The Use of Augmented Reality in Sensor and Actuator Device Learning: Is It Effective in Enhancing Students' Conceptual Understanding?

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***Abstract*—Augmented Reality (AR) technology allows Three-Dimensional (3D) visualization to resemble real conditions. The advantages of AR complement the limitations of previous visual media in supporting material explanations. This study aims to investigate the effects of AR in enhancing students' conceptual understanding of sensor and actuator materials. The method applied was a quasi-experiment involving two groups, namely the control group and the experimental group, with 60 participants aged 15–16 years. AR learning was applied in the experimental group, while the control group followed traditional learning. Data were collected through pretest and posttest using a conceptual understanding test and analyzed using the W test, N-Gain, U test, and effect size analysis. The W test assessed enhancement within each group, while the N-Gain analysis compared score enhancements between groups. The U test evaluated the relative effectiveness of the two learning methods, and effect size analysis determined the magnitude of the impact. Results showed significant enhancement in conceptual understanding for both groups, as indicated by W test outcomes (control group: $Z = -4.63$, $p = 0.000$; experimental group: $Z = -4.79$, $p = 0.000$). However, the experimental group improved more (N-Gain = 54%) than the control group (N-Gain = 35%). The U test ($Z = -4.21$, $p = 0.000$) highlighted that learning with AR was more effective than traditional learning in enhancing students' conceptual understanding, with effect size analysis categorizing its impact as large ($d = 1.14$, $g = 1.14$). These findings confirm that AR is an effective tool for enhancing students' conceptual understanding and is recommended for teaching sensor and actuator materials in educational contexts.**

***Keywords*—Augmented Reality (AR), conceptual understanding, sensor and actuator**

I. Introduction

Augmented Reality (AR) is one of the most revolutionary technologies of the last decade. This technology has become popularly implemented in various fields [1]. AR has provided a breakthrough in supporting visualization and explanation in a more realistic context [2–4]. AR can visualize virtual objects in the real environment [5, 6].

AR has been implemented in various sectors of life. This technology is utilized in gaming to enhance interactivity during gameplay [7]. In the entertainment field, AR supports realistic visualization that enriches the user experience while watching [8–10]. Additionally, in education, AR provides support through visualizing and simulating objects, aiding in understanding complex phenomena [11].

The advantages offered by AR technology can complement the limitations of previous visualization media, which were only limited to Two-Dimensional displays (2D). In the educational environment, visualization media is crucial to supporting students' conceptual understanding during the learning process [12–14]. However, the current implementation of visualization is still limited to images and videos, which have limited interactivity [15]. More realistic and better-understood learning media is highly needed, especially in electrical-related learning that involves sensors and actuators.

The problem in learning about electrical circuits connected to sensors and actuators lies in the limitations of the media used, such as images and videos, which cannot comprehensively depict the form, function, and interaction of components from various angles [16, 17]. This results in incomplete information being acquired by students, potentially lowering conceptual understanding, enhancing the risk of errors in assembly, and hindering successful implementation in real-world applications. Preliminary research supports this finding, showing that although Indonesia's independent curriculum has encouraged the use of interactive media to enhance student-centered learning, its implementation remains suboptimal. Teaching methods tend to be teacher-centered, relying on non-interactive media, such as 2D visualizations, which have limitations in presenting information comprehensively, leading to low student conceptual understanding.

The limitations of learning media that do not support interactivity and the thorough presentation of material have created a gap in sensor and actuator learning. Meanwhile, more interactive approaches that support student-centered learning have become an urgent need to enhance students' conceptual understanding. This gap highlights the necessity for innovative and interactive learning media to help students fully understand and apply the theory effectively.

