JVCE 11 (1) (2026) : 45-53

Journal of Vocational Career Education

https://journal.unnes.ac.id/nju/index.php/jvce

Development of a Renewable Energy Based Smart Home Appliance Trainer Kit for Learning Technology Development

Saifur Risal[1]✉, Muhammad Harlanu[2], Yeri Sutopo[2]

[1]SMKN 3 Semarang, Indonesia
[2]Universitas Negeri Semarang, Indonesia

Article Info

Article History :
Received
November 2025
Accepted
January 2026
Published
July 2026

Keywords:
trainer kit; smart home system; renewable energy; ADDIE model; learning outcomes; electrical power engineering

Abstract

This research aims to develop a renewable energy based smart home appliance trainer kit utilizing a solar power generation system and to evaluate its feasibility, practicality, and effectiveness in improving student learning outcomes. The study is situated within the technology development learning element and addresses global issues in the electrical power industry in Phase E of the Merdeka Curriculum. A Research and Development approach was employed using the ADDIE model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. The research participants consisted of tenth grade students of Electrical Power Engineering at SMK Nurul Barqi Semarang as the experimental group and students from SMKN 3 Semarang as the control group. Data were collected through expert validation of learning materials and media, teacher practicality questionnaires, and student learning outcome assessments. Data analysis techniques included feasibility analysis, normality testing, homogeneity testing, N Gain analysis, and independent t test. The results indicate that the trainer kit was successfully developed using a stand-based structure with a plug and play system supported by banana socket connections. Expert validation classified the learning media as very feasible, with mean scores of 4.67 from media experts and 4.88 from material experts. Practicality evaluation conducted by ten Electrical Power Engineering teachers resulted in a score of 96.43%, indicating a very practical category. Effectiveness testing showed an improvement in students cognitive learning outcomes, with an average N Gain value of 56.83%, categorized as moderately effective. Furthermore, the independent t test revealed a statistically significant difference in learning effectiveness between students who used the trainer kit and those who followed conventional learning methods.

✉ Correspondence:
Jl. Atmodirono No.7a, Wonodri, Kec. Semarang Sel., Kota Semarang, Jawa Tengah 50242, Indonesia
E-mail: saifurrisal@gmail.com

p-ISSN 2339-0344
e-ISSN 2503-2305

INTRODUCTION

The Merdeka Curriculum is designed to provide flexible and meaningful intracurricular learning experiences that allow students sufficient time to deepen conceptual understanding and strengthen competencies in accordance with their interests and talents. This curriculum emphasizes student centered learning, independence, creativity, and the integration of technology to prepare learners for future challenges. Since its implementation in the 2022 to 2023 academic year, the Merdeka Curriculum has received positive responses. However, its implementation still faces several challenges, particularly related to the availability of resources, learning facilities, and teacher readiness in integrating innovative learning media.

In vocational education, particularly in the Electrical Power Engineering program, learning outcomes are structured based on learning phases rather than annual targets. Phase E, which is intended for tenth grade students, includes the technology development element and global issues related to the electrical power industry. This element requires students to understand the transformation of the electrical power industry toward electricity 4.0, including digitalization, the application of Internet of Things technology, and the use of intelligent electrical devices such as smart meters, smart sensors, smart appliances, Supervisory Control and Data Acquisition systems, and Human Machine Interface systems. Therefore, achieving the expected learning outcomes within this element requires learning media that are aligned with technological developments and industry needs.

Learning media play a crucial role in supporting the achievement of learning outcomes. Learning media are defined as tools, methods, or techniques used to enhance the effectiveness of communication and interaction between teachers and students in the learning process. The appropriate use of learning media can increase student motivation, interest, and engagement, while also positively influencing cognitive and psychomotor development. Consequently, the development of innovative and contextual learning media has become an essential requirement in vocational education.

Technological advancements in the electrical power sector are currently progressing rapidly. Residential electrical installation systems have increasingly adopted smart home technology, which enables remote monitoring and control of electrical devices through Internet of Things based systems. At the same time, global issues related to low carbon electricity generation have intensified alongside efforts to transition from fossil fuel-based energy sources to renewable energy. The commitment of Indonesia to accelerating energy transition, as demonstrated by the operation of large-scale solar power plants, highlights the importance of mastering renewable energy technologies within the electrical power industry. These conditions demand that future electrical power technicians possess competencies that are relevant to contemporary technological developments.

