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Development of A Virtual Laboratory Based on Augmented Reality (AR) for Series Circuit Material at SMPN 9 Kota Kediri

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Abstract: This study aims to develop and evaluate the practicality and effectiveness of a virtual laboratory based on Augmented Reality (AR) for teaching series circuits to 9th-grade students at SMPN 9 Kota Kediri. The media is designed to address students' difficulties in understanding concepts of current, voltage, and resistance, which often result from teacher-centered learning methods. The research method used in this study is research and development with ADDIE design are analysis, design, development, implementation, and evaluation. The validity of the media was assessed by experts, and its effectiveness was evaluated through pre-tests, post-tests, and questionnaires. AR technology enables a more interactive and visual learning experience without the limitations of physical laboratory tools. The design and development of the Augmented Reality (AR)-based virtual laboratory learning media effectively improve the learning outcomes and motivation of ninth-grade students at SMPN 9 Kota Kediri, particularly on the topic of series electric circuits.

Keywords: Augmented Reality, Virtual Laboratory, Series Circuits, Physics Education

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INTRODUCTION

Education cannot be separated from human life, as it is a fundamental and essential aspect of human existence. People need education to develop into good individuals. In general, education serves as a means to bring about social change and maintain social stability, as it plays a vital role in the learning process. Education is crucial for the younger generation—the future leaders of the nation—as it helps shape individuals who are excellent, creative in various fields of science, capable of critical thinking, effective communication, and cooperation, and who possess a sense of solidarity (Andrian & Rusman, 2019). Education is a humanistic process aimed at “humanizing humans.” Its purpose is not only to shape individual character distinctively but also to develop independent, critical, and virtuous individuals (Pristiwanti et al., 2022). Education does not aim to strip humans of their dignity, but rather to enhance their quality, essence, and value. Thus, education influences rather than erases; it redirects negative aspects toward positive development and helps individuals fully develop their potential in accordance with their abilities (Bp et al., 2022).

In education, there must be elements that support the abilities of learners, including the use of effective and innovative learning models. Learning models are closely related to methods and the overall effectiveness of the learning process, especially in physics education. To date, physics instruction in schools has often been dominated by teacher-centered learning models (Socrates & Mufit, 2022). In such models, interaction is largely one-way—students act as passive listeners and receivers of information, while teachers actively deliver lessons using lecture-based methods. Education is often misunderstood as merely the transfer of knowledge, when in fact it also involves setting examples, shaping character, and developing student potential (Budiman, 2017).

Series circuits, as part of the topic of dynamic electricity, require a deep understanding of the relationships between current, voltage, and resistance in electrical components arranged sequentially. A series circuit is a type of electrical circuit that does not have branching wires. In a series circuit, all electrical components are connected in such a way that there is only one path for current to flow. The electric current flows from the battery, passes through a fuse (as a protective device), a switch (as a control device), continues to the lamp (as a load), and then returns to the ground. All components in the circuit are connected in series (Budiman, 2017).

However, in many schools, teaching about series circuits is still limited to verbal theoretical explanations from the teacher using a teacher-centered approach. This often results in students struggling to grasp the concepts deeply and apply them to real-life situations. Many students also have difficulty distinguishing between series and parallel circuits, which often

leads to confusion in problem-solving. Additionally, the lack of teaching aids or hands-on practice in school laboratories exacerbates students' understanding, making the learning process less effective. As a result, many students are only able to memorize formulas without understanding how electrical circuits actually work in real contexts.

