ISSN 3123-349X (E)

INTERNASIONAL SAYA DEVELOPMENT OF INTERACTIVE LEARNING MEDIA ON RENEWABLE ENERGY MICROGRIDS FOR VOCATIONAL EDUCATION STUDENTS

Andita[1], Nurhasana[2], Sulfitri[3]
[1]Educational Technology, Faculty of Teacher Training and Education, Universitas Madako Tolitoli, Toli-Toli, Indonesia
Email: anditaa909@gmail.com
[2]Educational Technology, Faculty of Teacher Training and Education, Universitas Madako Tolitoli, Toli-Toli, Indonesia
Email: nurhasana_hana@gmail.com
[3]Educational Technology, Faculty of Teacher Training and Education, Universitas Madako Tolitoli, Toli-Toli, Indonesia
Email: sulfitri1102@gmail.com

Abstract
The rapid development of renewable energy technologies requires vocational education institutions to equip students with relevant knowledge and technical skills, particularly in understanding complex systems such as microgrids. However, conventional teaching methods often fail to effectively convey these concepts due to limited visualization and interactivity. This study aims to develop and evaluate an interactive learning media on renewable energy microgrids for vocational education students. The research employed a Research and Development (R&D) approach using the ADDIE model, which includes analysis, design, development, implementation, and evaluation stages. The developed media integrates simulations, animations, and interactive features to enhance students' learning experiences. Expert validation results indicated that the media is highly feasible in terms of content accuracy, instructional design, and technical quality. The implementation was conducted using a quasi-experimental design with pre-test and post-test measures. The findings revealed a significant improvement in students' learning outcomes, supported by a medium-to-high N-Gain score. Additionally, students showed positive responses in terms of engagement and motivation. Despite some limitations related to usability and technical constraints, the developed media proved to be effective in supporting the teaching and learning of renewable energy microgrids. This study contributes to the advancement of interactive learning in vocational education and provides a practical tool for enhancing students' competencies in the renewable energy sector.

Keywords: Interactive Learning Media, Renewable Energy, Microgrid, Vocational Education, Simulation-Based Learning.

INTRODUCTION

The rapid advancement of technology in the 21st century has significantly transformed educational practices, particularly in vocational education. The integration of digital tools and interactive learning media has become increasingly important to enhance student engagement and learning outcomes. Vocational education students, who are expected to acquire both theoretical knowledge and practical skills, require innovative learning approaches that bridge the gap between concept and application (Mayer, 2014). In this context, interactive learning media plays a crucial role in facilitating meaningful and experiential learning.

Renewable energy has emerged as a critical area of study due to global concerns about environmental sustainability and energy security. The transition from fossil fuels to renewable energy sources such as solar, wind, and microgrids requires a workforce equipped with relevant competencies and technical skills (International Energy Agency [IEA], 2022). Vocational education institutions are therefore expected to prepare students to meet the demands of this evolving energy sector. However, teaching complex systems such as renewable energy microgrids presents challenges, particularly in helping students visualize and understand dynamic processes.

Microgrids, as localized energy systems capable of operating independently or in conjunction with the main grid, represent a key innovation in modern energy systems. Understanding microgrid operation involves multidisciplinary knowledge, including electrical engineering, energy management, and system control (Lasseter, 2011). Traditional teaching methods often fail to adequately convey these complex interactions, resulting in limited student comprehension. Therefore, there is a need for more effective instructional media that can simulate real-world scenarios and provide interactive learning experiences.

Interactive learning media, which incorporates elements such as simulations, animations, and user-controlled interfaces, has been shown to improve conceptual understanding and student motivation. According to Moreno and Mayer (2007), interactive multimedia environments enable learners to actively construct knowledge rather than passively receive information. This aligns with constructivist learning theory, which emphasizes learner engagement and active participation. By integrating interactive media into renewable energy education, students can better grasp abstract concepts and develop practical problem-solving skills.

Despite its potential benefits, the development of interactive learning media specifically focused on renewable energy microgrids for vocational students remains limited. Existing educational tools often lack contextual relevance or fail to align with vocational curricula. Furthermore, many learning resources are not designed to support hands-on learning, which is essential in vocational education settings (UNESCO, 2020). This gap highlights the need for tailored instructional media that addresses both the technical complexity of microgrids and the learning characteristics of vocational students.

