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Development and Evaluation of an Augmented Reality Chiller System Simulator for TVET Teaching

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Abstract

This study investigates the potential of augmented reality (AR) technology to enhance teaching quality in courses on water cooled chillers and air-cooled chillers. It addresses the critical need for more interactive and engaging learning experiences, particularly for students in skills-based institutions who often exhibit a preference for visual and kinesthetic learning styles. Highlighting the importance of diversifying teaching methods, this research aims to improve student engagement and deepen their understanding of complex subject matter. Utilizing the ADDIE design model, the study develops an AR simulator and assesses its effectiveness through a questionnaire distributed to students from three vocational colleges. A descriptive analysis method was employed to evaluate the data, with the research instrument demonstrating a high reliability value ($\alpha = 0.890$). The findings reveal significant levels of perceived usefulness ($M = 4.34$), ease of use ($M = 4.36$), and positive attitudes ($M = 4.25$) towards the AR simulator. Consequently, the study concludes that AR technology is highly accepted among vocational college students, recommending the broader incorporation of AR technology in vocational education to enhance the efficacy of the teaching and learning process.

1. Introduction

The education sector is pivotal in cultivating a reservoir of highly skilled individuals and leaders, essential for national development. Lecturers, at the forefront of this endeavour, are tasked with imparting knowledge and skills to students with various learning preferences. Visual and kinesthetic learning styles are notably prevalent in vocational education over auditory ones. According to a study by Hanif, Azman, Pratama, Nazirah & Imam (2017), teachers who do not diversify their teaching methods can negatively impact their students, losing focus and attention. The use of various teaching aids can help teachers diversify their teaching methods. To address this, incorporating various teaching aids becomes instrumental, as highlighted by Bakhir (2016), who emphasises their role in infusing excitement and interest into the learning environment.

With the advent of the fourth industrial revolution, integrating modern technology in education is essential to ensure students' preparedness to navigate the technologically advanced landscapes of the contemporary workplace. Elements of the Industrial Revolution 4.0, such as the Internet of Things (IoT) and augmented reality

(AR), are increasingly being incorporated into pedagogical strategies to enhance students' readiness for the industry Chou et al. (2015). Nonetheless, educators should not disproportionately bear the financial implications of developing these educational tools. Sivakumar (2014) advocates developing cost-effective teaching aids that alleviate financial burdens and enhance student engagement.

Augmented reality (AR) emerges as a particularly advantageous technology for educators. Fidan and Meric (2018) describe AR as a technology that amalgamates digital images or objects with the real-world environment, offering a dynamic and interactive learning experience. Ali, Yahya, and Omar (2020) highlight AR's capability to facilitate lecturers' reference to subject content in real time, thus improving their explanatory clarity and student understanding. Furthermore, Aziz, Rahman, and Othman (2020) state that AR's utilisation by deploying three-dimensional virtual objects can significantly bolster student achievement. This is corroborated by Bölek, De Jong, and Henssen (2021), who elucidate AR's educational efficacy through a systematic review focusing on anatomy education.

Despite these advancements, the prevalence of traditional lecture methods in vocational colleges often leads to student disengagement and comprehension difficulties, particularly in complex subjects such as engineering. Hanif, Azman, Pratama, Nazirah & Imam (2017), and Hamdan and Yasin (2010) stress the challenges inherent in understanding engineering disciplines and advocate for integrating teaching aids to surmount these obstacles. This suggests that the strategic integration of teaching aids can significantly contribute to a more comprehensive and accessible learning experience for students and educators. Recognising this challenge, developing compact, interactive, and cost-effective teaching aids emerges as a practical solution, especially in courses like commercial air conditioning. This study will discuss the development of the chiller cooling system teaching aids for the air conditioning and refrigeration program at the vocational college in the water-cooled chiller & air-cooled chiller course.

2. Literature Review

In contemporary educational systems, where theory takes precedence over practical skills, the significance of teaching aids cannot be overstated, as they play a pivotal role in enhancing the quality of instructional delivery. Azman et al. (2014) state that teaching aids are crucial in teaching and learning. Moreover, every teaching aid created needs to have specific criteria that can help to aid the teaching so that the teaching and learning process can be more effective. Sulaiman, Yunus, and Umar (2017) also stated that criteria in selecting materials are essential because they can improve students' understanding of the content. These criteria are crucial as they contribute to students' comprehension and engagement with the content, particularly in the context of the Fourth Industrial Revolution, which has revolutionised educational technology with the proliferation of artificial intelligence and digital-physical systems (Shahroom and Hussin 2018).