Therefore, efforts are needed to improve the effectiveness of learning about series circuits by using interactive, student-centered learning methods that help students understand these concepts thoroughly and apply them meaningfully. One innovative alternative is the use of virtual laboratories based on Augmented Reality (AR), which can bridge the gap caused by limited physical resources while enhancing student participation and learning experiences. This study aims to develop and evaluate the practicality and effectiveness of a virtual laboratory based on Augmented Reality (AR) for teaching series circuits to 9th-grade students at SMPN 9 Kota Kediri

METHOD

This study employed a research and development method, commonly known as Research and Development (RnD) with ADDIE design are analysis, design, development, implementation, and evaluation. This method is designed to produce a product and test its feasibility. The primary goal of RnD is to develop effective products or learning media that can be utilized in schools or other educational institutions, rather than to formulate or test theories. This method was chosen by the researcher to create a specific product through a process that begins with a needs analysis and proceeds to test the product's effectiveness, with the aim of enabling its broader application in society. In this study, the product being developed is a virtual laboratory learning media based on Augmented Reality (AR), using the Assemblr Edu application. This media is designed to assist teachers and students in the learning process of science subjects, specifically in the topic of series circuits. **Figure 1** shows reasearch method design.

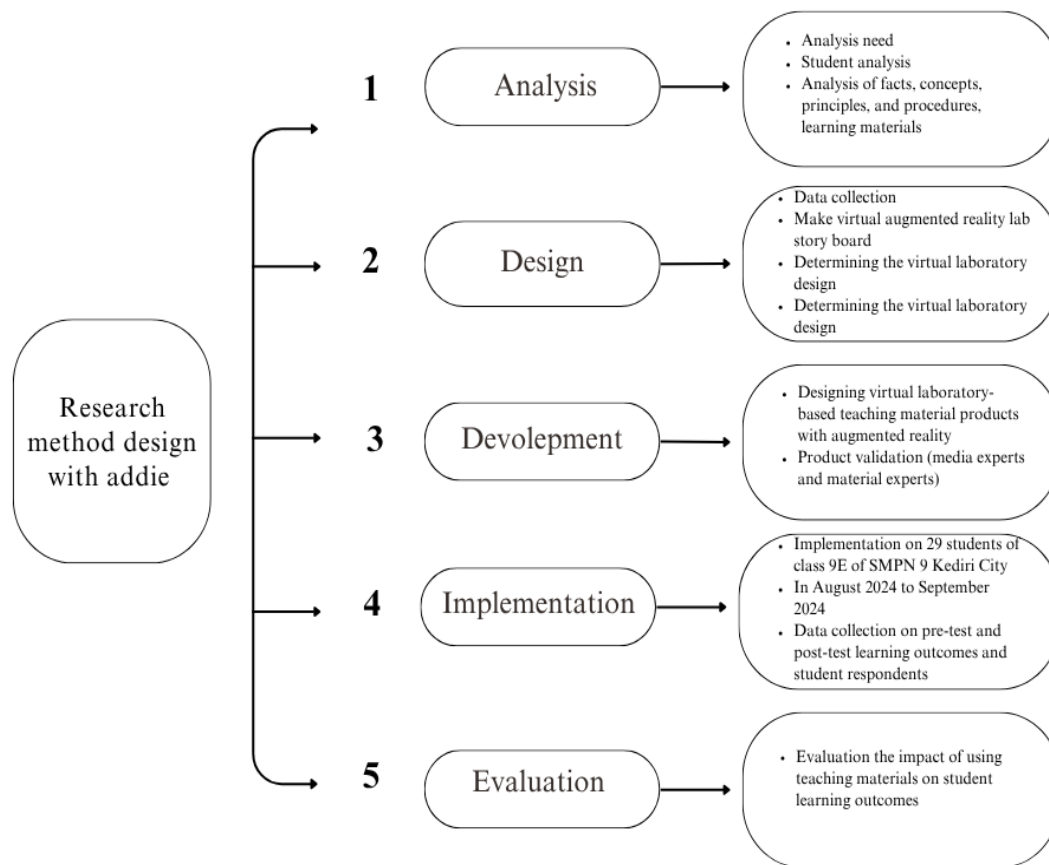


Figure 1. Research method design with ADDIE

FINDING AND DISCUSSION

1. Analysis Stage

The initial analysis was conducted through observations and interviews with teachers and ninth-grade students at SMPN 9 Kota Kediri. The results showed that students experienced difficulties in understanding the topic of series circuits. The learning method used was still predominantly teacher-centered with minimal use of practical teaching aids. Teachers tended to rely on lectures without the support of interactive media, causing students to be less active and unable to understand the connection between conceptual principles and real-life applications.