Despite these demands, the availability of learning facilities in vocational high schools has not yet fully aligned with technological advancements and industry requirements. Preliminary observations conducted at SMK Nurul Barqi Semarang indicate that learning activities related to the technology development element and global issues in the electrical power industry still utilize separate components that are not integrated into a comprehensive learning system. This condition makes it difficult for students to understand the interconnections between systems and the working principles of modern electrical power technologies. Previous studies have developed learning trainers based on solar power systems or Internet of Things technology. However, these developments remain largely partial and have not integrated both technologies into a single learning medium that represents real world industrial applications.

Based on these issues, there is a need to develop a learning medium that integrates smart home appliance technology and renewable energy systems into a single trainer kit. An integrated trainer kit is expected to provide more contextual and practical learning experiences, thereby assisting students in comprehensively understanding technological developments and global issues in the electrical power industry. Therefore, this study aims to develop a Trainer Kit of Smart Home Appliances Based on

Renewable Energy and to analyze its feasibility, practicality, and effectiveness in improving student learning outcomes in the technology development element and global issues related to the electrical power industry for Phase E of the Electrical Power Engineering program within the Merdeka Curriculum.

METHODOLOGY

This study employed a research development approach known as Research and Development. Research and Development is defined as a systematic process used to develop and validate educational products. This approach is also intended to produce a product and examine its effectiveness. The product developed in this study represents an improvement of existing learning media and is expected to address the limitations of previous products.

The purpose of this research was to develop and evaluate the feasibility, practicality, and effectiveness of an educational product. The product developed was a Trainer Kit of Smart Home Appliances Based on Renewable Energy, which functions as a learning medium for the technology development element and global issues related to the electrical power industry.

The media development design adopted the ADDIE model, which consists of five stages, namely Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic and structured framework that is easy to apply in learning media development and allows continuous evaluation at each stage of the process. During the analysis stage, this study employed a needs assessment and front end analysis approach based on the Lee and Owens model to identify initial learning conditions, user needs, and required media specifications.

The analysis stage was conducted to identify learning needs, student characteristics, and the alignment of learning media with the learning outcomes of Phase E in the Electrical Power Engineering program. The design stage focused on developing the blueprint of the Trainer Kit of Smart Home Appliances Based on Renewable Energy, including system architecture, solar power generation components, smart home appliance systems, as well as the design of learning modules and instructional job sheets. The development stage involved the realization of the design into a functional trainer kit that was technically operational and ready for instructional use.

The implementation stage was carried out through product trials involving media experts, material experts, and users. Feasibility testing was conducted by media and material experts to evaluate technical aspects, visual design, and content relevance. Practicality testing was performed by Electrical Power Engineering teachers to assess ease of use, clarity of instructions, and the applicability of the trainer kit in learning activities. Furthermore, effectiveness testing was conducted by implementing the learning media in the experimental class and comparing the results with those of the control class.

The evaluation stage aimed to analyze all testing data to determine the feasibility, practicality, and effectiveness of the trainer kit as a learning medium. Data analysis techniques included quantitative descriptive analysis of feasibility and practicality test results and analysis of learning outcome improvement using the N Gain method. Prior to effectiveness testing, the data were examined using normality and homogeneity tests. Differences in effectiveness between the experimental and control classes were analyzed using an independent t test on the N Gain scores. The results of these analyses served as the basis for drawing conclusions regarding the quality and effectiveness of the developed learning media.

RESULTS

The feasibility testing stage of the Trainer Kit of Smart Home Appliances Based on Renewable Energy aimed to evaluate the extent to which the developed product met feasibility criteria or required further improvement. This feasibility testing process was conducted by media experts and material experts to obtain feedback, suggestions, and constructive criticism regarding the developed trainer kit.

The implementation of this stage was evidenced by the results of evaluation questionnaires completed by the validators, which indicated that the Trainer Kit of Smart Home Appliances Based on Renewable Energy was deemed feasible for use in the research. The feasibility testing instrument used in this study was adapted from the National Education Standards Agency instrument, which has been proven to possess established validity. Therefore, item level instrument testing was not required.

The validators involved in the feasibility assessment consisted of three media experts, including an academic lecturer, a nationally recognized expert media teacher, and an industry professional in the electrical power sector. In addition, three material experts were involved from professional institutions, namely the Electrical Power Competency Certification Institute Sertikomlis, the PLN Electricity Certification Center, and industry practitioners in the electrical power field.

a) Feasibility Analysis by Media and Material Experts

The feasibility analysis of the Trainer Kit of Smart Home Appliances Based on Renewable Energy was conducted based on assessments provided by media and material expert validators. The feasibility scoring involved three media experts and three material experts from academic, professional, and industrial backgrounds. The overall scoring results for each assessment aspect are summarized in Table 1.