There are two categories of chiller systems: water cooled chiller (WCC) and air-cooled chiller (ACC). According to Arya and Chavda (2014), WCC is a cooling system that uses two refrigerants that reject heat using water. Meanwhile, ACC is a system that has quite the same function as WCC, but the difference is that ACC rejects heat using air. The differences between these two chillers can be seen in the condenser area. For the WCC system, the cooling tower rejects heat for the condenser. But for ACC, the condenser system is in the open space, and heat is rejected using a fan. Figure 1 shows an example of the cooling system of WCC.

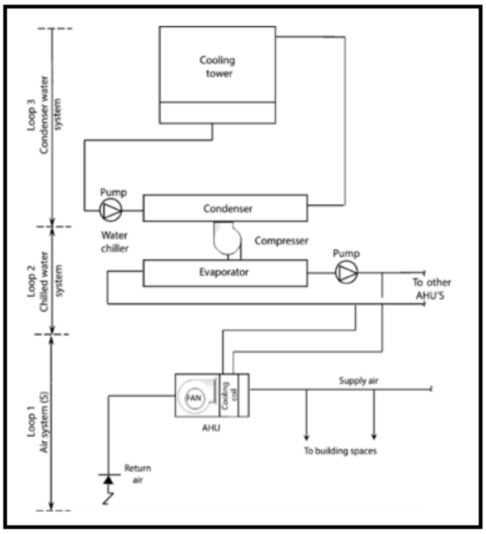


Fig. 1 *Water cooled chiller block design (Stanford, 2012)*

The integration of Internet of Things (IoT) technology has revolutionised human-machine interactions by facilitating seamless connectivity via the Internet. Ahmad Getso and Z. (2017) elucidate the core components of IoT, including output devices, software applications, cloud servers, and internet connectivity, often facilitated by microcontrollers. This technology holds immense potential for enhancing industrial skill sets among youth, as it enables efficient data exchange and remote access to servers (Idris, Mohammad Ridzwan, and Safie 2017). Furthermore, IoT's capacity to store vast amounts of data in cloud storage, also known as big data, underscores its pivotal role in modernising various sectors and improving living standards (Adesta, Agusman, and Avicenna (2017).

The rapid evolution of technology, exemplified by augmented reality (AR), has permeated diverse sectors, including education. AR offers an interactive overlay of computer-generated content onto real-world environments, enriching users' experiences Ramli, Nordin, and Ahmad Sokri (2018). Initially conceptualised in the 1960s, AR gained practical traction in the 1990s, subsequently evolving to become accessible via smartphone applications equipped with camera functionalities (Juhász, Muhi, and Johanyák 2019). Ferrer Torregrosa et al. (2016) conducted a study comparing three teaching aids (notes with images, videos, and augmented reality) applied to anatomy study. The results show the effectiveness of augmented reality compared to other aids. At the same time, Abd Majid and Mohd Shamsudin (2019) identified the factors that could affect the acceptance of virtual reality (VR) in classrooms based on the technology acceptance model (TAM). Tarng et al. (2018) showcased the superiority of AR-based teaching aids in astronomy education compared to conventional methods, exemplifying its potential to enhance pedagogical outcomes.

In conclusion, the swift pace of technological advancement underscores the imperative for educators to leverage innovative tools such as AR and IoT to enrich the teaching and learning experience. By embracing these technologies and adhering to established criteria for designing effective teaching aids, educators can cultivate a dynamic and engaging educational environment conducive to student's holistic development and proficiency acquisition.

3. Methodology

The focal point of this research is the development of teaching aids integrated with augmented reality (AR) elements, with a methodological foundation rooted in the ADDIE instructional design model. The ADDIE model, comprising five iterative phases—analysis, design, development, implementation, and evaluation—is the guiding framework for crafting and refining the AR-enhanced teaching aids. This approach ensures a systematic and comprehensive development process that aligns with established pedagogical principles. According to (Aldoobie 2015), ADDIE is an instructional model widely used by researchers to develop a more effective product. Subsequently, the effectiveness of these teaching aids will be assessed using the technology acceptance model (TAM), which encompasses dimensions such as perceived usefulness and ease of use. By leveraging the ADDIE model and TAM framework, this research endeavours to advance educational practices by integrating cutting-edge technology to enhance learning experiences and outcomes.

3.1 Analysis

During the analysis phase, the researcher conducted a comprehensive examination, dividing the process into several vital components. A pivotal aspect of this phase involved evaluating the suitability of different cooling systems, specifically the air-cooled and water-cooled systems. The analysis primarily focused on discerning discrepancies between the condenser and display systems. Drawing from the findings of Arya and Chavda (2014), the decision was made to develop the water-cooled chiller system due to its capacity to encompass a broader scope of content relevant to the subject area. Additionally, the selection of system components underwent meticulous scrutiny. Criteria discussed in this regard included deliberations on the type of condenser and the principal component, the evaporator. Based on the analysis outcomes, it was determined that employing a dry expansion shell and tube condenser type, coupled with a Tube-in-tube evaporator configuration, was optimal due to its compactness and developmental feasibility.

