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PAPER

Engineering Students' Acceptance of Augmented Reality Technology Integrated with E-Worksheet in The Laboratory Learning

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ABSTRACT

The use of augmented reality (AR) technology in the field of education has emerged as a rapidly growing trend. However, there is an urgent need for more comprehensive research to determine the reactions of engineering students and their acceptance of this technology in laboratory learning. This study investigates the acceptance of integrated augmented reality with e-worksheet (IARE-W) among engineering students in the laboratory learning (IARE-W) among engineering students the electrical machines course (EMC). This research empirically uncovers the factors that influence it based on the technology acceptance model (TAM), specifically perceived ease of use (PEU) and perceived usefulness (PU). Acceptance is indicated by students' attitudes toward the use. A survey-based quantitative research study using questionnaires was conducted to collect data, involving 102 students in the field of industrial electrical engineering. The partial least squares structural equation modeling (PLS-SEM) analysis was used to analyze the research data. The results demonstrated that engineering students had a highly positive attitude toward the use of the IARE-W in the EMC. Additionally, both PEU and PU had a positive and significant direct effect on engineering students' attitudes toward using IARE-W. Furthermore, PEU also had a significant and positive indirect effect through PU as a mediating variable. These findings have significant implications for the development of engineering education and the integration of AR technology in laboratory learning contexts. The results of this study underscore the importance of taking into account PEU and PU in the design, development, and implementation of the IARE-W.

KEYWORDS

engineering student's attitudes, integrated augmented reality e-worksheet, perceived ease of use, technology acceptance model, electrical machines course, perceived usefulness

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1 INTRODUCTION

In an era of rapid technological development, the use of digital technology is expanding across various sectors, including education. Within the field of engineering education, the incorporation of technology is becoming increasingly crucial to improving learning effectiveness [1], [2]. One technology that has garnered attention is augmented reality (AR), which offers an interactive and immersive learning experience [3], [4]. In the context of electrical engineering courses, AR holds significant potential to enhance understanding of complex concepts and promote student engagement [5]–[7]. By integrating AR technology with electronically accessible worksheets (e-worksheets), it is anticipated that the learning process can be optimized to adapt to technological advancements. However, there is limited understanding of engineering students' attitudes toward the use of IARE-W in electrical engineering courses. Therefore, this study aims to describe and analyze the attitudes of engineering students toward the implementation of this technology, as well as the influencing factors based on the technology acceptance model (TAM), specifically perceived ease of use (PEU), and perceived usefulness (PU) [8], [9].

Previous studies have shown that users' attitudes toward technology significantly influence its adoption and acceptance [8], [9]. In the context of engineering education, understanding students' attitudes toward the utilization of AR technology in electrical engineering courses is important for optimizing the learning process [10], [11]. PEU and PU are critical factors that influence user attitudes toward technology. PEU refers to user perceptions of the ease and simplicity of using AR technology, while PU involves perceptions of its usefulness and benefits in educational settings [9], [12].

The use of AR technology in educational settings has shown significant potential for improving learning experiences and outcomes. Several previous studies have emphasized the advantages of AR in aiding the understanding of complex concepts, promoting student engagement and motivation, and enhancing interactions between students and learning materials [13–15]. Notably, AR has been integrated into various science and engineering courses, including physics, chemistry, and mathematics, resulting in positive outcomes such as improved student understanding and engagement [16], [17]. However, research on the application of AR, specifically in the context of EMC within engineering education, remains limited. Therefore, this research aims to enhance our understanding of the implementation of AR technology in the EMC while exploring engineering students' attitudes toward its use and the factors that influence them. Therefore, this study aims to make a significant contribution to the advancement of innovative and effective engineering education practices.

The novelty of this study lies in offering a comprehensive explanation of engineering students' attitudes toward the integration of AR technology with e-worksheets in the EMC, as well as investigating the influencing factors. Despite the widespread use of AR in various educational fields, there is limited research on its implementation in engineering education settings, especially in the context of the electrical machine course (EMC). Additionally, there is a lack of comprehensive studies exploring student attitudes toward the adoption of integrated augmented reality with e-worksheet (IARE-W) and the factors that influence these attitudes. Therefore, this study provides a unique and innovative contribution to understanding the potential of AR in improving electrical machine learning within engineering education. The aim of this study was to analyze engineering students' attitudes towards the use of IARE-W in the EMC and to examine the impact of the PEU and PU factors on these attitudes. Consequently, this research aims to provide a comprehensive understanding of student acceptance of AR technology in the context of engineering education, with a specific focus on the EMC. The results of this evaluation will provide valuable insights for curriculum developers and educators, enabling them to create more effective and innovative learning strategies and also influencing the progress of AR technology in education overall.