To address the identified gap, the availability of better visualization media is crucial for enhancing students' conceptual understanding of sensor and actuator materials. Implementing 3D visualization technology in the form of AR

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as an innovative solution supports interactive and detailed explanations that traditional methods lack when explaining sensor and actuator materials. The immersive nature of AR allows for better representation of components, promotes deeper conceptual understanding, and enables broader interaction with the material. As a form of innovation in the learning process, AR is expected to significantly enhance students' conceptual understanding. Therefore, this study aims to investigate the effect of using AR on enhancing students' conceptual understanding of sensor and actuator materials. To ensure the focus of the research, this study will address the following research questions.

1) Is there an increase in the pretest-posttest scores of students' conceptual understanding in each group?
2) Is there a significant difference in posttest results between the two groups?
3) What is the contribution of the effect size of using AR products in enhancing students' conceptual understanding?

II. Literature Review

A. Augmented Reality (AR)

AR is a visual technology that presents objects in three-dimensional (3D) form [18, 19]. This technology is commonly used to support explanations of complex and abstract objects. AR can visualize phenomena such as electron movement, object structures on a quantum scale, the solar system, and building simulations [20–22].

One characteristic of AR is its ease of access. AR can be presented in the user's environment by utilizing the cameras available on smartphones or tablets. The advantages of this technology are that it provides more interactive presentation support compared to previous learning methods dominated by two-dimensional images [23, 24]. This allows users to better understand and support more detailed material explanations [25, 26].

The object presentations provided by AR assist in visualizing objects in their actual conditions within the user's environment. Research indicates that AR positively impacts students' learning interests [27, 28]. Additionally, AR contributes to delivering material explanations in an engaging 3D format. This condition supports a better learning experience for students during the learning process.

AR technology has received significant attention in the fields of science, engineering, and mathematics in supporting learning. Several studies report the need for AR integration in various learning materials to support interactive learning and innovative visualizations to support students' interest and motivation to learn. Integrating AR in technical education has become a crucial aspect of enhancing the delivery of learning materials through 3D visualizations [29]. AR demonstrates significant potential in engineering education, particularly in simulating digital and electronic devices, which helps bridge the gap between theoretical knowledge and practical application [30].

Both hardware and software learning tools are recommended for AR integration across various engineering topics [31]. This recommendation presents an opportunity to expand AR's role in supporting learning in other technical subjects, providing versatile applications in diverse areas of study.

In electronics education, visualization support is essential for explaining the complex functions, components, and systems involved. AR aligns seamlessly with the need for realistic and interactive content, making it a valuable tool for improving student comprehension. By providing detailed simulations, AR allows learners to explore intricate systems and understand their operations more effectively.

However, the development of AR applications in the field of engineering remains limited, posing challenges to its widespread adoption [32]. Addressing these challenges is critical for leveraging AR's full potential in enhancing the learning experience and supporting advanced educational methodologies in technical fields.

B. Sensor and Actuator Devices

Sensor devices and actuators are productive subjects in the Industrial Automation competency, especially in the electronics engineering program, which focuses on understanding electronic hardware components and structures [33, 34]. This learning includes an introduction to sensors that detect physical changes and convert them into processable signals, as well as actuators that receive these signals to perform physical actions, such as moving motors or opening valves [35, 36].

Sensor devices and actuators play a significant role in industrial automation and are widely applied in various electronic systems, including electronic devices, computer systems, and robotics [37]. Effective understanding of these components requires not only theoretical knowledge but also practical application to avoid errors when implemented in real-world scenarios. This highlights the importance of learning materials that strengthen conceptual understanding to support students in designing and maintaining these systems effectively.

Various alternative approaches have been implemented to support sensor and actuator education. Learning materials for these topics have often been delivered through e-learning platforms, such as learning management systems, which provide access to instructional content [38]. However, these systems primarily focus on delivering textual and video-based learning materials without incorporating 3D object visualizations. Traditional methods, such as using manuals and textbooks, have limitations in providing comprehensive explanations of sensor and actuator components [39]. They often constrain the number of devices covered and the depth of visualization offered [40, 41]. The lack of diversity in representations of different sensor and actuator systems, as well as the reliance on static images and videos, limits students' ability to fully analyze and understand the structure and function of these components.