Furthermore, the analysis extended to evaluating the type of controller employed within the system, considering timed two-position and PID controllers. Utilising a two-position controller was deemed the most viable option for ease of development.

3.2 Design

In product development, the significance of an intricately planned design phase is paramount, serving as the foundation for successful development outcomes. The literature underscores the necessity of evaluating multiple design alternatives to ascertain the most feasible option, focusing on enhancing safety and developmental efficiency. This evaluative process involves proposing distinct designs, each characterised by unique features to optimise various factors, including safety and cost-effectiveness. In this design phase, the researcher first suggested three different designs of the same product. Every design has distinct characteristics contributing to other aspects, such as safety and ease of development. Table 1 shows the conceptual design selected for air conditioning design to review & evaluate the best design based on the design specification. Design specifications for this product include the safety factor, cost, size, material & maintenance. Among the designs, Design 2 emerged as the superior choice, attributed to its exemplary fulfilment of the design specification.

Table 1 *Conceptual design was developed by the researcher*

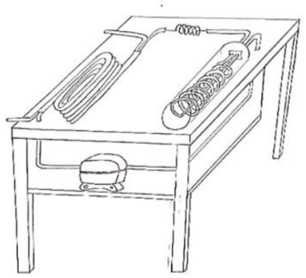
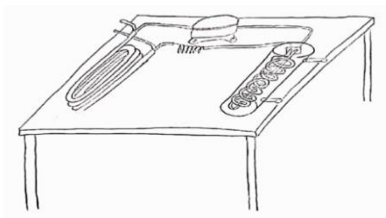
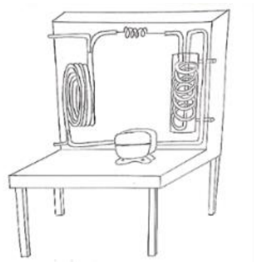
Conceptual Design		
Design 1	Design 2	Design 3
		

Fig 2 *shows the final three-dimensional design that the researcher developed*

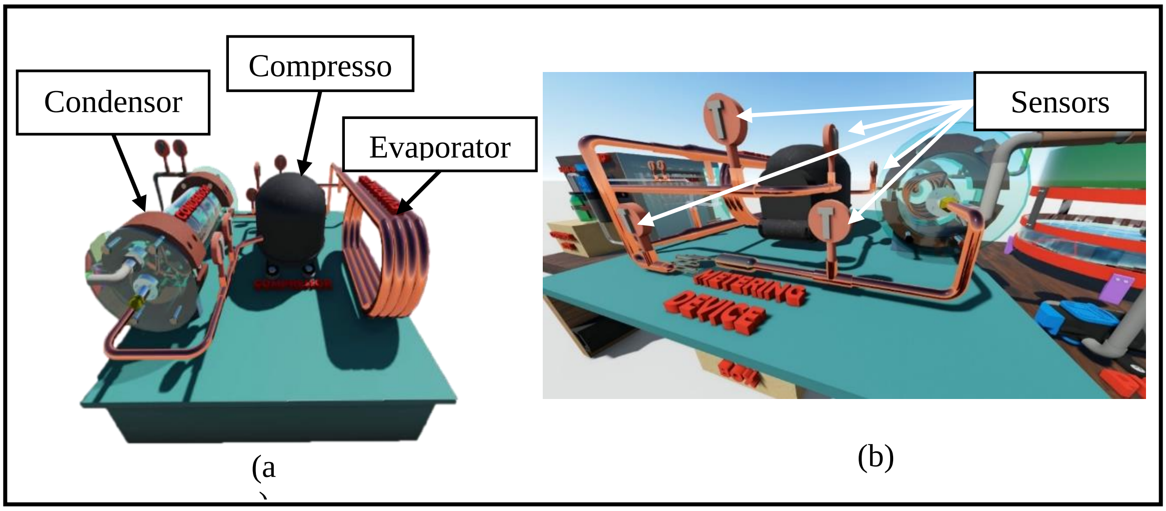


Fig. 2 *(a) main component of the product; (b) Position of the sensor in the product*

In the subsequent developent phase, the operating system's design emerged as a critical component. The intricacy of this product necessitated the incorporation of multiple sensors to accurately monitor system parameters, including inlet and outlet pressure, as well as the temperature at key components such as the compressor, condenser, evaporator, and metering device. These measurements are pivotal, as they directly reflect the product's performance. Consequently, the strategic placement of these sensors is paramount to ensure the accuracy of readings, which, in turn, facilitates the optimisation of the product's functionality. Figure 3 delineates the precise positioning of the sensors within the system, highlighting their integral role in the operational efficacy of the product.

