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Development of an Electrical Lighting Installation Demonstration Tool Using a Triac-Based Light Sensor Switch

Salvo Eka Wibowo[1]✉, Samsudin Anis[2], Ulfah Mediaty Arief[2]

[1]SMK Negeri 1 Tonjong Kab. Brebes
[2]Postgraduate of Semarang State University

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Abstract

The automatic light sensor switch commonly used in the Electrical Power Installation Engineering Department at SMK Negeri 1 Tonjong is a factory-manufactured sensor switch with a complex circuit design, which has led to a decline in student learning motivation. This issue becomes the main reason for conducting research on the development of an instructional model for electrical lighting installations using a TRIAC-based light sensor switch, specifically applied in smart building lighting systems. This study employed a Research and Development (R&D) approach using the ADDIE development model. The findings of the study are as follows: (1) The developed product was deemed suitable for use, with a Content Validity Index (CVI) score of 0.88 from media experts and a Percentage of Agreement (PA) of 88%, and a CVI score of 0.91 and PA of 91% from subject material experts; (2) Product testing results indicated a high level of effectiveness, as shown by the Independent Sample t-Test on the N-gain Score, yielding a significance value (Sig. 2-tailed) of 0.000 < 0.05; and (3) The reproducibility coefficient (Kr) and scalability coefficient (Ks) were 92% and 81.5%, respectively, indicating that the instructional model for electrical lighting installation using the TRIAC-based light sensor switch is highly practical.

✉ Correspondence:
Jl. Raya, Pandansari, Kutamendala, Kec. Tonjong, Kabupaten Brebes, Jawa Tengah 52271, Indonesia
E-mail: salvoeka@students.unnes.ac.id

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INTRODUCTION

In an increasingly modern era, society continues to integrate technology into daily life to ease human tasks. One such technological advancement is automation, which is increasingly being adopted to solve everyday problems (Jouahri & Boulghasoul, 2023). Automation can be applied in household lighting systems, such as lights that can turn on and off automatically. This is achieved through the design of automatic light switches utilizing light sensors that convert light intensity into electrical signals. These systems commonly use an LDR (Light Dependent Resistor) as the light sensor and a TRIAC as the electronic switch. The LDR sensor's input value varies depending on the intensity of the light it receives—brighter light results in lower resistance, and vice versa (Prasetya & Aulia, 2020).

At SMK Negeri 1 Tonjong, specifically within the Electrical Power Installation Engineering competency program, an automatic light switch that factory-assembled photocell sensors is still in use. However, these devices often employ complex circuitry, which can lead to a decrease in student interest and engagement. The complexity makes it difficult for students to understand how the system and its components function. This issue highlights the importance of using demonstration tools as instructional aids to enhance student competence, particularly in applying procedures for installing lighting systems in smart building environments at SMK Negeri 1 Tonjong.

To address this need, the Project-Based Learning (PjBL) model is implemented. PjBL is an instructional approach that uses real-world problems as the starting point for learning, encouraging students to gather and integrate new knowledge through hands-on experiences. The model fosters collaboration, promotes group work, and helps students focus on their personal development (Okpatrioka, 2023).

This study is grounded in the need to develop a demonstration tool for electric lighting installations that uses a TRIAC-based light sensor switch within the context of smart buildings. The development involves replacing commonly used factory-assembled automatic switches with TRIAC-based light sensor switches that feature simpler circuitry and improved sensitivity. The research design includes a control class using conventional coil-based light sensor switches and an experimental class using the TRIAC-based light sensor switch demonstration tool.

RESEARCH METHODOLOGY

This study employs a Research and Development (R&D) approach. The primary objective of this research is to design and develop an effective and engaging instructional demonstration tool (Okpatrioka, 2023). The tool being developed in this research is an automatic switch demonstration device using a light sensor (photocell) based on TRIAC electronic components. It is intended to support the teaching of core competencies related to the installation of lighting systems in both basic and smart buildings, specifically for Grade XI students in the Electrical Power Installation Engineering program. The development process of the automatic light sensor switch tool follows the ADDIE model**,** which means for Analysis, Design, Development, Implementation, and Evaluation. This model provides a structured framework to ensure the instructional product is systematically and effectively developed.

Revisions to the demonstration tool are carried out based on feedback and suggestions from expert validators, ensuring that the development aligns with pedagogical principles and established instructional design standards (Sudaryono, 2016). To evaluate the effectiveness of the developed tool, a limited-scale trial was conducted. This trial tested the demonstration tool within the context of installing lighting systems. The study employed a Pretest-Posttest Control Group Design, in which participants were randomly assigned to experimental and control groups to ensure that both groups possessed similar characteristics at the outset of the intervention.