The primary contribution of this research is to provide a deeper understanding of engineering students' attitudes toward the use of IARE-W in the EMC, as well as the factors that influence them. This research offers the advantage of providing valuable insights for curriculum developers and educators to design more effective and innovative learning strategies using AR technology. By gaining a deeper understanding of students' attitudes toward AR technology and the factors that influence them, this research can lay a strong foundation for the creation of a personalized learning approach that meets the requirements of engineering students in electrical engineering courses. Furthermore, this research can serve as a point of reference for other researchers who are interested in further exploring the use of AR in the context of engineering education.

2 RELEVANT LITERATURE

2.1 Engineering student's acceptance of IARE-W

Applying the TAM theory, we can measure engineering students' acceptance of IARE-W utilization in the laboratory learning process by assessing their attitudes toward this technology. Engineering students' attitudes toward the use of technology is a construct that refers to their attitude or approach toward the use of a technology or learning tool [12], [18]. In the context of this study, engineering students' attitude toward the use of technology specifically refers to their attitude toward the use of IARE-W in the EMC. The TAM can be used to understand the factors that impact engineering students' attitudes toward technology usage [8], [18]. According to the TAM, user attitudes toward the use of technology are primarily influenced by two factors: PEU and PU. PEU refers to the degree to which engineering students perceive the use of IARE-W in the EMC as easy [8], [18]. When engineering students perceive this technology as user-friendly and requiring minimal effort, they tend to have a positive attitude toward its use. Factors such as an intuitive user interface, clear instructions, and ease of navigation can influence the perception of usability [8], [18]. On the other hand, PU reflects the extent to which engineering students believe that the use of IARE-W provides benefits and added value in the learning process of the EMC. When engineering students believe that these technologies improve conceptual understanding, increase engagement, or provide more immersive learning experiences, they are likely to hold a positive attitude toward their use [12], [19], [20]. Factors such as the clarity of benefits, relevance to learning content, and the technology's ability to improve learning outcomes can influence the perception of usefulness [12], [18].

2.2 Integrated augmented reality e-worksheet

The e-worksheet is a digital learning tool that students can access through laptops or smartphones. It contains practical learning materials and student worksheets for laboratory learning. Similar to their traditional counterparts, e-worksheets serve the fundamental purpose of providing structure, guidance, and instructions to students during the learning or experimental processes [7], [17]. The distinguishing factor lies in their digital format, which is accessible through electronic devices such as laptops, tablets, or smartphones. The IARE-W for the EMC refers to an innovative learning tool that combines AR technology with e-worksheets specifically designed for laboratory learning in the EMC. These technologies integrate digital information and virtual elements into real-world environments, enhancing the learning experience and providing students with interactive and immersive activities [21]. With IARE-W, students in the EMC can access a digital platform that presents virtual content on physical worksheets. Through the use of AR, students can visualize and interact with three-dimensional models of electrical machines, explore their components, simulate operating conditions, and conduct virtual experiments [14], [17].

This technology enables students to engage more practically and interactively with the subject matter, bridging the gap between theoretical concepts and practical applications [5], [14], [22]. By incorporating AR into an e-worksheet format, IARE-W offers several benefits to students. First, this technology enhances students' understanding of complex electrical machine concepts by providing visualizations and simulations that facilitate comprehension and absorption of information [3], [23]. The interactive nature of this technology also fosters active learning and student engagement, as students actively manipulate and explore virtual objects in real time [3], [24]. Additionally, IARE-W provides a personalized and adaptive learning experience. Students can engage in learning activities at their own pace and receive direct feedback and guidance through the accessible online AR platform. The IARE-W framework comprises several key elements: (1) course identity; (2) learning objectives; (3) brief theory integration with AR technology; (4) experimental tool integration with AR technology; (5) experimental procedures and simulation using AR technology; (6) experimental circuit integration with AR technology; and (7) assignments. The IARE-W display examined in this study is shown in Figure 1.

a) b)

Fig. 1. *(Continued)*

c)