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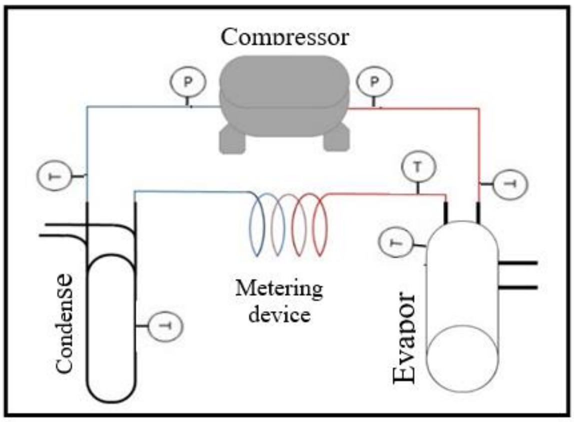

Fig. 3 *Type of sensor used in the product*

3.3 Development

3.3.1 Development of Product

During the development phase, the researcher embarked on the product's construction, segmenting the process into distinct stages to ensure a seamless progression of tasks. Initially, the focus was placed on establishing the core components of the cooling system, specifically the development of the condenser and evaporator. Subsequently, the researcher expanded the scope to include the complete system assembly, incorporating the product's base, the compressor, and the metering device. Upon finalising the development phase, a meticulous testing procedure was conducted to identify any potential leaks within the system. Following this, the installation of sensors and the execution of necessary wiring were carried out. The programming phase ensued, aimed at enabling the acquisition of operational data and facilitating the integration of augmented reality (AR) features. Before the product's completion, a final review was undertaken to address any minor adjustments and rectify any detected damage or leaks, ensuring the product's optimal performance. Figure 4 illustrates the completed product as developed by the researcher, showcasing the culmination of the comprehensive development process.

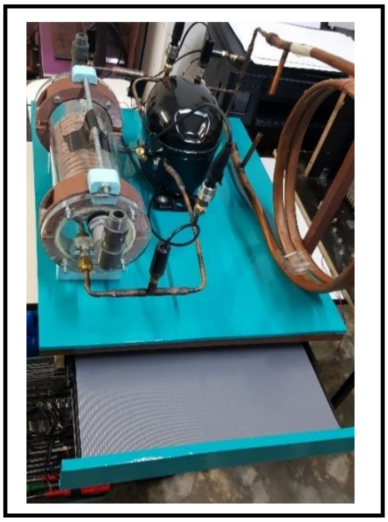

Fig. 4 *Actual product of chiller simulation system*

3.3.2 Development of IoT

The initial phase of the technological implementation involves the installation of Arduino IDE and Blynk software on both computers and smartphones. The Blynk application serves a pivotal role, acting as a conduit for communication between the server and the smartphone boards while offering a user-friendly interface accessible to users. After successfully installing the necessary applications and software, the researcher proceeds to engage in programming activities utilising the C language within the Arduino IDE software environment. This process entails specifying input/output parameters within the programming workspace and integrating appropriate libraries before initiating the primary programming sequence. Subsequently, the researcher configures the Blynk application on a smartphone, selecting suitable icons and functionalities to align with the project's requirements. Figure 5 visually depicts the interface between the Arduino IDE software and the Blynk application, illustrating the setup and operational context.

3.3.3 Development of Augmented Reality

Fig 5 *(a) Arduino software used by researcher; (b) Interface has been setup by researcher on Blynk application*

To facilitate the development of augmented reality (AR) access, the researcher employed web-based software tools, including Codepen, Glitch, and Google SketchUp. Specifically, Glitch software was utilised to host 3D models created with Google SketchUp. Once a 3D model was integrated, its web address was employed for programming within the Codepen platform. The researcher meticulously catalogued each model within this environment to correspond with specific markers. Before enabling the display of the 3D product through each marker, users are required to activate Codepen's web view mode. The programming languages adopted in Codepen—HTML, Java, and CSS—were instrumental in associating each model with its respective marker. To streamline access to the AR experience, the researcher integrated a QR code into the product, which directs users to the Codepen web view mode, facilitating immediate interaction with the 3D models. Figure 6 illustrates the programming workspace, highlighting how each three-dimensional model is linked to a marker, showcasing the intricate process of embedding AR functionality into the product.