Table 1. Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Eksperimen	O1	X	O2
Kontrol	O1		O2

Description:
O1 : Pretest
X : Treatment using the TRIAC-based automatic switch demonstration tool
O2 : Posttest

Design and Development of the Demonstration Tool

The design phase involves planning the instructional demonstration tool. It consists of a technical explanation of the TRIAC-based light sensor (photocell) circuit, PCB track design, component placement on the PCB, circuit testing, product packaging, and final testing of the automatic switch prototype. The initial product design includes the development of a workflow that outlines the manufacturing process of the tool, intended to manage each stage effectively (Gede,2021). *The workflow for the demonstration tool design is illustrated in Figure 1.*

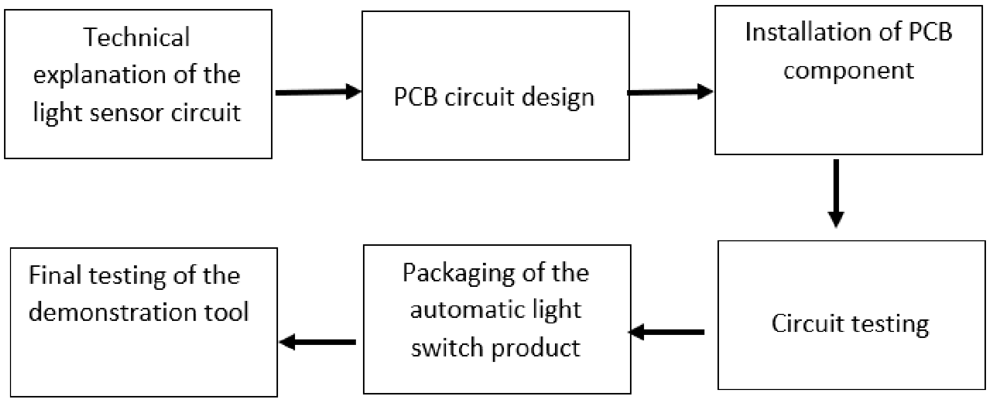

Figure 1. The Workflow of the Instructional Demonstration Tool

Data Sources and Research Subjects

The study was conducted at SMKN 1 Tonjong, Brebes Regency, involving a total of 106 Grade XI Electrical Power Installation Engineering (TITL) students that divided into three classes. As shown in Table 2, a limited-scale trial involved 36 students in the experimental group, 36 in the control group, and 10 in the small-scale pilot group. Data sources include subject matter experts, media experts, teachers, and students for assessing practicality (Sugiyono, 2017).

Table 2. Data Sources and Research Subjects

No	Data Source	Number of Participants	Description
1	Media Experts	10 experts	Inter-rater (Feasibility)
2	Material Experts	10 experts	Inter-rater (Feasibility)
3	TITL Teachers	2 teachers	Teacher Practicality Testing
4	Students	36 students	Student Practicality Testing
5	Control and Experimental Classes	36 control + 36 experiment	Effectiveness Testing

Effectiveness testing was conducted using pretest and posttest results to determine whether a statistically significant difference existed before and after treatment (Sugiyono, 2017). The research subjects were Grade XI TITL students studying the *Lighting Installation* subject, on the competency of installing lighting systems in basic and smart buildings.

Data Collection Techniques

The data collection techniques in this study included observation, questionnaires, and interviews. Observations were used to evaluate the feasibility of the demonstration tool using observation sheets (Arikunto, 2019). Practicality testing employed dichotomous-scale questionnaires distributed to both teachers and students. Observations and performance tests were also used to assess effectiveness. The research instruments used for developing the TRIAC-based light sensor switch demonstration tool included four types: questionnaires, interview guides, observation sheets, and question test items.

Data Analysis Techniques

The data analysis was performed using quantitative descriptive analysis following the developmental research procedure. Data were collected from evaluations by ten media experts, ten material experts, and responses from users. Media experts included teachers from the Electrical Power Installation field. Effectiveness testing was conducted by comparing an experimental group using the TRIAC-based tool with a control group using a factory-made light sensor switch.

Pretest

Pretests were conducted before the treatment phase in both the experimental and control groups. The pretest results were analyzed using a two-sided test to determine whether there was a significant difference in the mean scores between the groups (Miles, 2018).

Descriptive Analysis

Quantitative analysis was used to determine the validity and reliability of the TRIAC-based tool according to expert evaluations. The data provided a basis for describing the feasibility and consistency of the instrument. The analysis also assessed students' success in implementing smart building lighting installations using the presented tool.