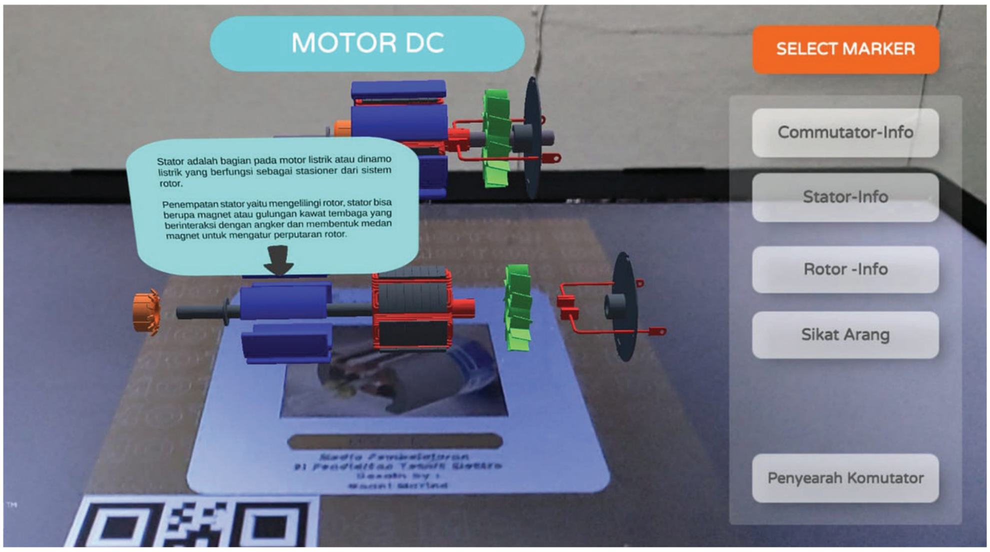

Fig. 1. The view of IARE-W: (a) IARE-W cover; (b) AR target image, and (c) AR display in IARE-W

3 METHODS

3.1 Research design

This study utilizes a survey method that is based on a quantitative approach. Surveys are a systematic research method used to gather information and provide answers to problems, both in descriptive form and in understanding the relationship between variables, while ensuring the accuracy of the obtained information [12], [25].

The research variables examined in this study include PU, PEU, and attitudes toward use. The partial least squares structural equation modeling (PLS-SEM) method was used for data analysis. The SmartPLS software was utilized to perform PLS-SEM analysis, examining the direct and indirect impacts of exogenous variables on endogenous variables. Thus, this study can be used to examine the attitudes of engineering students towards the use of IARE-W in practical learning processes in electrical engineering courses.

3.2 Research instruments

The research instrument used in this study was a questionnaire that employed a Likert scale ranging from 1 to 5. The indicators used in the questionnaire were drawn from comprehensive and relevant literature, as shown in Table 1. The use of a Likert scale questionnaire provided a standardized method for assessing respondents' attitudes and perceptions regarding the research topic [18], [26]. The data collected with this instrument will contribute to a better understanding of the variables being investigated.

Table 1. Research instrument indicators

Variables	Indicators	Theoretical Framework
PEU	PEU.1. The utilization of the IARE-W is easy to comprehend. PEU.2. The utilization of the IARE-W does not necessitate excessive exertion. PEU.3. Students feel at ease and confident when utilizing the IARE-W to study the EMC. PEU.4. The user interface of the IARE-W is user-friendly and straightforward to navigate. PEU.5. Incorporating the IARE-W is effortless when performing learning tasks in the EMC. PEU.6. Utilizing the IARE-W does not demand significant additional time or effort.	[8], [9], [12]
PU	PU.1. The utilization of the IARE-W will enhance the effectiveness of students' learning in the EMC. PU.2. The IARE-W assists students in achieving their learning goals in the EMC. PU.3. Using the IARE-W will aid students in mastering crucial concepts in the EMC. PU.4. The incorporation of the IARE-W streamlines the learning process for the EMC. PU.5. Employing the IARE-W will yield long-term benefits for students' understanding and skills in the EMC. PU.6. The utilization of the IARE-W enhances the quality of students' learning in the EMC. PU.7. The IARE-W provides valuable information and resources for studying the EMC.	[12], [18], [27]
A	A.1. The utilization of the IARE-W is an effective approach to enhance students' understanding of the EMC. A.2. Students experience enthusiasm and motivation when utilizing the IARE-W to study the EMC. A.3. The utilization of IARE-W can assist students in mastering challenging concepts in the EMC. A.4. The incorporation of the IARE-W makes the learning process in the EMC more captivating and interactive. A.5. Employing the IARE-W will increase students' engagement in studying the EMC. A.6. The utilization of the IARE-W will yield long-term benefits for students' understanding and skills in the EMC.	[12], [18], [27]

3.3 Research subjects

The study focused on a population of 139 second-year engineering students who were enrolled in the EMC within the industrial electrical engineering study program at the Faculty of Engineering, Universitas Negeri Padang. To obtain a sample, the sample size was calculated using Slovin's formula [27–29]. Based on the calculations, a total sample size of 102 students was determined. Simple random sampling was employed as the sampling technique for this study [18], [27].