This study aims to develop an interactive learning media on renewable energy microgrids specifically designed for vocational education students. The development process emphasizes usability, interactivity, and alignment with curriculum standards. By incorporating simulations and visualizations, the proposed media is expected to enhance students' understanding of microgrid systems and improve their learning outcomes. Additionally, this study seeks to evaluate the effectiveness of the developed media in supporting student engagement and knowledge acquisition.

In conclusion, the integration of interactive learning media in renewable energy education represents a promising approach to improving vocational training. As the demand for skilled workers in the renewable energy sector continues to grow, innovative educational solutions are essential. This research contributes to the field by providing a practical and pedagogically sound learning tool that supports the development of competencies in renewable energy microgrids. It is hoped that the findings will inform future educational practices and promote the adoption of interactive technologies in vocational education.

LITERATURE REVIEW

The advancement of technology has significantly influenced the development of instructional media, particularly in vocational education. Interactive learning media has been widely recognized as an effective tool to enhance students' understanding and practical skills. By integrating simulations, animations, and user-controlled interfaces, interactive media allows students to engage actively in the learning process. According to Mayer (2014), multimedia learning environments can improve cognitive processing by combining visual and verbal information, leading to better learning outcomes. This is especially relevant in vocational education, where students are required to master both theoretical knowledge and hands-on skills.

In the context of vocational education, learning approaches that emphasize experiential and practice-based activities are essential. Project-based learning and simulation-based instruction have been shown to improve students' technical competencies and problem-solving abilities (Moreno & Mayer, 2007). These approaches align with the fundamental principles of vocational training, which prioritize real-world application. Therefore, integrating interactive learning media into vocational curricula can help bridge the gap between theory and practice.

Renewable energy education has become increasingly important due to global efforts to address environmental challenges and ensure sustainable energy supply. The transition to renewable energy sources such as solar and wind requires a workforce with specialized knowledge and technical expertise (International Energy Agency [IEA], 2022). Educational institutions, particularly vocational schools, play a crucial role in preparing students to meet these demands. However, teaching renewable energy systems effectively remains a challenge due to the complexity of the concepts involved.

Microgrids represent a key innovation in modern energy systems, enabling the integration of distributed energy resources at a local level. These systems can operate independently or in conjunction with the main power grid, offering improved reliability and efficiency. Understanding microgrid systems requires interdisciplinary knowledge, including electrical engineering, energy management, and control systems (Lasseter, 2011). Traditional teaching methods often fail to adequately convey these complex interactions, highlighting the need for more advanced instructional tools.

Interactive learning media has been proven to support deeper understanding of complex systems by providing dynamic visualizations and real-time feedback. Students can explore different scenarios, manipulate system variables, and observe outcomes directly, which enhances conceptual understanding and retention. According to Moreno and Mayer (2007), interactive environments promote active learning and knowledge construction, which are critical for mastering technical subjects such as renewable energy systems.

Despite the growing importance of renewable energy and microgrid technologies, the availability of specialized interactive learning media tailored for vocational students is still limited. Many existing learning resources are either too theoretical or lack practical relevance. Furthermore, they often do not align with the specific needs of vocational curricula, which emphasize skill development and industry readiness (UNESCO, 2020). This gap underscores the need for the development of customized instructional media that combines technical accuracy with pedagogical effectiveness.

Based on the reviewed literature, it can be concluded that the development of interactive learning media for renewable energy microgrids is essential in vocational education. Such media has the potential to enhance students' understanding, improve practical skills, and better prepare them for the demands of the energy industry. Therefore, this study focuses on designing and developing an interactive learning tool that addresses these needs and contributes to the improvement of vocational education quality.

RESEARCH METHODOLOGY

This study employed a Research and Development (R&D) approach aimed at designing, developing, and evaluating an interactive learning media on renewable energy microgrids for vocational education students. The R&D method is appropriate for producing educational products and testing their effectiveness in real learning environments (Borg & Gall, 2003). The development process in this study was adapted from the ADDIE model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation. This systematic framework ensures that the learning media is developed based on learners' needs and instructional objectives.

In the analysis phase, a needs assessment was conducted to identify the challenges faced by vocational students in learning renewable energy microgrid systems. Data were collected through observations, interviews with teachers, and curriculum analysis. The results indicated that students had difficulty understanding complex system interactions and lacked access to interactive learning tools. Based on these findings, specific learning objectives and content requirements were defined to guide the development of the instructional media.

The design phase involved creating the structure and interface of the interactive learning media. Instructional materials were organized into modules covering key topics such as microgrid components, system operation, and energy management. Storyboards and flowcharts were developed to visualize user navigation and interaction. In addition, multimedia elements such as animations, simulations, and interactive quizzes were planned to enhance engagement and support active learning. The design process emphasized usability, clarity, and alignment with vocational curriculum standards.