(a) (b)

Fig. 6 *(a) Codepen used by researcher; (b) Model presented on marker from smartphone*

3.4 Implementation

During this implementation phase of the study, the researcher conducted comprehensive testing on the product to verify its capability to address the problem statement and fulfil the objectives outlined in the research. This involved meticulously recording temperature and pressure readings data, utilising specifically designed data collection forms. Furthermore, an assessment was conducted to ascertain whether the developed product conformed to the predefined design specifications, focusing on crucial aspects such as operational safety. This evaluation is essential to ensure that the product meets its intended functional requirements and adheres to safety standards during use. When the product failed to meet the established specifications, a systematic approach was adopted to identify and address the underlying issues. This process entailed a detailed analysis of the factors contributing to the discrepancies, followed by a strategic product redesign incorporating innovative solutions. Subsequent construction efforts were directed towards rectifying the identified problems aligning the product with its design specifications and research objectives.

3.5 Evaluation

To facilitate the evaluation phase, the researcher employed a descriptive quantitative survey methodology, utilising a questionnaire as the primary instrument for data collection. This approach collects information regarding specific variables, enabling a detailed description of the observed phenomenon. Descriptive quantitative research provides a systematic portrayal of the subject matter, allowing for identifying and analysing patterns and trends within the data set. Questionnaires in this context serve as an effective means to gather responses from participants, offering valuable insights into the research question. According to Chua Yan Piaw (2006), questionnaires are a fundamental tool in conducting studies that aim to explore and understand the characteristics of a particular group or phenomenon. This methodological choice underscores the researcher's commitment to capturing a comprehensive snapshot of the variables under investigation, facilitating a nuanced understanding of the study's focal points.

3.5.1 Population and Sample

This study is comprised of refrigeration and air conditioning diploma program students at Kolej Vokasional Batu Pahat, Kolej Vokasional Kluang, Kolej Vokasional Muar and Kolej Vokasional Segamat. The researcher chose students at four vocational colleges because of the constraints and lack of time to conduct research at all vocational colleges. The student population of the PPU Diploma program at these four vocational colleges is 114 people, as stated in Table 1. The number of respondents in this study was determined based on the sample size table developed by Krejcie and Morgan (1970). The sampling method used in this study is probability sampling, which is simple random sampling. The selected sample at least has the same characteristics as the population in the research (Mohd Majid Konting 1993). Therefore, for a population of 114 people, the appropriate sample size for this study is 88 respondents.

Table 2 *Population distribution and sample of PPU diploma program students*

Kolej Vokasional Johor	Total Population	Total Sample Selected
KV Batu Pahat	17	13
KV Kluang	23	17
KV Muar	51	41
KV Segamat	23	17
Total	114	88

3.5.2 Instrument of Study

For the research instrument, researchers used the questionnaire as an instrument of information collection and the questionnaires were adapted from previous reviews containing 21 items. These items were organised into three constructs: perceived usefulness, perceived ease of use, and attitude towards the technology. To further ensure the reliability and validity of the questionnaire, a validation group was convened, comprising lecturers with expertise in linguistic proficiency and technological understanding. The assessment of responses gathered through the questionnaire was conducted utilising a Likert scale, as delineated in Table 3, to quantitatively evaluate the extent to which the research objectives were met. Abdul Ghafar (2001) posits that instruments employing a five-point Likert scale exhibit enhanced stability, making them particularly suitable for studies aiming to gauge nuanced attitudes and perceptions.

Table 3 *Likert scale (Mohamed Najib, 2001)*

Rating	Scale
Strongly Disagree (SD)	1
Do Not Agree (DA)	2
Disagree (D)	3
Agreed (A)	4
Strongly Agree (SA)	5

Before distributing the research instrument to the respondents, its reliability was scrutinised through a pilot study employing Cronbach's alpha to evaluate reliability. This pilot study was crucial for verifying the questionnaire's suitability for the main study. Mohamad Najib (1999) underscores the importance of selecting pilot study samples from demographics identical to the target population to ensure relevance and accuracy. Cooper and Schindler (2011) advocate for a pilot study size ranging from 25 to 100 participants to achieve statistical significance while maintaining manageability. Aligning with these guidelines, this study engaged 30 Bachelor of Vocational Education students specialising in the PPU program, all of whom possess prior knowledge pertinent to chiller systems, as respondents for the pilot study. The instrument utilised for this purpose was a structured questionnaire. Data derived from the pilot study were analysed using the statistical package for the social sciences (SPSS) software, facilitating the Cronbach's Alpha coefficient computation. This step is instrumental in assessing the reliability of the questionnaire, thereby ensuring the integrity and validity of the subsequent main study's findings.

Jailani et al. (2017) critically evaluate Cronbach's Alpha as a statistical measure to assess the reliability of instruments used in a pilot study. According to their analysis, Cronbach's Alpha values span from 0.00 to 1.0, with values approaching 1.0 signifying high reliability. This metric is instrumental in determining the consistency of responses across items within a questionnaire, thereby indicating the instrument's reliability. Table 3.4 in the study delineates the thresholds for interpreting the reliability coefficient, offering a structured framework for evaluating the acceptability of Cronbach's Alpha values. Such a categorisation is essential for researchers to ascertain the reliability of their study instruments, ensuring that the data collected are reliable and valid for subsequent analysis.