3.4 Data analysis technique

The findings, which align with the research objectives, were derived from the analysis of the research data collected using research instruments. In this study, the data were analyzed using PLS-SEM analysis [8], [26]. The SmartPLS application was used to perform the PLS-SEM analysis, enabling an investigation of the factors that influence engineering students' attitudes toward the use of IARE-W in the EMC. Before conducting the main analysis, the validity of the variables and instrument indicators was also assessed using PLS-SEM analysis [26], [30]. Additionally, a descriptive analysis was conducted to offer insights into students' attitudes toward the use of IARE-W based on six key indicators. These analyses contribute to a thorough understanding of the research topic and bolster the interpretation of the research findings.

4 RESULTS

4.1 Research model

This study aims to examine engineering students' attitudes toward the use of IARE-W (A) in the EMC. The research also examines the factors that influence these attitudes using PLS-SEM analysis. The study specifically examines the direct impact of PEU and PU on A, as well as the influence of PEU on PU. Furthermore, the study examines the indirect impact of PEU on A through PU as an intervening variable. Additionally, the study examines the joint impact of PEU and PU on attitudes. The initial research model, depicted in Figure 2, outlines the conceptual framework used. Reflective indicators, which are used as manifestations or representations of variables, are utilized in this study. Detailed indicators for each variable studied are available in Table 1.

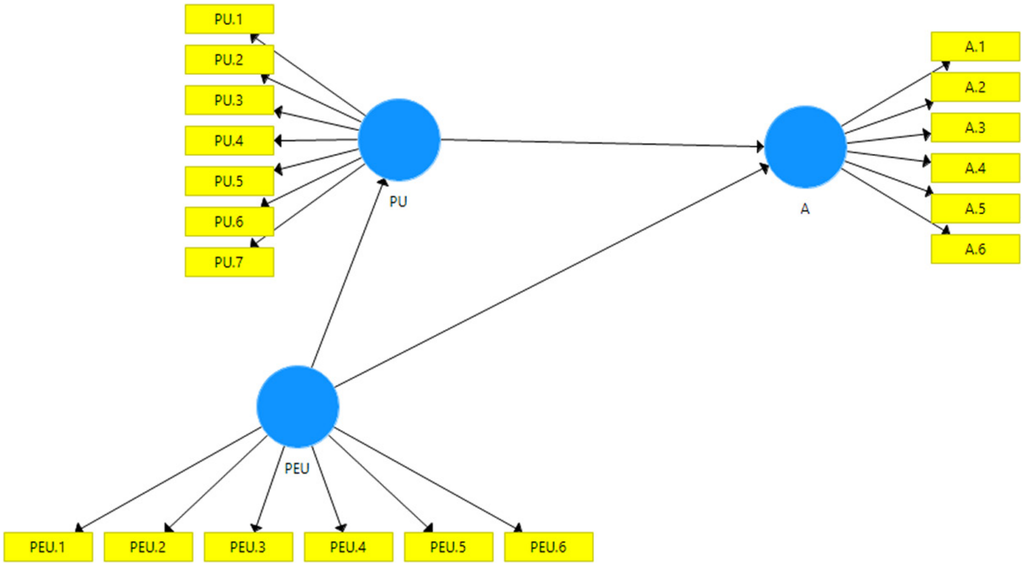

Fig. 2. Preliminary research model

The preliminary research model is being evaluated to assess its compliance with the assumptions and requirements of the analysis. This evaluation covers all variables (inner model) and indicators (outer model) to ensure the absence of multicollinearity issues and adherence to the goodness of fit (GoF) criteria [18], [26], [30]. The analysis of the outer variance inflation factor (VIF) values in Table 2 indicates that all indicator VIF values are less than 5 (VIF < 5). This suggests that there are no issues of multicollinearity among the indicators related to the research variables [18], [26].