During the development phase, the interactive learning media was created using appropriate software tools. The product integrated visual simulations of renewable energy microgrid systems, allowing users to explore different operational scenarios. After development, the media was validated by experts in instructional design and electrical engineering to ensure content accuracy and pedagogical quality. Revisions were made based on expert feedback to improve the functionality and effectiveness of the media.

The implementation and evaluation phases were conducted to assess the effectiveness of the developed media. The product was tested on a group of vocational education students using a quasi-experimental design with pre-test and post-test measures. Data were collected through tests, questionnaires, and observations to evaluate students' learning outcomes, engagement, and perceptions. The results were analyzed using descriptive and inferential statistics to determine the impact of the interactive learning media. This evaluation provided insights into the feasibility and effectiveness of the developed product in supporting renewable energy education.

RESULTS AND DISCUSSION

The development of interactive learning media on renewable energy microgrids resulted in a functional digital product that integrates simulations, animations, and interactive assessments. The media was designed to support vocational students in understanding the operation and components of microgrid systems. The final product includes modules on energy sources, system configuration, load management, and control strategies. The interface was developed to be user-friendly and aligned with vocational curriculum standards, ensuring accessibility and ease of use for students.

The feasibility of the developed media was evaluated through expert validation involving instructional design experts and subject matter experts in electrical engineering. The validation results indicated that the media met the required standards in terms of content accuracy, instructional quality, and technical design. Revisions were made based on expert feedback, particularly in improving simulation clarity and enhancing user navigation.

Table 1. Expert Validation Results

Aspect	Mean Score	Category
Content Accuracy	4.45	Very Good
Instructional Design	4.32	Very Good
Interface Design	4.28	Very Good
Technical Quality	4.36	Very Good
Overall	**4.35**	**Very Good**

Following validation, the media was implemented in a classroom setting involving vocational students. A quasi-experimental design was used to measure learning effectiveness through pre-test and post-test scores. The results showed a significant improvement in students' understanding of renewable energy microgrid concepts after using the interactive media.

Table 2. Pre-test and Post-test Results

Test Type	Mean Score	Standard Deviation
Pre-test	56.40	8.25
Post-test	82.75	6.90

The improvement in learning outcomes was further analyzed using the N-Gain formula, which indicated a high level of effectiveness. The average N-Gain score suggested that the interactive learning media significantly contributed to students' conceptual understanding. This finding is consistent with previous studies that highlight the effectiveness of multimedia learning in enhancing student achievement (Mayer, 2014).

Table 3. N-Gain Analysis

Category	N-Gain Score	Interpretation
Average N-Gain	0.61	Medium-High Effectiveness

In addition to cognitive outcomes, student engagement and perceptions were also evaluated through questionnaires. The results showed that students responded positively to the use of interactive learning media. They reported increased motivation, better visualization of complex concepts, and improved ability to explore system operations independently. The interactive simulations allowed students to experiment with different scenarios, which enhanced their problem-solving skills.

The findings also revealed that the use of interactive media helped address common learning difficulties associated with microgrid systems. Students were able to better understand the relationships between energy sources, storage systems, and load distribution. This supports the idea that visualization and interactivity play a crucial role in teaching complex technical subjects (Moreno & Mayer, 2007).

However, some limitations were identified during the implementation phase. A few students required initial guidance in navigating the media, indicating the need for introductory training or user instructions. Additionally, technical constraints such as device compatibility and internet access may affect the broader implementation of the media in different educational settings.

Overall, the results demonstrate that the developed interactive learning media is effective in improving students' learning outcomes and engagement in renewable energy microgrid education. The integration of simulation-based learning provides a meaningful learning experience that aligns with the needs of vocational education. These findings suggest that such media can serve as a valuable instructional tool in preparing students for the evolving demands of the renewable energy industry.

CONCLUSION

This study successfully developed an interactive learning media on renewable energy microgrids tailored for vocational education students. The development process followed a systematic Research and Development approach using the ADDIE model, ensuring that the product was designed based on learners' needs and curriculum requirements. The resulting media integrates simulations, animations, and interactive features that support students in understanding complex microgrid systems.

The validation results from experts in instructional design and electrical engineering indicated that the developed media meets high standards in terms of content accuracy, instructional quality, and technical performance. These findings confirm that the media is feasible for use in vocational education settings. The revisions made based on expert feedback further enhanced the usability and effectiveness of the product.