Table 1. Summary of Feasibility Evaluation by Media and Material Experts

No	Expert Category	Expert 1	Expert 2	Expert 3	Mean Score	Category
1	Feasibility by media experts	4.67	4.96	4.37	4.67	Very feasible
2	Feasibility by material experts	5	4.71	4.94	4.88	Very feasible
Overall expert mean					4.78	Very feasible

Based on the data presented in Table 1, the overall mean score across all assessed aspects was 4.78, which falls within the very feasible category according to the established criteria. These results indicate that the Trainer Kit of Smart Home Appliances Based on Renewable Energy is valid and highly feasible for instructional use. Minor revisions were recommended, particularly related to improving the soldering strength of the banana jack connectors used for component connections. Overall, the trainer kit was considered suitable for use as a learning medium for students in the Electrical Power Engineering program.

b) Practicality Testing and Analysis of the Trainer Kit

Practicality testing of the Trainer Kit of Smart Home Appliances Based on Renewable Energy was conducted during the development stage using a response questionnaire consisting of fourteen items. The questionnaire was administered to ten vocational high school teachers from the Electrical Power Engineering department. Prior to completing the questionnaire, the teachers were first provided with instructional videos and photographs of the trainer kit. The results of the practicality testing are presented in Table 2.

Table 2. Practicality Test Data of Trainer Kit Usage by Teachers

ITEMS	RESPONSES OF ELECTRICAL ENGINEERING TEACHERS									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
3	1	0	1	1	1	1	1	1	0	1
4	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1
6	0	1	1	1	1	1	1	1	0	1
7	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1

9	1	1	1	1	1	1	1	1	1	1	
10	1	1	1	1	1	1	1	1	1	0	
11	1	1	1	1	1	1	1	1	1	1	
12	1	1	1	1	1	1	1	1	1	1	
13	1	1	1	1	1	1	1	1	1	1	
14	1	1	1	1	1	1	1	1	1	1	
E	1	1	0	0	0	0	0	0	2	1	5
Tn	13	13	14	14	14	14	14	14	12	13	135

Reproducibility Coefficient Calculation (K_r)

$$K_r = 1- e/n$$

The reproducibility coefficient was calculated using the following formula:

K_r = 1-total number of questionnaire items multiplied by the number of respondents

$$= 1 - \frac{5}{(14\ x\ 10)}$$
$$= 1 - 0{,}036$$
$$= 0{,}96$$

According to Singarimbun et al. on pages one hundred eighteen to one hundred nineteen, a Reproducibility Coefficient value greater than zero point nine zero meets the required criterion. The results of the reproducibility coefficient calculation in this study show a teacher Kr value of zero point nine six. This result indicates that the developed Trainer Kit of Smart Home Appliances Based on Renewable Energy is highly practical for use, as it satisfies the practicality requirement of exceeding zero point nine zero.

$$K_s=1- e/k$$

The scalability coefficient was calculated using the following formula:

Ks = 1 – the number of errors / 0.5 of the product of the number of items and the number of respondents minus the total S score

$$= 1 - \frac{5}{0.5\ (14\ x\ 10)-135}$$
$$= 1 - 0.08$$
$$= 0.92$$

In this study, the practicality test results of the Trainer Kit of Smart Home Appliances Based on Renewable Energy were further confirmed through scalability testing using the Scalability Coefficient. The obtained teacher Ks value was 0.92, which meets the required criterion of being greater than 0.60 (Nazir, 2005: 343).

Based on these results, with an average assessment conducted by ten teacher validators, the mean practicality score reached 96.43% and was classified as very practical. Therefore, it can be concluded that the Trainer Kit of Smart Home Appliances Based on Renewable Energy is practical for use as a learning medium in the Electrical Power Engineering program.

c) Effectiveness Testing Using N Gain Analysis

The effectiveness of the Trainer Kit of Smart Home Appliances Based on Renewable Energy was evaluated using normalized gain analysis. The N Gain score was calculated based on the difference between pretest and posttest scores, with an ideal maximum score of 100. The N Gain calculation results for both the experimental and control classes are summarized in Table 3.

Table 3. Results of N Gain Calculation for Each Class

No	Class	Mean N Gain	Category
1	Control class	44.01%	Less effective
2	Experimental class	56.83%	Moderately effective

Source: Calculation Results (2025)

The analysis results show that the experimental class achieved an average N Gain score of 56.83%, with minimum and maximum scores of 13.04% and 92.50%, respectively. In contrast, the control class achieved an average N Gain score of 44.01%, with minimum and maximum scores of 8.51% and 90.90%. The obtained scores were then interpreted using the following N Gain effectiveness classification table 4.