The learning process requires realistic visualizations that provide a holistic understanding of the systems. Detailed depictions of components and their operations are crucial for reducing errors that could lead to significant failures in electronic system design and operation. Consequently, effective visualization becomes an urgent need in education, supporting students in mastering both individual components and their integration into complete systems [42].

Effective visualization is vital for understanding the operation and integration of sensors and actuators in electronic systems. Traditional instructional methods, dominated by static visuals, cannot adequately support the development of a complete understanding of these components. Without realistic visual aids, students may struggle to connect theoretical knowledge with practical applications, increasing the risk of errors during implementation.

Visualization is crucial for understanding system workflows, analyzing individual components, and preparing for real-world scenarios. Introducing realistic visualizations helps students grasp concepts more effectively and minimizes errors that could result in costly system failures. To address the limitations of traditional visualization methods, 3D visualization technology offers a promising solution. Presenting components through interactive 3D models allows for a deeper exploration of their structures and functionalities. This approach reduces the likelihood of misinterpretation and supports better comprehension of the material [43, 44].

However, even within network systems, errors in static image presentations are common and can lead to risks in real-world implementations. Therefore, employing 3D visualizations that provide detailed and accurate representations of objects is essential. These tools simulate real-world environments, allowing learners to engage with the material in a meaningful and risk-free manner. One of the most effective forms of 3D visualization is AR. This technology allows for the simulation of electronic components in an interactive and realistic manner. In the context of sensor and actuator education, AR enables students to visualize device operations and interactions before applying them in physical settings.

AR enhances students' comprehension and technical skills by providing realistic and detailed explanations of components and their functions. It serves as a medium to bridge the gap between theoretical learning and practical application, reducing costs associated with prototyping and minimizing the risk of design errors. Additionally, AR aligns with the educational need for realistic and interactive content, making it an invaluable tool in modern electronics education.

Integrating advanced visualization technologies, such as AR, is essential for enhancing the learning experience in sensor and actuator education. These tools address the limitations of traditional methods by providing interactive and realistic content that improves understanding, reduces errors, and supports practical application. By incorporating AR into educational practices, students can develop the skills and knowledge to design and implement advanced electronic systems efficiently and effectively.

III. Materials and Methods

A. Research Design and Methods

This research applies a quasi-experimental design to compare conceptual understanding among several groups. The characteristics of a quasi-experimental design aim to investigate the effects of different treatments on several groups. Therefore, this design is well-suited to the present study, which examines the impact of different treatments in enhancing students' conceptual understanding [45].

The research population consists of 125 students divided into five classes, grouped according to the arrangements set by the school. The research sample was taken using random sampling techniques based on class levels, resulting in the selection of two classes, each serving as the control and experimental groups. The quasi-experimental research design is presented as shown in Fig. 1.

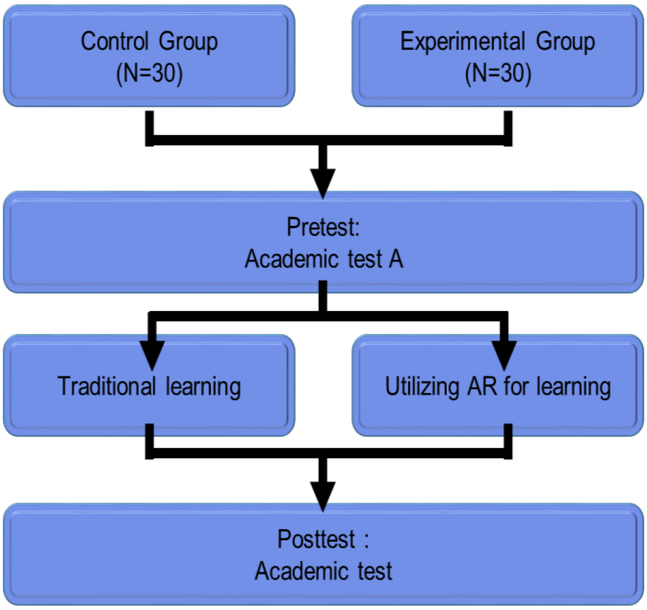

Fig. 1. Design quasi-experimental.