Table 2. The results of outer VIF values

Indicators	VIF	Indicators	VIF	Indicators	VIF
PEU.1	2.716	PU.1	3.664	A.1	1.498
PEU.2	1.316	PU.2	1.231	A.2	1.671
PEU.3	1.145	PU.3	1.546	A.3	2.811
PEU.4	1.116	PU.4	3.781	A.4	2.713
PEU.5	2.997	PU.5	3.689	A.5	1.519
PEU.6	2.336	PU.6	3.287	A.6	2.397
–	–	PU.7	2.891	–	–

The next step involves conducting multicollinearity testing on the research variables. Similar to the previous indicators, it is crucial to ensure that there is no multicollinearity among the research variables. The results of the internal VIF value analysis in Table 3 show that the VIF values for the study variables are all less than 5 (VIF < 5). Hence, it can be inferred that there is no issue of multicollinearity among the observed research variables.

Table 3. The results of inner VIF values

	PEU	PU	A
PEU	–	1.711	1.211
PU	–	–	1.275

The next step in the analysis involves assessing the adequacy of the research model by applying the Goodness of Fit (GoF) criteria, as shown in Table 4. The results of the GoF assessment indicate that the standardized root mean square residual (SRMR) values are below 0.08, the normed fit index (NFI) exceeds 0.9, and the root mean square error of approximation (RMSEA) value is less than 0.102 [18], [26]. Based on these results, we can conclude that the research model meets the GoF criteria. After confirming the initial model's compliance with the GoF standards, assumptions, and criteria, further analysis is conducted. Figure 3 presents the results of the PLS-SEM analysis.

Table 4. The results of GoF analysis

	SRMR	NFI	RMS Theta	GoF
Saturated Model	0.061	0.996	0.096	Fit
Estimated Model	0.061	0.996	0.096	Fit

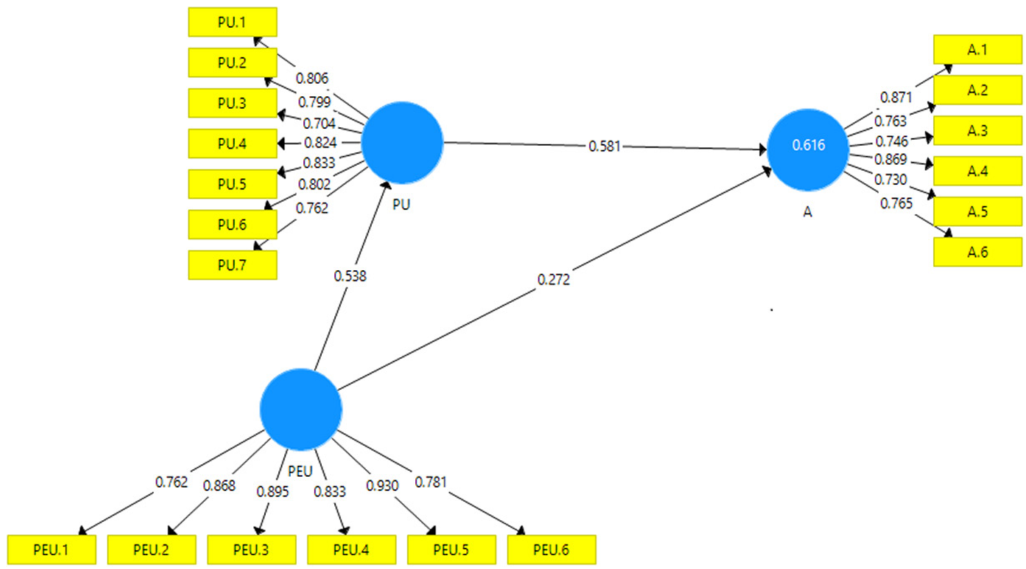

Fig. 3. The display of PLS-SEM analysis using SmartPLS

4.2 Outer model analysis

In the PLS-SEM analysis, the outer model analysis is conducted, which involves examining the indicators. This analysis assesses various aspects, including construct reliability (CR), average variance extracted (AVE), model unidimensionality (MU), convergent validity (CV), and cross-loading [26], [30]. The indicators' ability to measure their respective variables, known as internal consistency reliability (ICR), is evaluated using Cronbach's alpha (CA). Table 5 displays the CA values for all tested variables, all of which are greater than 0.6. Therefore, it can be concluded that all the variables tested are considered reliable [7], [18], [26]. To ensure the absence of measurement issues, a test for unidimensionality test is performed. As indicated in Table 5, all constructs fulfill the unidimensionality requirements, with CR values exceeding 0.7. Furthermore, all tested variables have been found to be valid and meet the criteria for convergent validity [18], [30]. This is evident from the AVE values, each of which exceeds 0.50, as presented in Table 5.