The success of this program is based on the students' scores in the subject of Electrical Power Installation in basic and smart buildings. Student performance was measured across four components: accuracy of schematic preparation, component installation quality, installation output, and timing during practical implementation. Final scores were calculated as the average percentage across components, with a range of 0–100 (Riduwan,2018). Student performance categories are shown in Table 3.

Table 3. Student Performance Categories in Implementing Smart Building Lighting Installations

No.	Score Range	Category	Description
1	90–100	SB	Competent
2	80–89	B	Competent
3	72–79	C	Competent
4	≤ 71	K	Not Competent

Media Feasibility Testing

Media feasibility testing was used to assess whether the tool was suitable for use in instructional settings (Sugiyono, 2017). Quantitative descriptive analysis was implemented in this research, and the data were obtained from expert responses using feasibility questionnaires. Media validators were Electrical Power Installation teachers, while material validators assessed the practical worksheet content. Feasibility data were analyzed using the Content Validity Ratio (CVR) and Content Validity Index (CVI).

Media Effectiveness Testing

This research aimed to develop and test the effectiveness of the media in enhancing student skills (Sugiyono, 2017). The tool was tested in practical activities involving single-phase lighting installations for both simple and smart buildings. Feasibility, practicality, and experimental testing were conducted using a quasi-experimental method with a Pretest-Posttest Control Group Design. There were two groups for this research: the experimental group (Class XI TITL 2) used the TRIAC-based instructional tool, while the control group (Class XI TITL 1) used factory-manufactured tools. Both groups received a pretest to determine baseline performance. Furthermore, the experimental group received treatment using the developed tool, and both groups were then given the same posttest. Independent Sample T-Test and N-Gain analysis were used to analyze the results, after passing normality and homogeneity tests.

Media Practicality Testing

The practicality of the media was evaluated using the Reproducibility Coefficient (Kr) and Scalability Coefficient (Ks) calculated from predefined scores. A qualitative descriptive analysis was employed based on questionnaire responses from teachers and students (Sugiyono, 2017). The Reproducibility Coefficient Formula can be seen as follows:

$$Kr=1- e/n$$

The formula indicates that e = number of negative responses; n = total items × total respondents. After the value of Kr is determined, the calculation of the scalability coefficient (Ks) is carried out using the following formula:

$$Ks=1- e/k$$

k is half of the maximum value for 'Yes/Practical' responses divided by the total score obtained from those who answered 'Yes/Practical'. The instrument is considered valid if it meets the following criteria: the reproducibility coefficient scale, where $Kr > 0.90$, and the scalability coefficient (Ks), where $Ks > 0.60$ (Sugiyono, 2017). The category of practicality in using the automatic light sensor switch teaching demonstration for smart building lighting installation can be seen in Table 4 below

Table 4. Media Practicality Categories

No.	Score Range	Category
1	$80\% < x \leq 100\%$	Very Practical
2	$60\% < x \leq 80\%$	Practical
3	$40\% < x \leq 60\%$	Fairly Practical
4	$20\% < x \leq 40\%$	Less Practical
5	$0\% < x \leq 20\%$	Not Practical

(Source: Sugiyono, 2017)

RESEARCH RESULTS AND DISCUSSION

Research Results

Effectiveness of the Electrical Lighting Installation Demonstration Tool Utilizing a TRIAC-Based Light Sensor Automatic Switch

The effectiveness of the electrical lighting installation demonstration tool, which employs a TRIAC-based light sensor automatic switch, was evaluated using a structured performance assessment instrument. Prior to implementation, the test instrument was validated through consultations with the Head of the Electrical Power Installation Engineering (TITL) program and the teacher for Electrical Lighting Installation (IPL) for Grade XI TITL students at SMK Negeri 1 Tonjong, Brebes Regency. This process ensured that the instrument was aligned with the relevant basic competencies and targeted learning outcomes. The performance evaluation was conducted through practical activities involving the installation of a smart residential lighting system. The results of this performance assessment are presented in Table 5.

Table 5. Performance Test Results

No	Description	Performance Test Results
1	Highest score	92
2	Lowest score	76
3	Minimum Proficiency Score	72
4	Number of students	36
5	Number of students competent	36
6	Number of students not yet competent	0
7	Percentage of competent students	100%

Based on the table above, the results of the performance test in the practical implementation of smart residential lighting installation indicate a learning mastery rate of 100%, categorized as excellent. These results confirm that the developed electrical lighting installation demonstration tool, utilizing a TRIAC-based light sensor automatic switch, is effective for instructional use.

