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Feasibility of 3-Dimensional Media-Based Learning for Electrical Vocational High School Students

Abdul Muin Sibuea[1*], Bima Mustaqim[2]

[1]*Educational Technology, Universitas Negeri Medan, Medan, Indonesia, 20221*
[2]*Electrical Engineering Education, Universitas Negeri Medan, Medan, Indonesia, 20221*
**Email corresponding author: sibuea.muin@gmail.com*

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Abstrak

Kombinasi teknologi 3 Dimensi (3D) dengan konten edukasi bertujuan untuk menciptakan ide-ide baru yang dapat hal ini juga meningkatkan efisiensi dan daya tarik proses pengajaran dan pembelajaran bagi siswa dalam situasi kehidupan nyata. Penggunaan teknologi 3D dapat membuat proses pengajaran dan pembelajaran lebih menyenangkan, yang mana minat siswa dalam belajar dapat terstimulasi. Penelitian ini mengembangkan media pembelajaran 3D untuk materi penerangan jalan umum menggunakan model pengembangan ADDIE (Analisis, Desain, Pengembangan, Implementasi, Evaluasi). Media 3D yang dikembangkan menerima umpan balik yang sangat positif dari siswa, dengan lebih dari 90% sangat setuju bahwa media ini secara signifikan meningkatkan keterlibatan, minat, dan pemikiran kritis mereka. Hasil ini secara menonjol memvalidasi teknologi 3D sebagai masa depan pembelajaran yang berdampak. Ke depannya, analisis komparatif yang meneliti pengaruh berbagai desain media 3D dan interaksi pada pembelajaran mendalam akan lebih lanjut memandu praktik terbaik. Dengan perluasan yang cermat, penelitian ini mengantar era baru keterlibatan akademis yang dibayangkan kembali melalui pikiran yang terstimulasi, mata yang terpikat, dan inovator muda yang berdaya. Revolusi pembelajaran 3D baru saja dimulai.

Kata Kunci: *3 Dimensi, Model ADDIE, Instalasi Penerangan Listrik, Teknologi Pendidikan. Penerangan Jalan Umum, Sekolah Menengah Kejuruan*

Abstract

The combination of technology 3 Dimensions (3D) educational content is designed to generate innovative ideas that enhance the efficiency and engagement of teaching and learning in real-world situations. Integrating 3D technology into the learning process can make education more enjoyable, fostering students' interest and motivation to learn. This research developed 3D instructional media for a public street lighting material using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. The 3D media developed received overwhelmingly positive feedback from students, with over 90% strongly agreeing that this media significantly enhanced

their engagement, interest, and critical thinking. These results prominently validate 3D technology as the future of impactful learning. Moving forward, comparative analyses examining the influences of different 3D media designs and interactions on deep learning will further guide best practices. With thoughtful expansion, this research ushers in a new era of reimagined academic engagement via stimulated minds, captivated eyes, and empowered young innovators. The 3D learning revolution has just begun.

Keywords: *3 Dimension, ADDIE model, Electric Lighting Installation, Educational Technology. Public Street Lighting, Vocational High School*

INTRODUCTION

In the digital age, education is incredibly important, and making it better is the only way to train students to know everything there is about their course curriculum (Zhou et al., 2016). One of the main areas in Indonesian vocational schools that needs extra attention is the Electricity Power Installation Program of the Engineering Technology (Amin & Mustaqim, 2021; Mahadiraja & Syamsuarnis, 2020). In that class, the detailed study of the electrical systems is one of the basic elements, in it, the lighting of the public roads is the main mandatory competence of all the trainees. From traffic lights to zebra crossings, the external lights continue to be imperative for the safety and the everyday running of the road infrastructure, albeit, the installation of these lights is very technical and not adequately provided by the current training (Batubara & Hambali, 2021). Connecting this gap requires the transformation of the curriculum so that it may fit the state-of-the-art themes with the life skills. It is through the raising of standards, by stressing true in-depth knowledge only, that these courses give the would-be graduates thus enabling them to shine in communities waxing strong on their specific offers (Irawan & Hendri, 2022).