Based on this analysis, it can be concluded that the development of more innovative and interactive learning media is necessary to help students better understand the concept of series circuits. Attractive learning media that actively engages students is expected to improve student

participation, comprehension, and critical thinking skills in connecting theoretical concepts with real-life applications.

2. Design Stage

Based on the needs analysis, a learning media in the form of a virtual laboratory based on Augmented Reality (AR) was developed using the Assemblr Edu application. This media is designed by presenting electrical circuit components (battery, resistor, cable, switch, and lamp) in a three-dimensional visual form that can be accessed through digital devices.

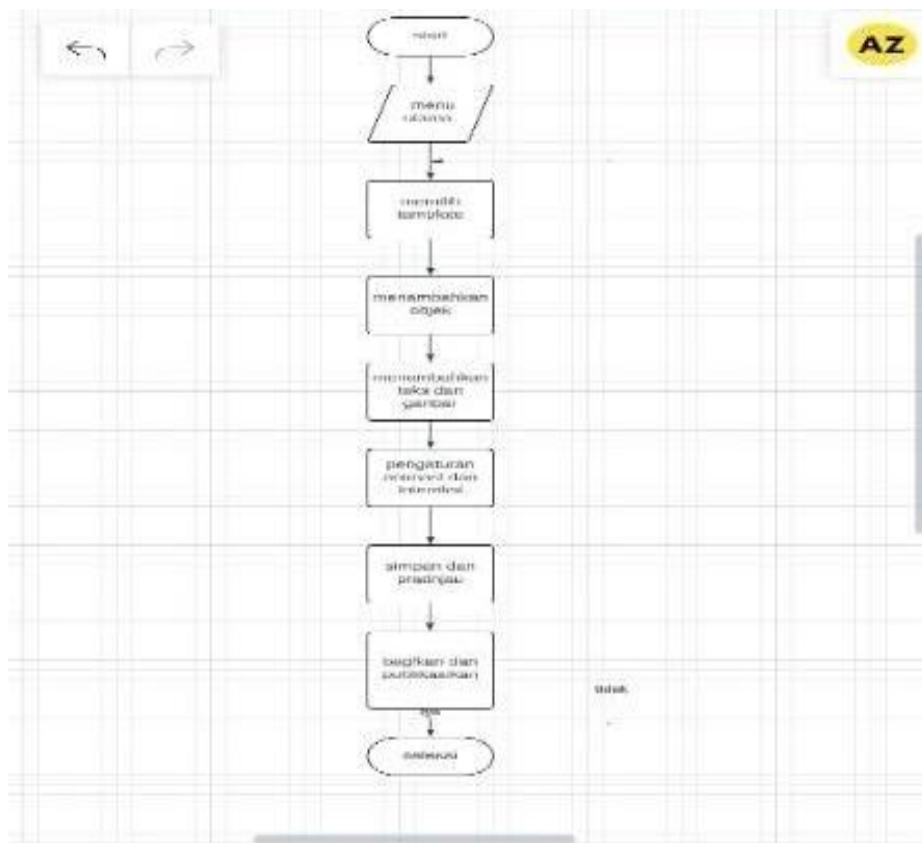


Figure 2. Assemblr Edu Storyboard

The design process involved preparing the storyboard and collecting materials using the Assemblr Edu software to create 3D objects. Full 3D features are available in the paid version, while the free version is very limited, and the 3D models used were selected to match the relevant input and output. Material collection also involved documenting the steps taken during the 3D object creation process, including design decisions, material selection, and other relevant considerations (Rahayu, 2021).



