally. As a result, all students correctly answered that solar cells can function with various light sources, not just sunlight.

Conclusion

Based on the results of this study, it can be concluded that the Model of Educational Reconstruction approach and guided inquiry learning with video assistance effectively identified and corrected misconceptions among 10th-grade Vocational High School (SMK) on Computer and Networking Engineering subject students in the IPAS (Science and Social Project) subject on the working principles of solar cells. As a recommendation for future research, implementing practical-based learning methods is suggested to provide students with hands-on experiences, allowing them to engage in a more immersive conceptual reconstruction process regarding solar cell principles.

Acknowledgements

This research was supported by the Indonesia Endowment Fund for Education (LPDP) and Center for Higher Education Funding and Assessment (PPAPT) through the Indonesia Education Scholarship (*Beasiswa Pendidikan Indonesia*) from the Ministry of Higher Education, Science, and Technology of Republic Indonesia. I also extend my gratitude to the

Graduate Program in Science Education, Faculty of Teacher Training and Education, University of Bengkulu, for their academic and institutional support.

References

Duit, R. (2007). Science Education Research internationally: Conceptions, research methods, domains of research. *EURASIA Journal of Mathematics, Science and Technology Education*, *3*(1). https://doi.org/10.12973/ejmste/75369

Fonash, S. (2010). *Solar Cell Device Physics*. Academic Press/Elsevier.

Fonash, S. (2015). *Introduction to Light Trapping in Solar Cell and Photo-detector Devices*. Academic Press/Elsevier.

Fujiwara, H., & Collins, R. W. (2018). *Spectroscopic Ellipsometry for Photovoltaics*. https://link.springer.com/book/10.1007/978-3-319-75377-5

Giannakos, M. N., Sampson, D. G., & Kidziński, Ł. (2016). Introduction to smart learning analytics: Foundations and developments in video-based learning. *Smart Learning Environments, 3*(1). https://doi.org/10.1186/s40561-016-0034-2

Hafizah, S. (2020). Penggunaan dan Pengembangan Video Dalam Pembelajaran Fisika [The Use and Development of Videos in Physics Learning]. *Jurnal Pendidikan Fisika Universitas Muhammadiyah Metro*, *8*(2). https://doi.org/0.24127/jpf.v8i2.2656

Lestari, P. A. S., Rahayu, S., & Hikmawati. (2015). Profil Miskonsepsi Siswa Kelas X SMKN 4 Mataram pada Materi Pokok Suhu, Kalor, dan Perpindahan Kalor [The Misconception Profile of Grade X Students at SMKN 4 Mataram on the Main Topics of Temperature, Heat, and Heat Transfer]. *Jurnal Pendidikan Fisika dan Teknologi*, *1*(3), 146-153. https://doi.org/10.29303/jpft.v1i3.251

McComas, W. F. & Kampourakis, K. (2015). Using the History of Biology, Chemistry, Geology, and Physics to illustrate general aspects of Nature of Science. *Review Of Science, Mathematics And ICT Education*, *9*(1), 47-76. https://doi.org/ 10.26220/rev.2240

Nasir, M., Cari, C., Sunarno, W., & Rahmawati, F. (2022). The effect of STEM-based guided inquiry on light concept understanding and scientific explanation. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(11). https://doi.org/ 10.29333/ejmste/12499

Niebert, K. & Gropengießer, J. (2014). Understanding the Greenhouse Effect by Embodiment – Analysing and Using Students' and Scientists' Conceptual Resources. *International Journal of Science Education*, *36*(2). https://doi.org/ 10.1080/09500693.2013.763298

Pido, R., Dera, N. S., & Rival, M. (2019). Analisa Pengaruh Kenaikan Temperatur Permukaan *Solar Cell* Terhadap Daya Output. *Gorontalo: Journal of Infrastructure & Science Engineering*, *2*(2). https://doi.org/10.32662/gojise.v2i2.683

Resbiantoro, G. & Nugraha, A.W. (2017). Miskonsepsi Mahasiswa Pada Konsep Dasar Gaya dan Gerak Untuk Sekolah Dasar [University Students' Misconceptions on the Basic Concepts of Force and Motion for Elementary School]. *Jurnal Pendidikan Sains (JPS)*, 5 (2). https://doi.org/ 10.26714/jps.5.2.2017.80-87

Sajidan, Baedhowi, Triyanto, Totalia, S.A., & Masykuri. (2018). *Peningkatan Proses Pembelajaran dan Penilaian Pembelajaran Abad 21 dalam Meningkatkan Kualitas Pembelajaran SMK [Improving 21st Century Learning Processes and Assessment to Enhance the Quality of Vocational High School Learning]*. Direktorat Pembinaan Sekolah Menengah Kejuruan Kementerian Pendidikan dan Kebudayaan: Jakarta. https://repositori.kemdikbud.go.id/10842/

Sam, A., Niebert, K., Hanson, R., & Aryeetey, C. (2016). Fusing Scientists' And Students' Conceptual Correspondences to Improve Teaching of Metal Complex Isomerism In Higher Education-An Educational Reconstructive Process. *International Journal of Academic Research and Reflection*, *4*(1), 54-64.

Simanullang, A. F., Panjaitan, M.B., & Manalu, A. (2024). Analisis Pengaruh Temperatur Radiasi Matahari Terhadap Daya Luaran Solarcell 150 Wp Pematangsiantar [Analysis of the Effect of Solar Radiation Temperature on the Output Power of a 150 Wp Solar Cell in Pematangsiantar]. *PENDIPA: Jurnal Pendidikan Sains*, *8*(2). https://doi.org/10.33369/pendipa.8.2.253-260

Sudira, P. (2016). *TVET Abad XXI: Filosofi, Teori, Konsep, dan Strategi Pembelajaran Vokasional [21st Century TVET: Philosophy, Theory, Concepts, and Strategies of Vocational Learning]*. UNY Press: Yogyakarta.