Public street lighting represents critical curriculum for Indonesia's vocational Electric Power Installation Engineering programs (Andermi & Eliza, 2021). However, student comprehension of these complex electrical systems falls short. Rote textbook diagrams fail to illuminate the intricacies underlying real-world illumination implementation. This dynamic material cries for multidimensional media that brings concepts to light through immersive simulation. Without such tools, the basics of lighting design and infrastructure integration remains shrouded in darkness, obscuring the safe, innovative application of these foundations. The cost manifests in substandard learning outcomes that threaten the quality of future training. If enhanced visualization does not brighten mastery, the widening expertise gap dims career prospects across essential regional industries. Only by prioritizing state-of-the-art solutions can schools empower graduates to shine as modern safety and technology demands accelerate. No learning environment can leave this defining knowledge in the dark if students are to grasp enlightened professional practice (Greenstein, 2012; Sutiadiningsih & Mahfud, 2023).

Studying electrical lighting installation, especially Public Street Lighting (PJU), is an important part of the vocational high school (SMK) curriculum in Indonesia, particularly in the Electrical Engineering program. This subject helps students build both theoretical knowledge and hands-on skills for installing PJU systems, which are becoming increasingly essential as the demand for street lighting infrastructure grows. The Ministry of Energy and Mineral Resources (ESDM) has reported that the PJU-TS (Solar-Powered Public Street Lighting) program has successfully installed thousands of streetlights in remote areas,

creating job opportunities for skilled electrical installation workers (Kementerian ESDM, 2023).

PUIL's technical guidelines include the necessary steps for proper management of electric circuits, protection of system and maintenance. Rising demand for workers who skilled in electricity and renewable energy sectors is impossible to be resolved without PJU materials found in SMK education. It is a key factor in preparing industry-ready and competent graduates. The report from the Ministry of Manpower signals the increasing demand for skilled professionals in this sector, particularly those who can use automation control to increase energy efficiency (Kementerian ESDM, 2023).

The PJU research area contains very important issues like, the lamps specification, pole data, and the whole system of the installation (Hirzan & Yuhendri, 2020). All these concepts are best tackled through 3D visualizations, which offer a more interactive and engaging learning experience than traditional text or 2D explanations (Ragunath et al., 2010). According to research findings, 3D visualizations have a capability to improve student's understanding by 15-25% and have the added advantage of making even the hardest subjects more interesting and compelling (Dalgarno & Lee, 2010; Suleman et al., 2019). Nevertheless, research and development in the 3D learning media area specifically for PJU topics are still inadequate, which has prompted the opportunity for upgrading educational outcomes in this area.

Due to the lack of 3-dimensional media, teachers find it difficult when delivering public street lighting material so that it is easily understood by students (Molnár & Benedek, 2015). This impacts students' understanding which is still low and competency test scores on public street lighting materials that are still below the competency standards set. On average, only about 65% of students reach the minimum passing grade for competency tests, even though the standard set is at least 80% (Wiranto & Sukardi, 2022). To answer this challenge, the researcher intends to develop 3-dimensional learning media for public street lighting topics in Lighting Electrical Installation subjects. It is hoped that this 3-dimensional media can provide a thorough visualization for students so that their understanding increases, which in turn impacts the achievement of higher learning outcomes (Hairi et al., 2020; Israwati & Fauzi, 2023).

Based on a review of previous studies, 3-dimensional media has been proven to overcome complex and difficult to visualize learning problems in just 2 dimensions (Prasetya et al., 2023; Zuhairy et al., 2021). 3-dimensional media can also convey multimedia information at once audio, visual, animation, and interactive simulations so that students can learn contextually (Peterson & Mlynarczyk, 2016; Sriadhi et al., 2021). This research is expected to contribute 3-dimensional media for public street lighting topics which currently do not have 3D visualization media. The focus of this research is to develop 3-dimensional media for public street lighting materials in Lighting Electrical Installation subjects at Vocational High Schools in the Electric Power Installation Engineering Expertise Program. The development model that will be used adapts the general steps recommendations of ADDIE, namely Analysis, Design, Develop, Implementation and Evaluation of media impact on student learning outcomes (Almelhi, 2021).