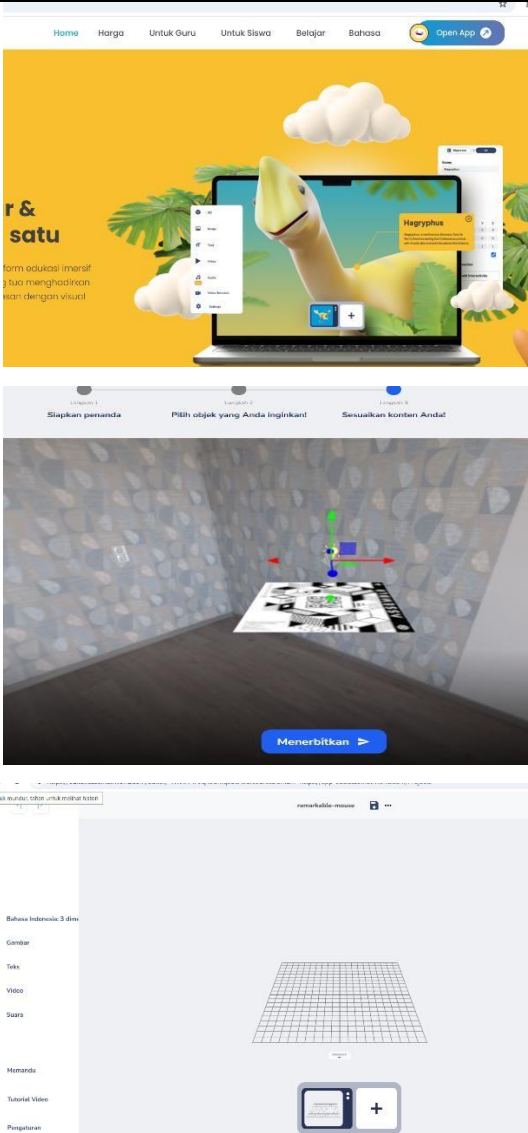
Figure 3. 3D Object Creation

The results of this design stage serve as an essential foundation for product development in the next stage, the *development* phase.

3. Development Stage

In the development stage, the designed media was realized in digital form using the Assemblr Edu application. The media includes interactive simulations of electrical circuits, an introductory video, and practice exercises. The finished product was validated by two experts: a media expert and a subject matter expert. The validation results showed that the media received a score of 90% from the subject matter expert and 98% from the media expert, both falling into the "very valid" category. Suggestions from the experts were used to revise the display, content depth, and narrative structure of the media. Table 1 show learning media development results.

Table 1. Learning Media Development Results

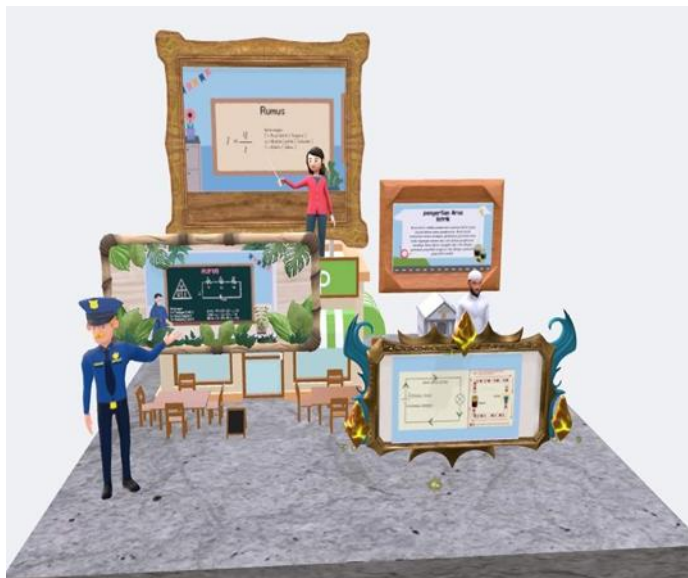
No	Image	Description
1.		The image on the side shows the initial screen when entering the Assemblr Edu (AR) Media.
2.		The image on the side shows the cover information and the title of the Series Circuit material.

3.



The image on the side displays a short video content as a warm-up to start the learning process and to engage students to proceed to the next page.

4.



The image on the side shows formulas to help familiarize students with the problems that will be given.

5.