Table 4 *The level of interpretation according to alpha Cronbach's value (Lam et al., 2017)*

Cronbach's Alpha Value	Interpretation
= 0.9	Excellent
0.8 - 0.9	Very Good
0.7 - 0.8	Good
0.6 - 0.7	Moderate
< 0.6	Weak

The results of the pilot study revealed that the perception of usability achieved a Cronbach's alpha coefficient of 0.899. In contrast, the perceived ease of use attained a Cronbach's alpha coefficient of 0.928. Additionally, the attitude level received a Cronbach's alpha coefficient of 0.655. The overall scale reliability, as indicated by Cronbach's alpha coefficient, was 0.890. These results suggest that the reliability of the questionnaire is excellent, indicating its suitability for use in further research.

3.5.3 Data Analysis

The data that has been collected will be analysed using the Statistical Package for the Social System (SPSS) software. This study employed quantitative analysis techniques using descriptive statistics to facilitate an in-depth examination of student technology acceptance aspects such as perceived usefulness, perceived ease of use, and attitude. Descriptive statistics, using mean scores, were used to analyse questionnaire item responses, measured on a Likert scale. This approach allowed for a better understanding of participants' perceptions and attitudes towards technology, providing insights into the student population's acceptance levels. Table 3 shows the detailed interpretation of the mean range levels, categorising the results into low, medium, and high tiers of acceptance. This classification delineates student attitudes and perceptions, offering valuable information for formulating strategies to enhance technology acceptance for the developed AR teaching aid in educational settings.

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Table 4 *Interpretation of the mean range level (Abdul Ghafar, 2013)*

Mean Value	Interpretation level
3.68 - 5.00	High
2.34 - 3.67	Medium
1.00 - 2.33	Low

4. Results and Discussion

4.1 Result

The data analysis addressed the conclusions of the data obtained from the respondents. The main aim was to identify students' acceptance of technology, particularly augmented reality (AR) in chiller simulation systems. Each item was assessed along with its corresponding frequency and percentage values, reflecting how the respondents perceived them. These values were then organised based on the Likert scale, ranging from 'Strongly Disagree' to 'Strongly Agree', to clearly understand the participants' attitudes towards AR technology in chiller system simulation teaching aid.

4.1.1 Demographic Analysis

The demographic data of the respondents analysed in this section encompassed gender, age, race, education level, and semester information as gathered from the questionnaire. Seventy-one male respondents filled out the questionnaire, while female respondents had 17 students. In addition, the majority of the study respondents are Malay, which is a total of 84 people, which is equivalent to 95.45%, while Indian respondents have 4.55%, which is equal to 4 students.

Table 5 *Demographic analysis*

Demographic Information		Total	Percentage %
Gender	Male	71	80.68
	Female	17	19.32
Age	19 years old	88	100
Race	Malay	84	95.45
	Indian	4	4.55
Level of Education	Diploma Vokasional Malaysia	88	100
Semester	Three	88	100

4.1.2 Level of Perceived Usefulness

Eight question items were provided to address the research inquiry, aiming to ascertain the perceived usefulness level of students regarding the application of AR technology in chiller simulation system teaching aids. The analysis of perceived usefulness among vocational college students for each item was organised based on their mean values, with Table 5 presenting the results from the highest to lowest mean. The overall perceived usefulness level was high, with a mean value (M=4.34).

Table 6 *Perceived usefulness level and average mean of each item*

No item	Statement		SD	DA	D	A	SA	Average mean	Level
B5	The use of AR technology can improve my performance in the chiller topic.	F	0	0	9	22	57	4.55	High
		%	0	0	10.2	25	64.8		
B4	The use of AR technology can increase my learning motivation	F	0	0	9	34	45	4.41	High
		%	0	0	10.2	38.6	51.1		

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B2	The use of this AR technology is effective in helping me to know the phase condition of the refrigerant on each component	F %	0 0	0 0	18 20.5	19 21.6	51 58	4.38	High
B6	The use of AR technology can improve the quality of learning in chiller topics	F %	0 0	0 0	14 15.9	35 39.8	39 44.3	4.28	High
B1	The use of AR technology is useful for me to recognise the actual shape of the components used in the chiller system	F %	0 0	0 0	15 17	34 38.6	39 44.3	4.27	High
B3	The use of AR technology was effective in helping me to know the type of coolant pressure on each component	F %	0 0	0 0	19 21.6	26 29.5	43 48.9	4.27	High
B7	The use of this AR technology during the class facilitated my understanding of the chiller system concept	F %	0 0	0 0	13 14.8	38 43.2	37 42	4.27	High
B8	I can learn faster by using this AR technology	F %	0 0	0 0	14 15.9	38 43.2	36 40.9	4.25	High
							Average Mean	4.34	High