Specifically, this 3-dimensional media is expected to visualize types of public street lighting lamps along with their technical specifications, pole design and public street lighting electrical installations, public street lighting protection system simulations, to cable network layouts and light pole placements. Through contextual 3D visualizations, it is hoped that students' understanding and interest in these materials will increase. In the

end, increasing understanding of this material is important to support the competencies of future public street lighting technicians (Nurtanto et al., 2020; Ponnusamy & Raman, 2023). The importance of this research lies in efforts to improve the quality of education at the vocational high school level, specifically in the Electric Power Installation Engineering Expertise Program. By developing appropriate learning media for public street lighting materials, it is hoped that it can increase students' absorption, increase teaching effectiveness, and ultimately, make a positive contribution to the ability of students to apply their knowledge in the real world. Thus, this research is expected to provide a sustainable solution with a positive impact on vocational education in Indonesia (Handaru & Pujiriyanto, 2020; Suharno et al., 2020).

METHOD

Analyzing the perceptibility of the design and content of 3D-based learning by students, this research takes a quantitative approach (Sibuea et al., 2021). The structured questionnaire was employed to the participants to elicit in-depth feedback on the learning application. The sample of the study had 50 male and 25 female students who were selected through stratified random sampling in order to have the same gender distribution in vocational high schools. To collect different points of view, students from various departments were included. Only the actively enrolled students took part in the research, while those who had recently transferred or had extended absences were excluded. The data that were collected were analyzed using descriptive statistics, which gave a lot of insights into the students' experiences with the learning application.

It should be mentioned that the design was based on ADDIE, a widely recognized model for effective educational materials (Muruganantham, 2015; Stapa & Mohammad, 2019). ADDIE is a systematic approach to ensure that the instructional products are well designed, developed, and refined to optimize the learning outcomes. The model consists of five key phases, which can be taken from Figure 1 (Widyastuti, 2019). Every phase was a vital part of forming the 3D application and so, it was the easiest way to create it. The structured form made it a consistent planning process, and the iterative part followed the whole course of transformation from static to interactive features konsep. By implementing the ADDIE framework, the process of the installation helped to bring in the features with the regular checks and updates. This solution was an efficient way to make the development process easy and ensure the final product was well-organized, engaging, and effective teachers in enhancing students' learning experiences.

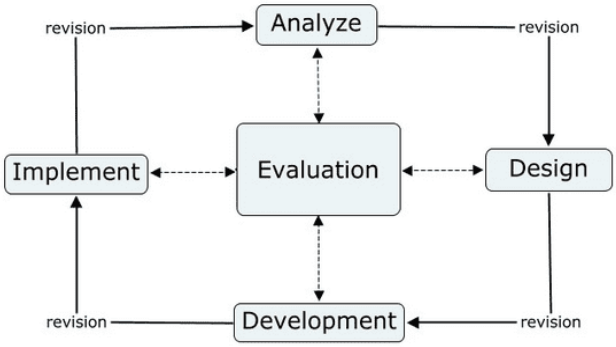

Figure 1. ADDIE Model

Analysis Stage

The analysis phase is a critical part of identifying challenges that exist in the learning environment as well as understanding student characteristics and fixing learning difficulties, it is a central part of the whole learning process. At this point, several types of examination is done with evaluations of the learning environment, student needs, and instructional objectives (Hidayat et al., 2018) being the most common. The detailed analysis carried out by the educators is significant as it helps them to come out with the specific skills and knowledge areas the students need to develop and get to know their attitudes and the overall learning objectives.

According to surveys and observations, it was concluded that 40% of students have a difficult time with the skills and knowledge needed to solve problems of public street lighting, especially in the lighting installation course. These discoveries display an inadequacy of students' grasp of fundamental ideas constituting the challenges on the public street lighting. This, however, is an important part of their curriculum. The remedy for this problem may be the introduction of only one scientific subject. In order to comprehensively tackle the problem, the development of special learning software has been deemed inevitable. The software is made with the aim of closing the gap in knowledge by providing students with interactive gadgets and resources that boost their understanding of the applications of public street lighting. Besides, the program will necessitate a more enlightened approach to teaching street lighting by showing students how these complex ideas are related to the works as well as other similar things. In this way, the software helps in getting off several birds with a single shot! It not only removes the problems that were revealed in the query but it also supports the broader educational approaches in place. Eventually, this specific strategy encourages students to study in a more entertaining way, it revitalizes their practical skills, and they become better prepared to tackle street lighting installations. The revamped XML payload content is:

Design Stage

After carefully analyzing the initial research and insights, we'll move into the design phase. This is where we'll map out the most effective way to teach our content. We'll sketch out the big picture - deciding on the overall approach, choosing the right media and technologies, and crafting specific learning objectives that will guide our instructional strategy. Think of it like drawing up a detailed blueprint for learning, where every element is carefully considered to create the most impactful educational experience.