Fig. 1 shows a research design applied with two groups. In the early stages, a pretest was carried out to measure academic ability through a conceptual understanding test conducted in the early stages of students before being treated in both classes. The next stage is applying learning to both groups using traditional and AR learning methods. After learning, a posttest was carried out to measure students' academic ability after the learning process. The data from the pretest and posttest results from both classes were used to investigate the effects of learning on each group and compare the learning outcomes between the two groups.

B. Participants

The participants in this study were vocational secondary schools. The students involved were 60 people (aged 15–16 years). The experimental group consists of 18 males and 12 females, while the control group consists of 17 males and 13 females. They voluntarily participate in this research process without coercion or pressure.

C. Implementations

The implementation of learning to investigate the influence of AR on education was carried out by establishing the learning process in two groups in this study. Traditional learning methods were applied in the control group using printed book media, while the experimental group utilized AR. The AR products used in the learning process are presented, as shown in Fig. 2.

Fig. 2 shows the implementation of AR and presents visualizations of sensor and actuator devices in learning by displaying them in 3D through AR technology. This media was utilized in the experimental group, while the control group used printed books to support the presentation of phenomena in image form. Before the implementation, the teachers involved had been trained to apply AR in the learning process. In addition, each student was asked to voluntarily install the AR application used for independent learning on their respective smartphones. In both groups, each learning session lasts for 120 minutes per meeting. The sensor and actuator device material is covered in three meetings. In the initial stage, both groups were given a pretest to measure their initial abilities, followed by treatment through the learning process. At the end of the study, a posttest was conducted to evaluate the final results.

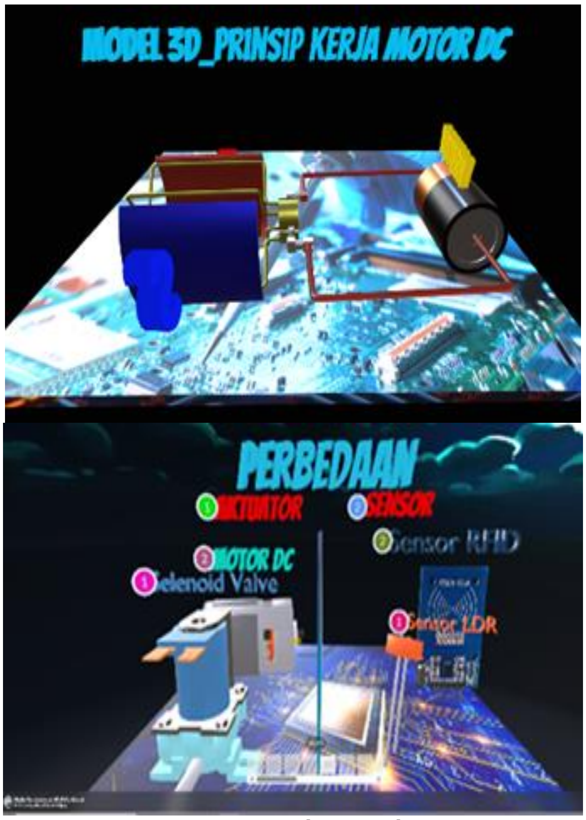

Fig. 2. AR sensor and actuator devices.