Table 5. Outer model analysis

	CR	AVE	CA	rho_A	ICR	MU	CV
PU	0.809	0.681	0.811	0.841	Reliable	Reliable	Valid
PEU	0.879	0.715	0.821	0.819	Reliable	Reliable	Valid
A	0.821	0.579	0.756	0.727	Reliable	Reliable	Valid

4.3 Inner model analysis

This analysis aims to examine the relationships between variables and uncover the resulting effects, including path coefficients (direct effects), indirect effects, total effects, and simultaneous effects of exogenous variables on endogenous variables [18], [26]. The results of this internal model examination are presented in Table 6.

Table 6. Inner model analysis

<table>
<tr><th rowspan="2"></th><th colspan="3">PU</th><th colspan="3">A</th><th colspan="2"></th></tr>
<tr><th>Path Coeff.</th><th>Ind. Effects</th><th>Tot. Effect</th><th>Path Coeff.</th><th>Ind. Effects</th><th>Tot. Effect</th><th>R Square</th><th>R Square Adjusted</th></tr>
<tr><td>PEU</td><td>0.538</td><td>–</td><td>0.538</td><td>0.272</td><td>0.363</td><td>0.635</td><td rowspan="2">0.616</td><td rowspan="2">0.611</td></tr>
<tr><td>PU</td><td>–</td><td>–</td><td>–</td><td>0.581</td><td>–</td><td>0.581</td></tr>
<tr><td>P-Value</td><td>0.002</td><td>–</td><td>0.002</td><td>0.000</td><td>0.000</td><td>0.003</td><td>0.000</td><td>0.001</td></tr>
</table>

The direct impact between variables is indicated by the path coefficient values, which range from –1 to +1. A value approaching +1 indicates a stronger and more positive correlation between the variables, whereas a value closer to –1 suggests a weaker and more negative relationship [8], [26]. The results of the inner model analysis in Table 6 reveal the following insights: (1) The direct impact of PEU on PU is indicated by a path coefficient value of 0.538. This suggests that an increase of one unit in PEU leads to a 53.8% increase in PU (positive effect). This effect is statistically significant with a P-value less than 0.05 ($P < 0.05$) [26], [30]. (2) Additionally, the direct influence of PEU on A is represented by a path coefficient value of 0.272, indicating that a one-unit increase in PEU results in a 27.2% increase in A (positive effect). This effect is also statistically significant with a P-value less than 0.05 ($P < 0.05$) [30]. (3) Additionally, the direct impact of PU on A is reflected in a path coefficient value of 0.581, indicating that a one-unit increase in PU leads to a 58.1% increase in A (positive influence). This effect is statistically significant with a P-value less than 0.05 ($P < 0.05$) [26], [30].

An analysis of indirect effects was conducted to explore how an exogenous variable indirectly influences an endogenous variable using intermediary variables known as intervening variables [18], [26]. Based on the results of the inner model analysis presented in Table 6, it is evident that the indirect effect of PEU on A, mediated by PU as an intervening variable, has a value of 0.363. This implies that a one-unit increase in PEU leads to a 36.3% indirect increase in A through the mediation of PU (positive effect). The indirect effect of PEU on A is also statistically significant, with a P-value of less than 0.05 (P-value < 0.05). Subsequently, a total effect analysis was performed to investigate the overall impact, including both direct and indirect effects [18], [30]. According to the findings from the structural equation model analysis in Table 6, the total effect of PEU on A is determined to be 0.635. Thus, a one-unit increase in PEU can lead to a 63.5% overall increase in A (a positive effect). The overall impact of PEU on A is also statistically significant, with a P-value of less than 0.05 (P < 0.05).

When evaluating the R-squared (R^2) value, specific criteria are used. A value of $R^2 \geq 0.67$ is considered a strong influence, while a value in the range of $0.33 \leq R^2 > 0.67$ is considered a moderate influence. If the R^2 value is ≥ 0.19, it is considered to have a weak influence [26], [30]. Additionally, the adjusted R-squared (Adj. R^2) value is used to assess the influence of the variables (PEU and PU) on variable A. From Table 6, it can be observed that the R^2 value for the combined effect of PU and PEU on A is 0.616, with an adjusted R^2 value of 0.611. Therefore, it can be concluded that the exogenous constructs (PEU and PU) collectively explain 61.1% (moderate category) of the influence on A. The combined effect of (PEU and PU) on A is statistically significant, as the P-value is less than 0.05 (P < 0.05).