In this project, we visualized public street lighting using Autodesk Maya 2021 software (King, 2019; Murdock, 2023; Tickoo, 2018). This software is selected because it provides complete features for designing and building 3D content for interactive learning media needs for general street lighting materials. This 3D media for general street lighting material was developed by utilizing the modelling, texturing, animation, lighting and rendering features in Autodesk Maya software to create interactive and realistic 3D visualization. Figure 2 show the blueprints of the public street lighting that was created by using Autodesk Maya 2021.

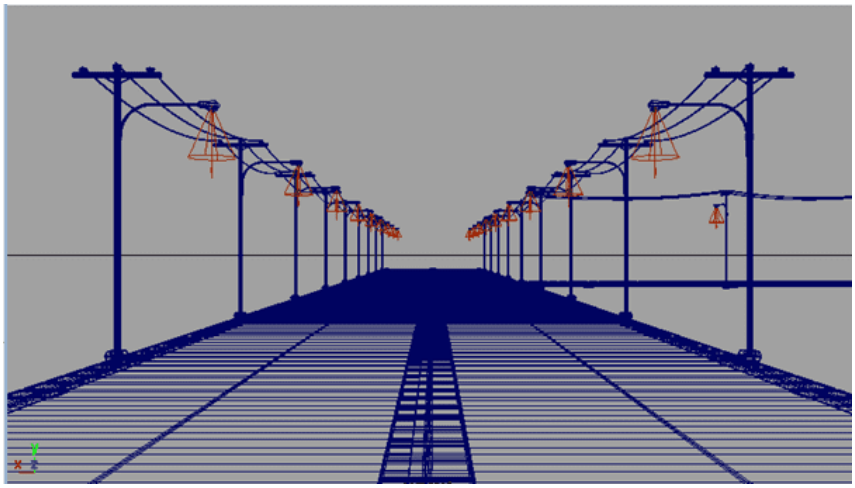

Figure 2. general street lighting blueprint

Development Stage

At this stage, the blueprint that has been designed will be developed in the form of a three-dimensional model. The resulting three-dimensional model must have a shape and size that matches what has been designed in the blueprint. The three-dimensional model that has been developed from its original form will be animated into several scenes which will then be rendered to produce a three-dimensional animated learning video media appropriate to the learning needs of public street lighting installations.

Creating the 3D content for Autodesk Maya 2021 was a nuanced technical and pedagogical exercise. Our team meticulously created a detailed visualization of street lighting infrastructure by strategically addressing complex problems. We created a product that balances technical precision with pedagogical imagination, with the goal of creating visually pleasing content explaining complex street lighting systems in depth and clarity. By integrating eight design principles, we made the media widely accessible, intellectually stimulating, and aligned with current education trends like the "Kurikulum Merdeka". Our approach was able to balance technical complexity with pedagogical effectiveness in transforming high-tech, advanced data into a simple, interactive learning process that directly targets the learning objectives of the 21st century. The result is a 3D media asset that not only demonstrates technical competence in visualization but also delivers a fantastic learning aid, bridging the divide between advanced technical knowledge and engaging, comprehensible learning material.