D. Data Collection and Data Analysis

The data collected in this study comprised pretest and posttest values from academic assessments measuring students' conceptual understanding. The instruments were multiple-choice questions focusing on learning material sensor devices and actuators. The test consisted of 10 validated multiple-choice questions deemed appropriate for this study. The questions cover every indicator necessary to comprehensively measure students' conceptual understanding. The validity of the questions was obtained at 0.85, indicating that they are highly suitable for measuring conceptual understanding of sensor and actuator material following the teaching objectives. Meanwhile, the reliability of the questions was obtained at 0.80 using Cronbach's Alpha method, which shows that the questions have sufficient consistency and can be relied upon to measure students' conceptual understanding stably under various conditions. Therefore, the test instrument used in this study can be considered valid and reliable for measuring students' conceptual understanding.

Data on students' conceptual understanding was then collected and analyzed statistically. Data analysis techniques were conducted using SPSS 26, including normality tests, homogeneity tests, Wilcoxon tests (W), and Mann-Whitney tests (U). The normality and homogeneity tests were used to determine whether the data were normally distributed and homogeneous, which would dictate the choice of further statistical tests. If the data were not normally distributed and not homogeneous, the testing was performed using the W and U tests. The W test was used to investigate the improvement in students' conceptual understanding in each class. In contrast, the U test was used to compare the enhancement in students' conceptual understanding between the two classes. Conclusions drawn from the W and U tests were based on the Z and P values. The results indicated a significant difference in students' conceptual understanding of the obtained *p*-value was > 0.05 or $z < -1.96$.

For effect size testing, data from each group's Mean (M), Standard Deviations (SD), and sample sizes (N) were used to obtain Cohen's (*d*) and Hedges' (g) effect size values. The equation used to obtain effect size follows eqs. (1) and (2). To interpret the effect size values, we use the following classifications: $d = 0.2$ (small effect), $d = 0.5$ (medium), $d = 0.8$ (large), $d = 1.20$ (huge), and $d = 2.0$ (very huge) [38].

$$d = \left(\frac{M_E - M_C}{SD}\right) \tag{1}$$

$$SD = \sqrt{\left(\frac{SD_E^2 + SD_C^2}{2}\right)} \tag{2}$$

IV. Result and Discussion

Data on students' conceptual understanding were collected from each group's pretest and posttest results. The data were then analyzed at an early stage to check for suitability. Normality and homogeneity tests were conducted to assess the distribution and consistency of the data. The results of these tests are presented in Table 1.

Table 1. Results of normality test and homogeneity test

Test	Group	Normality Test (Shapiro-Wilk)		Homogeneity Test (Levene Statistic)	
		df	Sig	df	Sig
Pretest	Control	30	0.016	58	0.045
	Experimental	30	0.000		
Posttest	Control	30	0.000	58	0.000
	Experimental	30	0.001		

Table 1 displays both groups' normality and homogeneity test results based on the pretest and posttest data. The Shapiro-Wilk test revealed a significance value of < 0.05, indicating that both groups' pretest and posttest scores were not normally distributed. In the Levene test, the significance values for the pretest (Sig = 0.045) and posttest (Sig = 0.000) were both < 0.05, indicating that the data were not homogeneous. Overall, the data were neither normally distributed nor homogeneous. Therefore, non-parametric statistical tests were chosen for further analysis, specifically the W and U tests.

A. Is There an Increase in the Pretest-Posttest Scores of Students' Conceptual Understanding in Each Group?

The enhancement in students' conceptual understanding was measured based on the mean of each group, accompanied by information about the standard deviation. Statistical testing was conducted using the W test to determine whether there was a significant change in students' conceptual understanding after the learning intervention. The results of the W test describe the differences in values before and after treatment for each group and are presented in detail in Table 2.

Table 2. Result of W test

Groups	Pretest		Postest		Mean of %N-gain	W				
	M	SD	M	SD		Positif Rank	Negatif rank	Ties	Z	p
Control	52.20	13.05	69.15	13.75	35%**	28	0	2	−4.63	0.000
Experimental	59.92	12.46	81.60	6.96	54%**	30	0	0	−4.79	0.000

*Low (%N-gain < 30), **Medium (30 ≤ %N-gain ≥ 70), ***High (N-gain > 70).