Descriptive Analysis

The performance test results for the smart residential lighting installation practicum (smart building) during the posttest phase were analyzed for both the experimental and control groups. The experimental group received treatment using a TRIAC-based light sensor automatic switch, while the control group relied on textbooks or instructional modules as the primary learning resources. The posttest results are presented in Table 6 below.

Table 6. Descriptive Statistics of Posttest Results

Group	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Experimental Class	36	76	92	84.67	3.108
Control Class	36	65	83	75.69	2.967
Valid N (listwise)	36				

Based on the data in Table 6, the average posttest cognitive performance score in the experimental group was 84.67, while the control group recorded an average of 75.69. Furthermore, the experimental group achieved a minimum score of 76 and a maximum of 92, while the control group ranged from a minimum of 65 to a maximum of 83. These results showed a clear difference in mean cognitive performance between the two groups. To assess the statistical significance of this difference, an *Independent Samples t-Test* was performed on the posttest data (Arikunto, 2019).

Independent Samples t-Test

The t-test, commonly known as a partial test, is used to examine the individual effect of each independent variable on the dependent variable (Arikunto, 2019). In this study, this test was used to determine whether a statistically significant difference exists between the experimental and control groups. The hypothesis for the Independent Samples t-Test is as follows: *Ha* is accepted if *t-calculated* > *t-table* (95%), indicating that the TRIAC-based light sensor automatic switch demonstration tool is effective in enhancing students' cognitive performance in the smart residential lighting installation practicum. The results of the *Independent Samples t-Test* by using SPSS software are presented in the following table.

Table 7. t-Test Result

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Posttest Cognitive Performance	Equal variances assumed	.784	.379	20.359	70	.000	14.222	.699	12.829	15.615
	Equal variances not assumed			20.359	69.315	.000	14.222	.699	12.829	15.616

Based on the data presented in the table above, the obtained t-value was 20.359. According to the t-table showed that t-table was 1,669 with df = 70 and a significance level of 0.05. Since the calculated t-value (20.359) is greater than the critical value (1.669), it can be concluded that *Ho* is rejected and the *Ha* is accepted. This indicates that the use of the electrical lighting installation demonstration tool employing a TRIAC-based light sensor switch is effective in improving students' cognitive performance in the smart residential lighting installation practicum.

N-Gain Analysis

The Normalized Gain (N-Gain) analysis was conducted to determine the extent of improvement in students' cognitive performance after the treatment (Arikunto, 2019). The N-Gain score is calculated by comparing the pretest and posttest scores. Based on the results, the average N-Gain score for the experimental group was 71.43 (or 71.43%), falling into the high category, with a minimum score of 58.33 and a maximum of 84.00. In contrast, the control group had an average N-Gain score of 55.08, which is categorized as moderate, with a minimum of 36.54 and a maximum of 70.09.

Practicality Test of the TRIAC-Based Light Sensor Automatic Switch Demonstration Tool for Electrical Lighting Installation

The researcher provided a questionnaire after implementing media in the teaching and learning process, with 36 students in Class XI TITL 1 (experimental group) as participants. The purpose of this questionnaire was to evaluate the level of positive student response toward the learning media. The assessed practicality aspects included: (1) Ease of use, (2) Support for learning, (3) Content relevance, (4) Engagement or attractiveness, and (5) Can be used for independent learning.

The student responses were analyzed for practicality, validity, and reliability. The overall practicality score of the media was 68%, indicating that the tool is practical. Furthermore, the reproducibility coefficient (Kr) for students was 0.91 and 0.93 for teachers, the data achieved a mean Kr of 0.92. According to Singarimbun (2018), a reproducibility coefficient >0.90 meets the criteria for high practicality. Therefore, the use of the TRIAC-based light sensor switch demonstration tool for the smart home lighting installation practicum is considered highly practical.