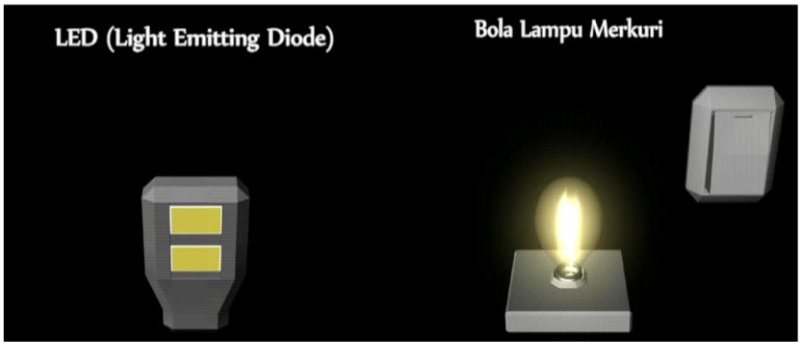

Figure 3. types of public street lighting lamps

Figure 4. types of public street lighting poles

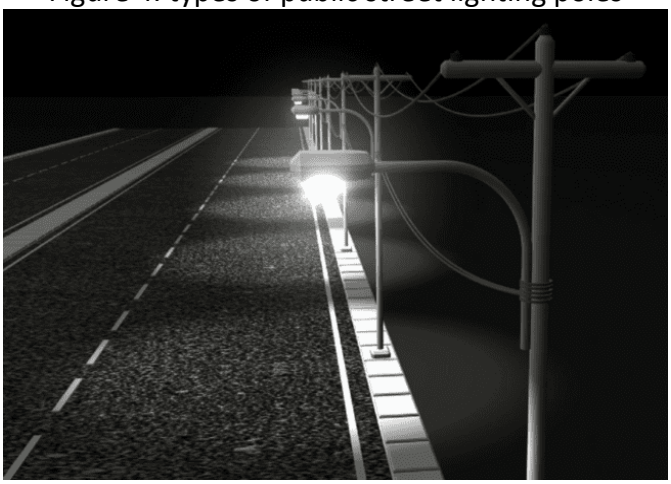

Figure 5. public street lighting installations

Implementation Stage

Our learning program moves from theoretical design to real-world application throughout the execution phase. Six specialist professionals—two media experts, two material experts, and two design experts—were engaged to thoroughly evaluate the 3D media and conduct rigorous testing. Through the use of comprehensive questions, these certified assessors methodically evaluated the resource's efficacy. As shown in Table 1, their results were meticulously computed and analyzed based on exact evaluation standards, offering a detailed confirmation of the learning module's quality and possible influence.

Table 1. Categories of validity evaluation

Intervention Score	Assessment Category	Description
$3{,}6 \leq P < 4$	Very good	Without revision
$2{,}6 \leq P < 3{,}5$	Feasible	Minor revision
$1{,}6 \leq P < 2{,}5$	Less feasible	Major revision
$1 \leq P < 1{,}5$	Not feasible	Cannot be used

To determine the score, the following formula is used:

$$Percentage = \frac{\sum Score \times component\ weight}{n \times score\ highest} \times 100\% \qquad \text{(Formula 1)}$$

Once the score is obtained, the product is considered feasible if it falls within the feasibility categories outlined in Table 2. A product is deemed feasible if it achieves a score greater than 61 and receives a "good" or "very good" qualification based on expert or student validation results.

Table 2. Expert validation eligibility categories

Achievement level	Qualification	Description
81 % - 100 %	Very good	No revision
61 % - 80 %	Good	No revision
41 % - 60 %	Simply	Revised
21 % - 40%	Less	Revised
0 % - 20 %	Not at all	Revised

Our research on the 3D public street lighting educational media yielded impressive results. Six expert reviewers gave the media a thorough evaluation, ultimately rating it highly effective with an outstanding 88.75% approval rating. We then conducted comprehensive student trials across different skill levels. We began with individual tests including three kids with different levels of ability, then worked through a small group of fifteen, and lastly, we worked through a bigger group of thirty-six. Every trial applied consistent evaluation criteria. With an 84.25% appropriateness score, the individual student tests revealed high initial support. While the large group trial showed overwhelming approval at 89.45%, the small group was far more hesitant, achieving 81.65%. From expert evaluation to various student groups, our 3D media constantly demonstrated its educational usefulness and interesting design across all testing phases. These findings confirm our strategy and imply that the media might greatly improve knowledge on street lighting infrastructure.