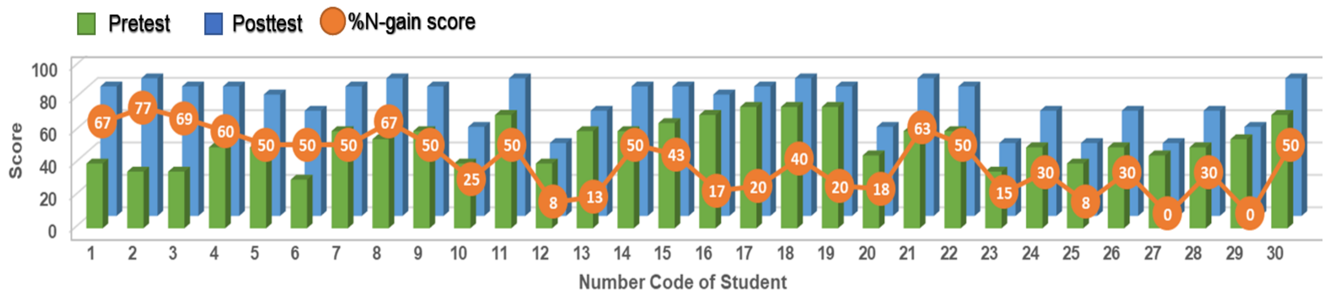

Fig. 3. N-gain of the control group.

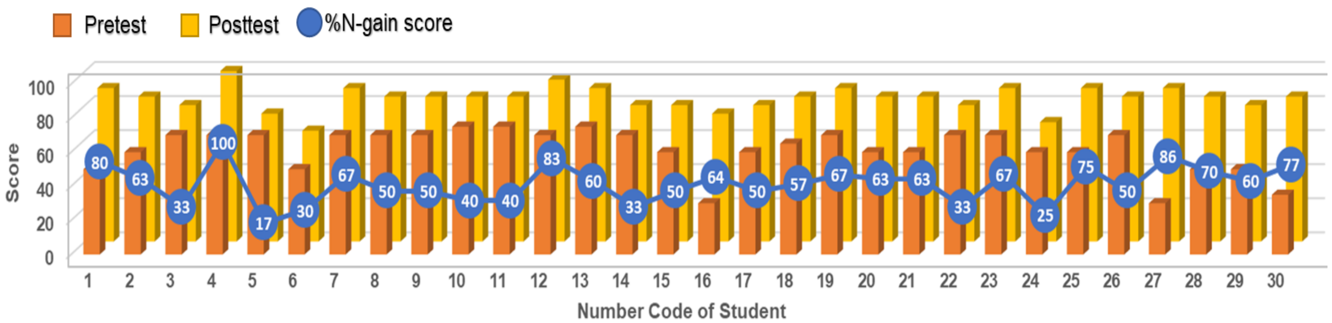

Fig. 4. N-gain of the experimental group.

Table 2 presents the results of the W test for both groups. In the control group, the average pretest score was 52.20 (SD = 13.05), while the posttest score increased to 69.15 (SD = 13.75). These enhancements highlight the effectiveness of traditional learning methods in supporting conceptual growth. The N-Gain value, illustrated in Fig. 3, confirms this progress, with 28 out of 30 students showing an increase and two students maintaining consistent value. The highest N-Gain was 77%, and the lowest was 0%, resulting in a mean N-Gain of 35%, categorized as medium.

The effectiveness of traditional learning was verified using the W-test. A Z-value less than − 1.96 and a p-value of < 0.05 indicate significant enhancements in conceptual understanding. The W-test results showed a Z-value of −4.63 and a p-value of 0.000, confirming that traditional learning methods are effective. In the experimental group, the average pretest score was 59.92 (SD = 12.46), which improved to 81.60 (SD = 6.96) on the posttest. The experimental group utilized AR learning, which demonstrated a significant enhancement. N-Gain scores, shown in Fig. 4, revealed that all 30 students experienced an increase, with the highest being 100% and the lowest 17%. The mean of N-Gain was 54%, also categorized as medium. The W-test results for the experimental group (Z = −4.79, p = 0.000) confirmed the significant impact of AR learning methods. These findings demonstrate that AR learning has a greater impact on conceptual understanding compared to traditional methods.