Table 4. N Gain Effectiveness Classification

Percentage	Interpretation
< 40	Ineffective
40-55	Less effective
56-75	Moderately effective
>76	Effective

Based on the N Gain effectiveness interpretation criteria, the experimental class falls into the moderately effective category, while the control class falls into the less effective category. These findings indicate that the application of the Trainer Kit of Smart Home Appliances Based on Renewable Energy was more effective in improving students cognitive learning outcomes compared to conventional learning methods.

d) Independent t Test Analysis

To determine whether there was a significant difference between conventional learning and learning that employed the Trainer Kit of Smart Home Appliances Based on Renewable Energy, an independent sample t test analysis was conducted using N Gain Score values in percent. The independent sample t test is a parametric statistical analysis technique that aims to compare the mean scores of two independent or unpaired data groups. The data analyzed using this test must be measured on an interval or ratio scale.

The application of the independent sample t test requires the data to be normally distributed and to have homogeneous variances. In this study, the independent t test was applied to N Gain values obtained from Pretest and Posttest results in both the experimental class and the control class. The normality test was conducted to identify whether the N Gain data were normally distributed. This test used a significance level of 0.05 as the reference. The testing criteria state that if the significance value is greater than 0.05, the data are considered normally distributed. Conversely, if the significance value is less than 0.05, the data are considered not normally distributed Darmawan Harefa 2023. The analysis was performed using the Kolmogorov Smirnov and Shapiro Wilk methods assisted by IBM SPSS software. The complete results of the normality test for N Gain values in the experimental and control classes are presented in the following table.

Table 5. Normality Test Results of N Gain Data

Class		Sig. Kolmogorof-Smirnov[a]	Sig. Shapiro-Wilk
N Gain Percent	Experimental	0.200	0.758
	Control	0.200	0.412

Source: Calculation Results (2025)

Based on the data presented in Table 5, the results of the normality test for N Gain effectiveness data indicate that the Kolmogorov Smirnov significance value was 0.200 for both the experimental class and the control class. Meanwhile, the Shapiro Wilk test results showed a significance value of 0.758 for the experimental class and 0.412 for the control class. All significance values were greater than the significance level of 0.05. Therefore, it can be concluded that the data were normally distributed. Accordingly, further data analysis could be conducted.

The next stage was the homogeneity test, which was carried out using the Test of Homogeneity of Variances with a significance level of 0.05. Decision making was based on the obtained significance value. If the significance value was greater than 0.05, the data variances were considered homogeneous. Conversely, if the significance value was less than 0.05, the data variances were considered not homogeneous Darmawan Harefa 2023.

Table 6. Homogeneity Test Results for Independent Sample t Test on N Gain Data

Independent Samples Test		*Lavene Statistic Sig.*	*Taraf Signifikansi*
N-Gain Persen	Equal variances assumed	0.81	0.013

Source: Calculation Results (2025)

Based on Table 6, the significance value in the Levene Test for Equality of Variances was 0.81, which was greater than 0.05. Therefore, it can be concluded that the variance of N Gain data in percent for the experimental class and the control class was equal or homogeneous. Consequently, the independent t test for N Gain scores referred to the significance value in the Equal variances assumed row, which was 0.013 < 0.05. Thus, it can be concluded that there was a statistically significant difference in effectiveness between learning using the Trainer Kit of Smart Home Appliances Based on Renewable Energy and conventional learning methods in improving student learning outcomes.

Discussion

The final product of the Trainer Kit of Smart Home Appliances Based on Renewable Energy is a learning medium in the form of a standing frame trainer. This trainer is equipped with a practical guidebook and banana sockets, which facilitate students in connecting and disconnecting cables according to the instructions provided in the module. Based on the identification of problems in the field, students demonstrated low learning achievement in the element of Technological Development and Global Issues Related to the Electrical Power Industry. Further analysis indicated that one of the main contributing factors was the limited availability of instructional media that support learning in this element. In response to this issue, the researcher developed a solar power plant trainer integrated with smart home devices to align with learning needs related to technological development and global issues in the electrical power industry.

The development of this trainer product involved several stages of feasibility testing. Referring to Sugiyono, feasibility testing aims to determine whether a developed product can be applied in the learning process or requires revision. Therefore, a high-quality product must undergo a validation stage prior to implementation. In this study, media expert validation was conducted by academic lecturers, nationally recognized media expert teachers, and practitioners from the electrical power industry. Based on the evaluation results, the trainer kit was categorized as very feasible from the media aspect. Furthermore, material expert validation was conducted by the Electrical Power Competency Certification Institution Sertikomlis, PT PLN Central Electrical Certification, and electrical power industry practitioners. The results of the material expert assessment also indicated a very feasible category, confirming that the developed trainer is highly suitable for use in learning activities.