Evaluation Stage

The evaluation phase concentrated on reviewing the product's development based on eight key criteria outlined in the Development Stage. This step was crucial to ensure that every aspect of the product met the required standards for its intended use. To gather feedback, 75 students from the Electrical Power Installation Techniques program—who had successfully completed the Electric Lighting Installation course—were carefully chosen to participate in the survey. They were asked to respond to a series of questions aimed at assessing the product's development in relation to the established criteria. The questionnaire was created using Google Forms and distributed online for easy access and efficient data collection.

The selected respondents provided valuable insights, particularly regarding the validity of the product's design and content, which helped pinpoint areas for improvement. Their feedback was instrumental in determining whether the product met the expected standards. To ensure accuracy and a thorough analysis, the collected data was processed using SPSS 20.0. For statistical analysis, descriptive statistics were employed, focusing on the frequency and percentage of students' responses. The data was analyzed by calculating the proportion of students who selected a specific answer, dividing it by the total number of respondents, and then multiplying by 100 to find the percentage. This method offered a clear, quantitative view of the overall feedback, enabling informed decisions on any necessary revisions or enhancements to the product.

RESULTS

This evaluation includes eight criteria focused on reviewing the application. The questionnaire was distributed to 75 students from the Electrical Power Installation Techniques program who had studied the Electric Lighting Installation course. These respondents were chosen to provide feedback on the eight product development criteria, helping assess the validity of its design and content. The collected data was analyzed using SPSS 20.0 and presented as percentages. Students' responses were scored based on a Likert scale, as shown in Table 3.

Table 3. Likert-Scale statements scoring rubric

Category of Response	**Strongly disagree (SD)**	**Disagree (D)**	**Agree (A)**	**Strongly agree (SA)**
Score	1	2	3	4

According to (Suharsimi, 2016) Likert-Scale methodology provides a nuanced approach to data collection, carefully designing response options to capture precise information. By creating graduated scales, researchers can more effectively examine and analyze student responses. The process involves first determining response frequencies, then calculating percentages using a specific formula (Formula 2), which transforms raw data into meaningful insights about student perceptions or experiences.

$$P = \frac{f_o}{n} \times 100\% \qquad \text{(Formula 2)}$$

Notes:

P : Percentage

f_o : Frequency of answers

n : Total respondents

The research involved a total of 75 student respondents. To calculate percentage values, each item's percentage is computed based on the total of 75 participants. The frequency of answers (f_o) is directly determined by the number of student responses in each category.

Table 4. Questionnaire's response per item

Description	**Items No**	**Answer Frequencies**				**Total**
		Strongly disagree (SD)	**Disagree (D)**	**Agree (A)**	**Strongly agree (SA)**	
The teaching aids being developed have the potential to garner interest and engagement from learners	1	-	-	6	69	75

From the Table 4. Above, the calculation of percentage is:

Strongly Agree : $\frac{69}{75} \times 100 = 92\%$
Agree : $\frac{6}{75} \times 100 = 8\%$
Disagree : $\frac{0}{75} \times 100 = 0\%$
Strongly Disagree : $\frac{0}{75} \times 100 = 0\%$

The calculation of the total frequency represents an advanced step carried out after determining the percentage of each response based on the overall number of students who completed the questionnaire. This process provides deeper insights into the response patterns observed throughout the study. A comprehensive summary of the research findings, including all key results and detailed analyses, is systematically organized and presented in Table 5. This table serves as a structured reference point, allowing readers to evaluate and analyse the data with clarity and precision.

Table 5. The findings obtained from the investigative questionnaire

No	**Description**	**Scale**			
		Strongly disagree (SD)	**Disagree (D)**	**Agree (A)**	**Strongly agree (SA)**
1	The teaching aids being developed have the potential to garner interest and engagement from learners	-	-	6 (8%)	69 (92%)
2	The instructional tools are that they effectively communicate information through strong visual depictions	-	-	17 (22.67%)	58 (77.33%)
3	The instructional materials are the inclusion of unambiguous descriptions to get the information across	-	-	13 (17.33%)	62 (82.67%)
4	These instructional tools can effectively elucidate the intricate subject of the varieties of street lamps, street lamp poles, and common systems for installing street lighting found in the public domain	-	-	18 (24%)	57 (76%)
5	These instructional resources have high usability and the ability to be utilized by a variety of audiences	-	-	21 (28%)	54 (72%)
6	The instructional materials utilize user interfaces that are engaging and appealing	-	-	2 (2.67%)	73 (97.33%)