The results of the W-test indicated that both groups were effective in enhancing students' conceptual understanding. However, the N-Gain results revealed differences in the extent of enhancement between the two groups. The disparity in N-Gain scores indicated a variation in conceptual understanding. Learning using AR resulted in a higher N-Gain compared to the control group, demonstrating that AR-based learning is more effective than traditional learning in enhancing students' conceptual understanding.

Traditional learning that utilizes 2D images in supporting the theoretical explanation of sensor and actuator devices positively affects students' conceptual understanding. However, research shows that there is still minimal change in student understanding, both before and after the implementation of the learning. This condition indicates that traditional learning using 2D images is limited in evenly supporting the understanding of the material among students.

This study also reveals that traditional learning often fails to explain the material completely to students due to excessive focus on teaching methods. The lack of interaction in traditional learning impacts the understanding of incomplete concepts, which can eventually lead to misconceptions [46]. This affects students' interest and motivation in learning, which tends to be low due to limited support for material explanations that are relatively not presented interactively [47].

On the other hand, learning that utilizes AR positively impacts all students by enhancing conceptual understanding. AR provides better support in learning presentations, helping students understand concepts more clearly [48, 49]. The advantage of AR lies in its ability to visualize the components or objects presented so that students can learn and investigate more deeply [50]. Research has also shown that learning using AR enhances student engagement, which positively impacts better learning outcomes in conceptual understanding [51, 52].

B. Is There a Significant Difference in Posttest Results Between the Two Groups?

The data in the comparative test between the two groups are the result of the posttest. This data was used to investigate the significant differences between the two learning methods in enhancing students' conceptual understanding. The data results are presented through the U test, as shown in Table 3.

Table 3. Result of U test

Information	Value
Mann-Whitney (U)	1.71500
Z	−4.21
p	0.000

Table 3 displays the average comparison results of the U test in both groups. The data from this test showed a value of U = 1.71500, which indicates a clear difference between the two groups. The Z-value = −4.21, greater than −1.96, indicates that the test results are outside the critical boundary, reinforcing the indication of a significant difference. This is supported by a *p*-value smaller than 0.05, indicating a high significance level. The results revealed significant differences between the control group and the experimental group. This condition confirms that learning using AR significantly enhances students' conceptual understanding compared to traditional learning.

Learning using AR has a better effect on supporting students' conceptual understanding of sensor and actuator materials than traditional learning. This condition is supported by AR's ability to provide an explanatory visualization of the components of the sensor device and its array in 3D form, while traditional learning only utilizes 2D images [53, 54]. These findings align with previous studies highlighting the role of AR in technical education, particularly in electronics topics such as sensors and actuators. AR has been shown to support students' experimental skills in laboratory settings after learning with its assistance [55]. By providing visual representations of sensors and actuators, AR enhances students' understanding and practical abilities.

This is consistent with research indicating that the adoption of technology positively impacts learning outcomes [56]. Additionally, studies reveal that learning with AR improves students' conceptual understanding, driven by an enriched and interactive learning experience [57]. These outcomes underscore AR's potential to transform technical education by fostering deeper engagement and enhancing skill acquisition.

Research reveals that 3D visualization support provides a more complete presentation of information [58]. Previous research has been limited to investigating the level of validity related to the study of network and electronic concepts [59]. The research conducted has investigated its effect on teaching. The results of this study make an important contribution to the learning materials of devices and sensors, especially in explaining the material before the practical application stage to real objects and components. This reduces errors and breakdowns in the actual circuit practice process [60]. Previous research has also revealed that the availability of support media to understand practices is urgently needed in learning, especially when working on projects related to circuit systems on sensor and actuator devices [58, 61]. Thus, AR provides a new form of learning implementation that supports the learning process.