4.4 Engineering student's acceptance of IARE-W for the EMC

In this study, EMC instructors use AR objects within IARE-W to enhance students' understanding of the basic principles of electrical machines. These AR objects depict machine structures, internal components, and interactions among machine parts. This visual presentation allows students to observe the operational mechanisms and interconnections of electrical machines, thereby improving their understanding of theoretical concepts. Furthermore, the IARE-W serves to provide immersive virtual practice opportunities. Lecturers use this technology to simulate practical scenarios involving the assembly, testing, and operation of electrical machines. Through the manipulation of AR objects, students can observe the operation of machines and gain a more concrete understanding before participating in hands-on laboratory activities.

The study's findings revealed that engineering students showed a positive attitude towards using IARE-W in the learning process of the EMC. The six indicators used to assess engineering students' attitudes toward IARE-W demonstrated an overall high average rating. Indicator A.1. The study indicated that engineering students perceived IARE-W as an effective approach to enhancing their understanding of the EMC, with an average score of 4.79. Indicator A.2. The engineering students showed great enthusiasm and motivation when utilizing IARE-W to study electrical machines, achieving an average score of 4.57. Indicator A.3. The study indicated that engineering students perceived IARE-W as a helpful tool in mastering challenging concepts in the EMC, with an average score of 4.33. Indicator A.4. A study revealed that engineering students believed that the Interactive Augmented Reality Environment for Wearables (IARE-W) made the learning process in EMC more engaging and interactive, receiving an average score of 4.86. Indicator A.5. The study indicated that engineering students believed that IARE-W would increase their engagement in studying the EMC, scoring an average of 4.49. Lastly, indicator A.6. The study demonstrated that engineering students believed that IARE-W would yield long-term benefits for their understanding and skills in the EMC, as indicated by an average score of 4.69. These results confirm that engineering students have a positive attitude towards using IARE-W in laboratory learning within the EMC. This indicates a high level of acceptance among engineering students for the use of IARE-W.

This study also gathers open feedback from students. This feedback serves as the basis for refining and improving the development and implementation of IARE-W in the EMC, ensuring better alignment with students' needs and expectations. A significant number of students appreciate IARE-W for its multifaceted capabilities. They appreciate its ability to present learning materials and practical implementation procedures, as well as to deliver learning content visually and interactively. Students emphasized that the 3D visualization of machine components facilitated a deeper understanding of complex concepts, reinforcing their theoretical knowledge gained from practical learning sessions. The feature that allows for object manipulation and direct visualization of component interactions was particularly praised for helping users understand machine functionalities. However, some students suggested expanding the content and features of AR technology to include graphical representations of simulation outcomes. Additionally, there were suggestions to improve the technical stability of the applications, particularly on older smartphone operating systems, where minor issues were reported. Considering these suggestions, further improvements can be made to IARE-W to optimize its contribution to the learning experience and address any identified shortcomings.

5 DISCUSSION

The findings of this research reveal a high level of acceptance of IARE-W among engineering students during the laboratory learning process at EMC. This is evident in the overwhelmingly positive attitude exhibited by engineering students towards the use of IARE-W within the EMC. This suggests that engineering students have a strong interest in and inclination toward integrating AR technology within the learning environment. This positive attitude can be attributed to the interactive, visual, and hands-on learning experience facilitated by the integration of AR technology along with student worksheets. Through the application of AR in their learning process, engineering students actively engage in the educational journey, enhance their comprehension of electrical machine concepts, and boost their motivation and involvement in learning. Furthermore, the availability of electronic online access to IARE-W enables students to study independently without being limited by time or space.

The findings of this study highlight the significant role of PEU in shaping engineering students' attitudes toward the utilization of IARE-W. Engineering students perceive AR technology as user-friendly and uncomplicated, which facilitates their access to and utilization of AR as a learning tool. In the context of engineering education, the usability of AR technology emerges as a crucial factor influencing students' acceptance and adoption of this technology. Therefore, intuitive design, seamless navigation, and user-friendly interfaces are crucial for ensuring the effective adoption of AR technology by engineering students. Moreover, the results of this study also demonstrate the influence of PU on engineering students' attitudes toward the use of IARE-W. Students acknowledge the tangible benefits offered by AR technology in the realm of EMC. They recognize that AR technology enhances the learning experience through interactive, visual, and practical elements. In educational technology, AR technology facilitates clearer visualizations and stimulates students' imaginations regarding complex concepts. Consequently, the PU of AR technology serves as a driving force in cultivating positive attitudes among engineering students toward the integration of this technology in engineering education.