7	The instructional materials have an impact on the process of teaching and learning	-	-	6 (8%)	69 (92%)
8	These cutting-edge educational tools dynamically support the "Kurikulum Merdeka" framework, seamlessly integrating 21st-century learning competencies and innovative pedagogical strategies.	-	2 (2.67%)	3 (4%)	70 (93.33%)

DISCUSSION

The research conducted has resulted in the development of 3D instructional media for the subject matter of public street lighting. This media was developed with the aim of increasing student interest and engagement in learning this material. The results of the research indicate that the 3D instructional media developed has great potential to garner interest and involvement from students, as evidenced by 92% (69 people) of students strongly agreeing. Additionally, the developed 3D media was also assessed to be effective in communicating information through strong visual depictions, with 77.33% (58 people) of students strongly agreeing on this point. This instructional media also includes unambiguous descriptions to convey information, which 82.67% (62 people) of students strongly agreed with.

Furthermore, 76% (57 people) of students strongly agreed that the developed 3D media is able to elucidate the intricate subject matter well, such as the varieties of street lamps, lamp posts, and common installation systems for public street lighting. This media was also appraised to have high usability and the ability to be utilized by diverse audiences, with 72% (54 people) of students strongly agreeing. On top of that, 97.33% (73 people) of students strongly concurred that the developed 3D media employs user interfaces that are appealing and engaging. This media also impacts the teaching and learning process, which 92% (69 people) of students strongly agreed with. Finally, 93.33% (70 people) students strongly agreed that the developed 3D educational media can support the learning process of the “Curriculum Merdeka” in alignment with 21st century demands. In conclusion, it can be inferred that the developed 3D instructional media has great potential and benefits in improving the quality of learning for public street lighting material. The development of 3D media represents an appropriate innovation to undertake.

In this comprehensive research, the ADDIE model served as a robust framework for developing 3D educational media about street lighting. Scholars like (Almelhi, 2021; Fleming et al., 2020; Molnár & Benedek, 2015) have consistently highlighted the ADDIE model's effectiveness in instructional design, particularly for complex technological educational resources. The research meticulously followed the five stages: Analysis, Design, Development, Implementation, and Evaluation. By leveraging Autodesk Maya 2021, researchers created a sophisticated 3D visualization tool that transforms abstract street lighting concepts into tangible, comprehensible content. Studies by (Barchas-Lichtenstein, 2023; Farihah et al., 2023), underscore the potential of 3D media to enhance learning by making complex subjects more accessible. Empirical validation came through extensive student feedback. A comprehensive survey involving 75 students from the

electrical power installation engineering program revealed overwhelmingly positive responses. The 3D media was evaluated as not just visually appealing, but also highly effective in communicating intricate street lighting principles. This research contributes significant insights into using advanced 3D visualization techniques for technical education, demonstrating how strategic instructional design and cutting-edge software can revolutionize learning experiences.

CONCLUSION

The overwhelmingly positive student feedback on the developed 3D instructional media underscores its immense potential to redefine public street lighting pedagogy. With over 90% of students strongly agreeing that this visually striking and intellectually stimulating media significantly bolsters engagement, interest, and critical thinking, the results resoundingly validate 3D technology as the future of impactful learning. Moving forward, comparative analyses examining the influence of diverse 3D media designs and interactions on deep learning would further guide best practices. Additionally, leveraging augmented reality to blend 3D visualizations with students' physical environments could amplify real-world applications and outcome-based education. Excitingly, integrating 3D simulations alongside curriculum wide competency dashboards and adaptive learning algorithms would enable truly personalized and mastery-based instruction. The promising student response, particularly regarding 21st century skill-building, spotlights 3D media's versatility across subjects. Implementing experimental 3D solutions school-wide and assessing influences on achievement gaps as well as creativity and soft skill gains would unveil its extensive potential. With thoughtful expansion, this research ushers in an age of reimagined academic engagement via stimulated minds, captivated eyes, and empowered young innovators. The 3D learning revolution has only just begun.

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