C. What Is the Contribution of the Effect Size of Using AR Products in Enhancing Students' Conceptual Understanding?

The posttest data from the two groups were compared. The data consisted of mean results and standard deviations of the posttest in both groups. The two data were processed to investigate the effect size of the conceptual understanding between the two groups. The results of the effect size obtained are presented in Table 4.

Table 4. Effect size

Group	Postest			Cohen's d (d)	Hedges' g (g)
	N	M	SD		
Control	30	69.15	13.75	1.14	1.14
Experimental	30	81.60	6.96		

Table 4 presents the effect size results based on the posttest data for both groups. The experimental group demonstrated a higher average score (M = 81.60, SD = 6.96) compared to the control group (M = 69.15, SD = 13.75). Both Cohen's d and Hedges' g of 1.14 suggest a large effect. These values indicate a large effect size, which suggests that the intervention applied in the experimental group had a significant and meaningful impact on students' conceptual understanding. A large effect size, as shown in this study, reflects that the AR-based learning method not only enhanced students' conceptual understanding but also substantially influenced their academic performance compared to the traditional learning method.

The size effect on the results of the posttest comparison between the control group and the experiment showed a large effect. These results indicate that previous learning related to sensor and actuator materials significantly impacts students' conceptual understanding. On the other hand, other studies show that the size effect of implementing AR is in the medium category [62]. However, the great effects obtained from learning with AR show that this technology contributes well to the learning process.

The comparison of posttest results between the control and experimental groups demonstrates a large effect, highlighting the significant impact of prior learning related to sensor and actuator materials on students' conceptual understanding. In the field of electronics education, including topics like sensors and actuators, the effect size has been recorded at 0.76 in larger effect category [63]. This result exceeds findings from previous studies on the effects of AR in similar contexts. However, other studies have categorized the size effect of AR implementation in the medium range [63]. Despite this, the substantial outcomes observed in AR-based learning emphasize its positive contribution to the educational process.

The findings further support the acceptance of AR technology in electronics engineering education, particularly by both teachers and students [64]. While AR shows great promise in enhancing conceptual understanding and practical application, there remains room for improvement in its implementation to maximize its educational potential. These findings underline AR's value as a tool to elevate learning outcomes, particularly in technical fields like electronics.

V. Conclusion

This study identified three main focuses: enhancing conceptual understanding, comparing learning methods, and analyzing the effect size of learning using AR technology. The findings revealed that both traditional learning and AR-based learning improved students' conceptual understanding. However, AR-based learning resulted in a more significant improvement compared to traditional learning, as indicated by a higher N-Gain score. The comparison between the two learning methods showed that AR-based learning was more effective in enhancing students' conceptual understanding. This is attributed to AR's ability to provide a more interactive and visual learning experience, which helps students grasp abstract concepts more thoroughly. The effect size of learning with AR was categorized as large, indicating that implementing AR technology significantly enhances learning quality and improves students' conceptual understanding. Thus, the results of this study highlight the potential of AR as an innovative learning method that can be effectively utilized to enhance students' conceptual understanding, particularly in sensor and actuator materials.

Therefore, it is recommended that educational institutions integrate AR technology into the curriculum and train teachers to maximize its potential. Although the research findings suggest that AR has the potential to enhance understanding, further studies are needed to explore various aspects of AR implementation. This study has limitations, including a relatively small sample size, a limited implementation period, and a limited number of concept comprehension test items, as well as the need to assess other 21st-century skills. Additionally, the impact of AR on other learning materials should be explored further. Therefore, future research could examine the impact of AR on other aspects more comprehensively.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

IPD contributes to creating research ideas, creating AR, and analyzing data; MD and EMS contributed to designing and creating articles and writing the article; LM. TS. NH, SS contributed to investigating, methodology, and doing revision; all authors had approved the final version.

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