The analysis revealed that item B5, "The use of augmented reality (AR) technology can improve my performance on the chiller topic," received the highest mean score. This finding is in harmony with the broader literature on the subject. Specifically, Zambri, Khalid, and Kamaruzaman (2022) underscore the transformative potential of AR in education, spotlighting its role in rendering learning materials more interactive and engaging. This aligns with the high perceived usefulness reported in this study, where AR technology notably enhanced student performance in the chiller topic. Furthermore, integrating AR technology augments cognitive understanding and significantly elevates student motivation and engagement, as evidenced in research conducted by Zambri, Khalid, and Kamaruzaman (2022). Sirakaya and Cakmak (2018) further validate these observations, reporting that students utilising AR applications in an experimental group exhibited tremendous success in a computer hardware course.

Additionally, Mumtaz et al. (2017) found that students engaged in AR-based learning environments achieved higher mean scores than those in traditional settings, reinforcing the argument that AR technology can elevate students' understanding of complex concepts. The utility of AR extends beyond mere cognitive gains. The capacity of AR to facilitate hands-on, experiential learning is highlighted by its application across various educational contexts, suggesting a broad utility that transcends technical training. This versatility is supported by the observed improvement in learning quality and the enhanced understanding of intricate concepts, such as the phase condition of refrigerants in chiller systems.

Conversely, item B8, "I can learn faster by using this AR technology," registered the lowest mean value of 4.25. Yet, this score still indicates a robust agreement among students about the efficiency of AR in accelerating learning processes. Keçeci, Yildirim, and Zengin (2021) note that slow internet connectivity poses a significant barrier to rapid learning within AR environments, a challenge that, while notable, does not significantly detract from the overall positive student perceptions of AR's efficacy. Moreover, the findings from Amores-Valencia, Burgos, and Branch-Bedoya (2023) provide further evidence of the positive impact of AR on academic performance, emphasising its effectiveness in creating immersive and interactive learning environments. This comprehensive perspective underlines AR technology's role in facilitating a deeper understanding of subjects, thereby contributing to higher learning efficiency and speed despite potential technological barriers.

In summary, integrating AR technology into educational tools and materials is perceived as highly useful by students and empirically supported by recent academic research. These findings collectively advocate for the expanded use of AR in education to enhance learning outcomes across various disciplines. The evidence points to a significant correlation between the use of AR technology and improvements in student achievement, motivation, and engagement, highlighting the critical role of AR in modern educational strategies.

4.1.3 Level of Perceived Ease of Use

To address the second research question, this study investigates the perceived ease of use of augmented reality (AR) technology among students when applied to chiller simulation system teaching aids. This was accomplished by administering a questionnaire comprising seven items. As detailed in Table 6, the findings reveal the overall perceived ease of use among vocational college students for each item, ranked from the highest to the lowest mean value. The analysis indicates that the mean value for perceived ease of use is significantly high (M = 4.36), suggesting that students generally find the AR technology in chiller simulation systems user-friendly.

Table 7 *Perceived ease of use level and average mean of each item*

No item	Statement		SD	DA	D	A	SA	Average mean	Level
C6	The use of AR technology on this chiller simulation system is easy to understand	F	0	0	10	26	52	4.48	High
		%	0	0	11.4	29.5	59.1		
C5	I easily remember how to operate the AR technology found in the chiller simulation system	F	0	0	10	27	51	4.47	High
		%	0	0	11.4	30.7	58		
C4	This AR technology is easy to understand	F	0	0	13	30	45	4.36	High
		%	0	0	14.8	34.1	51.1		
C7	The AR technology used is easy to operate	F	0	0	14	31	43	4.33	High
		%	0	0	15.9	35.2	48.9		
C1	This AR technology does not use high effort to operate it	F	0	0	11	38	39	4.32	High
		%	0	0	12.5	43.2	44.3		
C2	I think that this AR technology is user friendly	F	0	0	14	34	40	4.3	High
		%	0	0	15.9	38.6	45.5		
C3	The image display on the application used when scanning the QR code is clearly visible	F	0	0	15	33	40	4.28	High
		%	0	0	17	37.5	45.5		
							Average Mean	4.36	High

The analysis identified item C6, "The use of AR technology on this chiller simulation system is easy to master," as receiving the highest mean value. This finding aligns with the research conducted by Delello, Mcwhorter, and Camp (2015), who observed that students could learn the AR application relatively quickly. This rapid learning curve may contribute to the perception among students that AR technology, particularly in the context of the chiller simulation system, is user-friendly. Further supporting this notion, Abdinejad et al. (2021) reported that 69% of the participants affirmed their ability to grasp how to navigate the application quickly. These outcomes collectively suggest that AR technology presents a manageable learning challenge for students.