The image on the side shows the Assemblr Edu media explaining the core material of series circuits, helping students confidently respond to their work results on the series circuits in the media. It presents conceptual content and aids in understanding the material explained by the teacher. After that, students are asked to present their work results.

6.



Before students present their learning outcomes, the teacher explains example problems using the AR media so that students can answer the questions well when given.

7.



The image on the side shows a barcode from the teacher to be shared with students so that it can be accessed individually via their smartphones through the Augmented Reality Assemblr Edu media.

4. Implementation Stage

After the product was developed, the implementation stage was carried out at SMPN 9 Kota Kediri involving ninth-grade students as the trial subjects. The students used the AR-based virtual laboratory application to study the series circuit material.

- a. Implementation Results: Before using the AR virtual laboratory, students were given a pre-test to measure their initial understanding of series circuits. After using the AR, students took a post-test to observe their improvement in understanding.
- b. Pre-test Results: The average score before using AR was 60/100.
- c. Post-test Results: The average score after using AR increased to 85/100, indicating a significant improvement in understanding. Additionally, a student response questionnaire showed that 90% of students felt helped by this virtual laboratory, and 85% found the AR-based learning method more engaging than conventional methods.

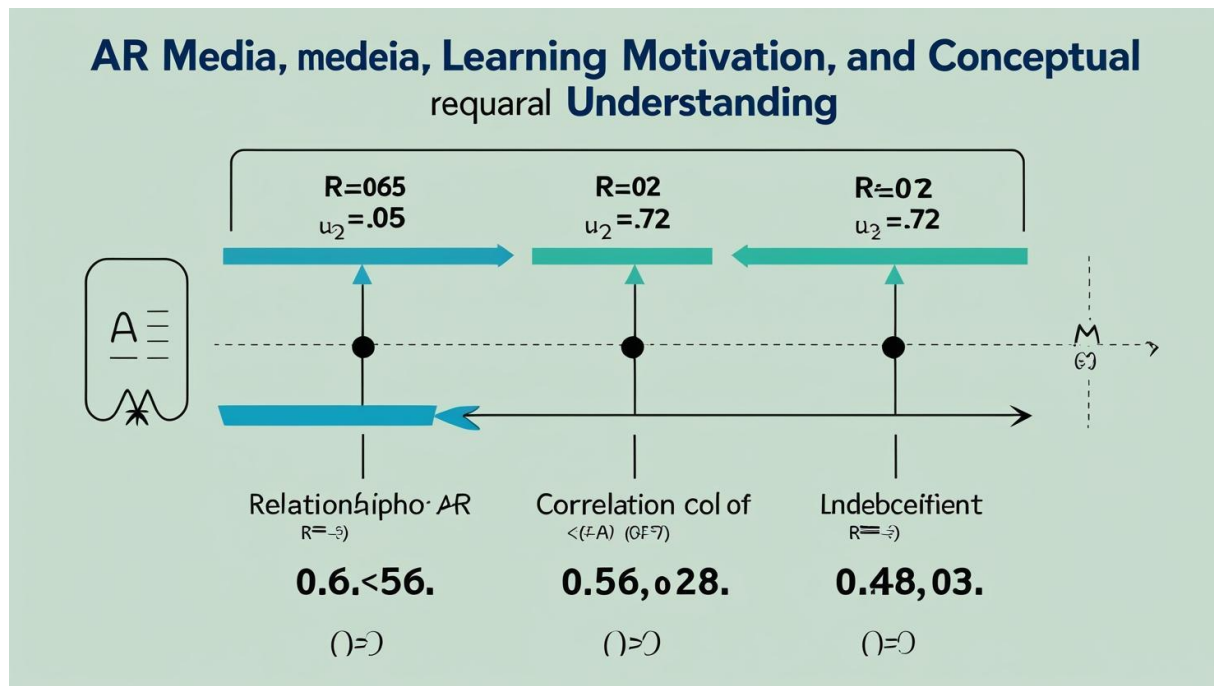


Figure 3. Pretest and Posttest result students' learning motivation and conceptual understanding

Media AR

There is a significant positive with learning motivation with a path coefficient of 0,56. Augmented Reality (AR) media contributes to the enhancement of students' learning motivation.