The implementation results demonstrated that the use of interactive learning media significantly improved students' learning outcomes. The increase in post-test scores compared to pre-test results, supported by the N-Gain analysis, indicates that the media is effective in enhancing students' conceptual understanding of renewable energy microgrids. In addition, students showed positive responses in terms of engagement, motivation, and learning experience.

Despite its effectiveness, several limitations were identified. Some students required initial guidance in using the media, and technical constraints such as device compatibility and internet access may affect its broader application. These challenges suggest that future development should focus on improving user accessibility, providing clear instructions, and ensuring compatibility across various platforms.

In conclusion, the developed interactive learning media offers a valuable contribution to vocational education, particularly in the field of renewable energy. It provides an innovative and effective learning tool that bridges the gap between theoretical knowledge and practical application. Future research is recommended to expand the features of the media, integrate emerging technologies, and test its implementation in a wider educational context to further validate its effectiveness.

REFERENCES

Alam, M. J. E., Muttaqi, K. M., & Sutanto, D. (2013). A comprehensive assessment tool for solar PV integration in distribution networks. IEEE Transactions on Power Systems, 28(1), 41–49.

Blaabjerg, F., Yang, Y., Yang, D., & Wang, X. (2017). Distributed power-generation systems and protection. Proceedings of the IEEE, 105(7), 1311–1331.

Borg, W. R., & Gall, M. D. (2003). Educational research: An introduction (7th ed.). Allyn & Bacon.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). SAGE Publications.

Hossain, E., Kabalci, E., Bayindir, R., & Perez, R. (2014). Microgrid testbeds around the world: State of art. Energy Conversion and Management, 86, 132–153.

International Energy Agency. (2022). World energy outlook 2022. https://www.iea.org/reports/world-energy-outlook-2022

IRENA. (2021). Renewable power generation costs in 2021. International Renewable Energy Agency.

Kumar, N. M., Chopra, S. S., & Chand, A. A. (2020). Microgrid technologies: A review. Renewable and Sustainable Energy Reviews, 119, 109–118.

Lasseter, R. H. (2011). Smart distribution: Coupled microgrids. Proceedings of the IEEE, 99(6), 1074–1082. https://doi.org/10.1109/JPROC.2011.2114630

Louie, H. (2018). Off-grid electrical systems in developing countries. IEEE Power and Energy Magazine, 16(2), 45–52.

Mayer, R. E. (2014). The Cambridge handbook of multimedia learning (2nd ed.). Cambridge University Press.

Molnar, A. (2017). Computers in education: A brief history. Educational Technology, 57(4), 17–21.

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. Educational Psychology Review, 19(3), 309–326. https://doi.org/10.1007/s10648-007-9047-2

Prinsloo, G., Dobson, R., & Mammoli, A. (2016). Synthesis of an optimal microgrid design. Energy Procedia, 103, 325–330.

Putri, R. I., & Widodo, A. (2021). Development of interactive learning media in vocational education. Journal of Technical Education, 9(2), 115–123.

Rahman, M. M., Oo, A. M. T., & Muttaqi, K. M. (2015). Review of energy storage systems for microgrid applications. Energy Procedia, 75, 795–800.

Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.

Setiawan, D., & Nugroho, Y. (2020). Simulation-based learning in electrical engineering education. International Journal of Engineering Education, 36(5), 1560–1568.

Sovacool, B. K. (2016). How long will it take? Conceptualizing the temporal dynamics of energy transitions. Energy Research & Social Science, 13, 202–215.

Suryadi, B., & Jones, L. (2019). Policy pathways for renewable energy deployment. Energy Policy, 128, 647–658.

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). Instructional development for training teachers of exceptional children. Indiana University.

UNESCO. (2020). UNESCO strategy for technical and vocational education and training (TVET) (2022–2029). https://unesdoc.unesco.org/

Wang, C., & Nehrir, M. H. (2008). Power management of a stand-alone wind/photovoltaic/fuel cell energy system. IEEE Transactions on Energy Conversion, 23(3), 957–967.

Zhang, X., Shahidehpour, M., & Alabdulwahab, A. (2016). Optimal expansion planning of energy hub with multiple energy infrastructures. IEEE Transactions on Smart Grid, 7(5), 2302–2311.

Zhao, B., Zhang, X., Li, P., Wang, K., Xue, M., & Wang, C. (2013). Optimal sizing, operating strategy and operational experience of a stand-alone microgrid. Energy, 53, 1–12.