A thorough analysis of the study's findings highlights the importance of incorporating AR technology into engineering education, especially within the field of EMC. The positive attitude exhibited by students towards the use of AR technology in the learning process underscores the potential for creating a more engaging and interactive instructional approach. Moreover, the PEU and PU of IARE-W technology are crucial factors influencing its acceptance and adoption among engineering students. This research makes a significant contribution to the existing literature on the integration of AR technology in engineering education. While previous studies have explored the applications of AR in various educational settings, this research specifically focuses on the use of AR integrated with online-accessible e-worksheets in the EMC for engineering students. Consequently, this study expands our understanding of the potential of AR in specific engineering learning environments.

The results of this study are consistent with previous research findings, showing that engineering students have a positive attitude toward the use of AR technology in learning. Numerous previous studies have indicated that implementing AR can improve student engagement, motivation, and conceptual comprehension [14], [23], [31]. These findings support the conclusions of this study, indicating that the use of IARE-W in the EMC can produce similar benefits for engineering students. Regarding PEU, this research aligns with other studies that highlight the importance of technological ease of use in students' adoption and acceptance of technology [2], [8], [18]. Previous studies have shown that intuitive user interfaces, seamless navigation, and user-friendly designs contribute to improved ease of use [8], [25], [32]. This finding aligns with the results of this study, demonstrating that the usability of IARE-W influences students' attitudes toward its adoption. Moreover, a comparative analysis with previous studies emphasizes the crucial role of PU in AR technology in influencing students' attitudes [11], [32], [33]. Prior research conducted in various educational settings has demonstrated that the tangible benefits provided by AR technology can impact students' attitudes and acceptance of the technology [8], [18]. This finding is consistent with the results of this study, indicating that engineering students acknowledge the benefits of using IARE-W to enhance their understanding of electric machine concepts.

Overall, the findings of this study make a significant contribution to the existing literature on the use of AR technology in engineering education. These findings are consistent with previous studies that have shown students' positive attitudes toward the integration of AR technology in the learning process. Furthermore, in terms of PEU and PU, the results of this study support previous findings that emphasize the critical role of these factors in students' adoption and acceptance of technology. Consequently, this study enhances the understanding of the application of AR technology in engineering education, especially in the context of EMC for engineering students specializing in industrial electrical engineering.

6 CONCLUSION

The data analysis results indicate that engineering students have a highly positive attitude towards using the IARE-W in the EMC, demonstrating a strong level of acceptance among them. Furthermore, the factors of PEU and PU significantly influence students' positive attitudes toward adopting this technology. Additionally, PU serves as an intervening variable, mediating the effect of PEU on engineering students' acceptance of IARE-W. These findings underscore the potential of incorporating AR technology into engineering education, as it can improve student engagement, motivation, and understanding of concepts. Furthermore, the study emphasizes the importance of considering factors such as PEU and PU to enhance engineering students' acceptance of IARE-W in the learning process. Consequently, the results of this research provide a strong foundation for the development of innovative learning methods that can effectively enhance the EMC experience for engineering students.

This study has certain limitations that need to be considered. Firstly, the study was conducted using a sample of engineering students from a specific educational institution, which limits the generalizability of the results to specific populations and contexts. Secondly, the study was conducted within a specific timeframe, potentially excluding certain aspects of the long-term use of the IARE-W and its impact on engineering students' attitudes over an extended period. Lastly, the research focused solely on the EMC, which may not fully represent the challenges and benefits associated with the integration of IARE-W across other engineering courses.

Several recommendations for future research are suggested. Firstly, conducting additional research with a wider and more representative sample of participants from various educational institutions will improve the generalizability of the findings and provide a more comprehensive understanding of the acceptance of IARE-W in engineering education. Secondly, extending the research duration would be beneficial for gaining deeper insights into the long-term evolution of engineering students' attitudes and technology adoption regarding the usage of IARE-W. This extension could offer valuable information about the long-term impact of the technology. Finally, continuous updates and improvements to the IARE-W system are essential to ensuring its relevance and usability for future engineering students. By adapting to the evolving needs and advancements in engineering education, the IARE-W system can more effectively support students' learning experiences and improve their overall understanding and skills in the subject matter.

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