Learning Motivation

It has a significant influence on conceptual understanding with a path coefficient of 0,32, The R^2 for learning motivation is 0,65, indicating 65% of the variation in learning motivation can be explained by AR media.

Conceptual Understanding

The R^2 for conceptual understanding is 0,72, meaning that 72% of the variation in students' conceptual understanding can be explained by learning motivation.

This diagram illustrates the relationships between AR media, learning motivation, and conceptual understanding, with the path coefficients indicating the strength of the relationships among the variables.

The trial results on a small group in class IX E at SMPN 9 Kota Kediri showed a significant increase in student scores after using interactive science teaching materials based on Augmented Reality (AR). In the first session, the average pre-test score of 29.82 increased to 65.17 in the post-test, while in the second session, the average pre-test score of 61.37 rose to

87.58 in the post-test. This improvement indicates the effectiveness of the AR media in science learning, with an effectiveness level reaching 100%, categorized as very effective.

The effectiveness of the Augmented Reality (AR)-based learning media is evident not only from the improvement in student scores but also from their positive responses regarding ease of use, material comprehension, visual appeal, and clarity of instructions, with the majority receiving over 90% positive feedback. Students also provided constructive suggestions related to image quality and task completion duration. The AR media implemented through the Assembly Edu application was tested using blackbox testing, demonstrating that all functions worked well, from accessing the 3D menu to interacting with the series circuit materials. Both formative and summative evaluations showed that the AR media effectively improved students' learning outcomes and interest, while supporting innovative learning in the era of the Industrial Revolution 4.0 and 5.0.

5. Evaluation Stage

The evaluation phase aimed to assess the success of the product based on its implementation, using both formative and summative assessments. Formative evaluation was conducted during the product revision process to improve aspects like clearer visuals and handwriting, encouraging first-time AR users, and ensuring the media's educational value. It was found that many teachers still rely on traditional methods without interactive media, highlighting the need for innovative tools like Assembly Edu, especially amid Indonesia's transition from Industry 4.0 to 5.0. Significant improvements in student scores and engagement were noted after using the AR media, with students enjoying the interactive 3D content.

Summative evaluation, based on pre-test and post-test results, showed an average increase of 25 points in student understanding. Teachers gave positive feedback, especially on how the virtual lab increased student interest in series circuits. The AR-based virtual laboratory was deemed effective and recommended for broader use in similar schools. Interviews and observations revealed that students found conventional lecture methods boring and the textbooks unengaging due to limited visuals and interactivity. Both students and teachers expressed a strong desire for more innovative, interactive learning materials, such as illustrated books and game-based exercises, to boost motivation and involvement in learning.

CONCLUSION

Based on the research and implementation results, it can be concluded that the design and development of the Augmented Reality (AR)-based virtual laboratory learning media effectively improve the learning outcomes of ninth-grade students at SMPN 9 Kota Kediri,

particularly on the topic of series electric circuits. The use of AR technology in learning provides a more interactive and visual experience, which greatly helps students understand abstract concepts that were previously difficult to grasp through conventional lecture methods. This is evidenced by the significant improvement between the students' pre-test and post-test scores after using this learning media.

The developed learning media has undergone validation by experts, showing a very high level of feasibility. Content experts gave a score of 90% and recommended expanding the material coverage beyond just series circuits. Meanwhile, media and design experts scored 98%, noting that the media possesses excellent design quality, readability, and relevance, and is easy for students to use. This indicates that the learning media not only aligns well with the curriculum but also excels in visual appeal and functionality.

Overall, the development of this AR-based virtual laboratory learning media has proven effective in enhancing student understanding, both in terms of learning outcomes and engagement in the learning process. The learning experience offered through AR has been shown to stimulate student interest and motivation in science learning and serves as an alternative solution to the limited practical facilities available in schools. Therefore, this media is suitable for broader implementation in science education based on the Merdeka Curriculum.

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