Based on the calculation of the scalability coefficient (Ks), 0.77 was obtained for students and 0.86 for teachers. The obtained values of the reproducibility coefficient and scalability coefficient were then compared against the practicality criteria. The data showed that the reproducibility coefficient (Kr) for students was 0.91, and for teachers was 0.93. Meanwhile, the scalability coefficient (Ks) for students was 0.77, and 0.86 for teachers, with an average score of 0.815. Therefore, the use of the TRIAC-based light sensor automatic switch demonstration tool for smart residential lighting installation practicum is considered highly practical

Discussion

The feasibility of using the electrical lighting installation demonstration tool equipped with a TRIAC-based light sensor automatic switch for the smart building was validated by both media experts and material experts. The validation process involved ten media experts and ten material experts. Based on the results of the media expert validation, the feasibility of the media instrument was declared "feasible" after undergoing analysis using the *Content Validity Ratio (CVR)*, *Content Validity Index (CVI),* and *Percentage of Agreement.*

The results of the Content Validity Ratio (CVR) analysis indicated that all indicators achieved CVR values from 0.8 to 1.0 (Sugiyono, 2017). For the overall test, the Content Validity Index (CVI) got 0.88. These findings demonstrate that all aspects (indicators) of the media instrument for the smart residential lighting installation practicum are valid, as both the CVR and CVI values exceed the minimum threshold of 0.62. This is further supported by the Percentage of Agreement, which reached 88%, surpassing the required agreement level of 80%. Therefore, the experts concurred and concluded that all aspects (indicators) of the media feasibility instrument for the smart residential lighting installation practicum are valid and reliable.

The limited trial was a form of implementation stage carried out after the developed media was declared valid and reliable by media and material experts. At this stage, the electrical lighting installation demonstration tool, utilizing a TRIAC-based light sensor automatic switch, was tested on a limited basis with 36 students from Class XI TITL 1 designated as the experimental group. Meanwhile, the control group, consisting of 36 students from Class XI TITL 2, received learning materials in the form of printed modules. Following the treatment of both the experimental and control classes, a performance test was administered as a posttest measure. The posttest results were then subjected to normality and homogeneity tests (Sudaryono, 2016). At the end of the research process, a practicality questionnaire was distributed to both students and teachers in the experimental class.

The selection of indicators is a crucial aspect in the development of the electrical lighting installation demonstration tool, utilizing a TRIAC-based light sensor automatic switch designed for students. This aligns with the view of Pane and Nainggolan (2022), who assert that a demonstration tool for electrical lighting installation using a TRIAC-based light sensor switch is a set of instructional media that simultaneously presents a miniature building model along with the integrated installation system, conveying specific educational messages. The feasibility test of media by expert judgment was based on the tool's sensitivity to changes in ambient light intensity.

The developed electrical lighting installation demonstration tool, utilizing a TRIAC-based light sensor automatic switch, is considered effective if it significantly improves students' cognitive abilities. Before analysis using the independent sample t-test, the posttest data were subjected to normality and homogeneity tests (Sugiyono, 2017). The effectiveness of the demonstration tool was then evaluated using the independent sample t-test. Analysis of students' cognitive abilities showed a t-value of 20.359 with a significance value (2-tailed) of $0.000 < 0.05$. Since the calculated t-value $20.359 >$ t-table 1.669, it can be concluded that there is a significant difference in the average cognitive abilities between the experimental class and the control class. Based on the presented data showed the tool's effectiveness.

Thus, it can be concluded that the use of the electrical lighting installation demonstration tool significantly enhances students' cognitive abilities. The N-Gain result of 0.71 indicates a high level of cognitive improvement in the experimental class that used the TRIAC-based light sensor automatic switch demonstration tool, compared to the control class that used textbook-based learning media. The N-Gain value was then assessed against the N-Gain Score (g) classification, where a value of $g > 0.7$ is categorized as high improvement. Furthermore, the developed TRIAC-based light sensor automatic switch demonstration tool was also classified as practical, based on the analysis of the reproducibility and scalability coefficients.

The data depicted that the Kr scores obtained 0.91 for students and 0.93 for teachers. Furthermore, the Ks scores got 0.77 for students and 0.86 for teachers, or it can be indicated that the demonstration tool meets the practicality criteria, which require $Kr > 0.90$ and $Ks > 0.60$. These findings align with the conclusions of Rivai & Hidayat (2022), who stated that the electrical circuit demonstration tool used in the Basic Electricity subject fulfills the definition of practical, with an average observation score of 77, or categorized as good. Therefore, the TRIAC-based light sensor automatic switch demonstration tool for electrical lighting installation can be considered a feasible and practical medium for instructional use.

CONCLUSION

This study involved the research and development of an electrical lighting installation demonstration tool utilizing a TRIAC-based light sensor automatic switch for smart residential lighting (smart building), developed using the ADDIE model. The developed tool has proven to be effective in enhancing students' cognitive abilities. Furthermore, the demonstration tool is highly practical for use as an instructional medium. This conclusion is supported by positive feedback from users, comprising students and instructors of Electrical Power Installation Engineering at SMK Negeri 1 Tonjong, Brebes Regency, who rated the tool as highly feasible.

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