Product development was continued with a practicality test to evaluate ease of use and instructional effectiveness. The practicality test involved ten electrical engineering teachers in Semarang City. The results showed an average practicality score of $\bar{x}$ equal to 96.43%, which falls into the very practical category. Therefore, the trainer can be considered practical for use in learning activities within the Electrical Engineering Study Program.

After the media was declared feasible and practical by the validators, the product effectiveness was tested to determine its impact on student learning outcomes. Effectiveness testing was conducted using N Gain analysis by comparing pretest and posttest results. The analysis revealed an N Gain score of 56.83%, indicating that the use of the trainer was moderately effective in improving the cognitive abilities of students.

The findings of this study are consistent with previous research, such as the development of a solar power plant trainer design by Lawal et al 2019. The developed product simulated the relationship between light intensity and the voltage and current generated by solar panels. Light intensity was modeled using adjustable lamp illumination, enabling students to understand changes in photovoltaic characteristics. The trainer was considered feasible as a learning medium. The similarity with the present study lies in the use of a solar power plant trainer, while the difference is the integration of smart home devices, which represents a novel contribution in this research. Another study by Wardiyanto and Yundra 2019 developed a trainer based on an Arduino microcontroller using an Internet of Things concept. The results showed a validity level of 91.67%, ease of use of 81.25%, effectiveness of 82.1286%, and an increase in student competence after using the trainer. The similarity with this study is the use of IoT for control and monitoring systems. However, the trainer developed by Wardiyanto and Yundra relied on Arduino, which is less aligned with the learning characteristics of the Electrical Engineering program. In contrast, the trainer developed in this study utilizes smart home appliances that are more relevant to student competency needs in the element of Technological Development and Global Issues Related to the Electrical Power Industry.

Vocational education emphasizes the integration of conceptual mastery, practical skills, and alignment with workforce demands (Prosser and Quigley,1950). In this context, the use of instructional media that provide direct experience and are connected to real world situations is essential to help students understand abstract concepts (Hamalik, 1989). The Trainer Kit of Smart Home Appliances Based on Renewable Energy developed in this study supports this learning process by enabling students to learn through direct practical activities. The integration of renewable energy technology and smart home devices allows students to gain a concrete understanding of developments in electrical power technology, ensuring that learning focuses not only on content mastery but also on the application of technology and global issues in everyday life (Kemendikbudristek, 2022).

The novelty of this research lies in the development of a solar power plant trainer integrated with smart home appliances and designed with a plug and play system using banana sockets. This integration enables simulation of modern electrical systems that closely resemble real world conditions while simplifying the assembly and configuration process for students. The research results demonstrate that these trainer characteristics contribute to improved student cognitive learning outcomes within the moderately effective category. This finding indicates that the use of advanced technology based instructional media can enhance student understanding of the element of Technological Development and Global Issues Related to the Electrical Power Industry, which previously faced limitations in supporting instructional media.

The main strength of this research lies in the relevance of the developed learning media to the characteristics and competency needs of students in the Electrical Engineering Program. Unlike previous studies that predominantly employed generic microcontrollers, the trainer developed in this study utilizes smart home appliances that more accurately represent modern electrical systems and current industrial trends. Additionally, the modular and user-friendly design of the trainer makes it not only feasible and practical but also adaptable for project based and practice-oriented learning. Thus, this research provides both scientific and practical contributions to the development of contextual and applicable vocational learning media that align with technological advancements and global issues in the electrical power industry.

CONCLUSION

The final product in the form of a Trainer Kit of Smart Home Appliances Based on Renewable Energy was successfully developed as a standing frame learning medium integrated with a photovoltaic power generation system and smart home appliances. The trainer was designed using a plug and play concept based on banana sockets and was equipped with a practical guidebook, enabling students to easily conduct practice-based learning activities. The testing results indicate that the trainer kit was categorized as very feasible based on validation by media experts and subject matter experts, very practical based on evaluations by electrical engineering vocational teachers, and moderately effective in improving students cognitive learning outcomes in the element of technological development and global issues related to the electrical power industry. The integration of renewable energy technology and smart home appliances makes this learning media relevant to the needs of vocational education and current developments in the electrical power industry, while also contributing to the delivery of contextual, applicative, and adaptive learning related to global issues. Therefore, this trainer kit has strong potential for broader development and implementation in electrical engineering vocational education.

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