Conversely, item C3, "The image display on the application used when scanning the QR code is visible," recorded the lowest mean value of 4.28. This lower satisfaction level may stem from inadequate hardware capabilities. Delello et al. (2015) noted that a subset of students experienced difficulties with their mobile device's ability to render the virtual images correctly, with one student even required to borrow a device for AR application use. Additionally, a contributing factor to the discontent with item C3 could be the instability associated with marker-based AR technology. Cheng, Chen, and Chen (2017) highlighted that marker-based AR often results in virtual objects appearing to wobble or flicker, further complicating the user experience. These findings underscore the technological and practical barriers that may impede the optimal use of AR applications in educational settings.

4.1.4 Level of Attitude

To address the third research question concerning students' attitudes toward using augmented reality (AR) technology in chiller simulation system teaching aids, the researcher administered a survey comprising six items. The analysis of responses, as detailed in Table 7, ranks the perceived ease of use among vocational college students from the highest to the lowest mean values. The findings indicate that the overall attitude toward AR technology is notably positive, with an average mean value of 4.25 (M = 4.25). This suggests students' receptivity and favourable disposition toward integrating AR technology into their learning environments.

Table 8 *Attitude level and average mean of each item*

No item	Statement		SD	DA	D	A	SA	Average mean	Level
D1	I think that it is necessary to use AR technology in class because this technology helps to increase my motivation	F	0	0	13	31	44	4.35	High
		%	0	0	14.8	35.2	50		
D2	My interest in learning increased when using AR technology	F	0	0	13	33	42	4.33	High
		%	0	0	14.8	37.5	47.7		
D6	AR technology makes learning more interesting	F	0	0	14	34	40	4.3	High
		%	0	0	15.9	38.6	45.5		
D3	I can pay more attention to the class when AR technology is used	F	0	0	14	38	36	4.25	High
		%	0	0	15.9	43.2	40.9		
D5	I would like AR technology to be used in other air conditioning subjects	F	0	0	18	37	33	4.17	High
		%	0	0	20.5	42	37.5		
D4	I believe the use of AR technology in the classroom is a good idea	F	0	0	18	41	29	4.13	High
		%	0	0	20.5	46.6	33		
						Average Mean		4.25	High

Item D1, which posits, "I believe that it is necessary to use AR technology in class because this technology helps increase my motivation," received the highest mean value. This aligns with the findings of Estapa and Nadolny (2015), who observed significant differences in student engagement levels, noting that AR technology captivated students' attention more effectively than traditional website-only approaches. Such evidence corroborates earlier research, indicating that incorporating AR in classroom settings by fostering an environment intertwined with reality can significantly boost student motivation Wu et al. (2013). Moreover, Chin, Wang, and Chen (2018) found that students engaged with AR-enhanced systems exhibited not only higher motivation towards learning but also improved academic performance. These findings collectively suggest that AR technology facilitates students' increased willingness to learn.

Conversely, item D4, "I believe the use of AR technology in the classroom is a good idea," recorded the lowest mean value of 4.13. Despite being the lowest, this score still reflects a strong interest among students in adopting AR as a pedagogical tool within classroom settings. Nufus (2013) argued that traditional teacher-centric methods could render students passive participants in their learning journey. This perspective is supported by Rusli et al. (2019), who reported diminished interest and motivation among students subjected to unidirectional Pedagogical (PdP) sessions in lecture environments. Therefore, it stands to reason that the application of AR technology, by promoting a more interactive and engaging learning atmosphere, is deemed a positive innovation by students, potentially leading to more active and enthusiastic participation in PdP sessions.

4.2 Discussion

In this research, several design concepts were developed and subsequently evaluated by three experts. Evaluating design concepts is a pivotal step in product development, ensuring the final product is functional, user-friendly, and aesthetically pleasing Hosking (1981). The selection of materials was carefully considered, with acrylic plastic utilised for the condenser to facilitate students' understanding of water and refrigerants within a Shell and tube-type condenser. Mustapha et al. (2014) support the idea that the physical properties of teaching aids, including material selection, labelling, and clarity, are crucial for enhancing educational quality.

The integration of augmented reality (AR) technology has been identified as a beneficial tool for educators, enabling the demonstration of actual components and the application of IoT-based devices, thereby simplifying the presentation of temperature readings to students. This technology makes the learning experience more engaging and fosters creative activities within the classroom setting. Feedback from experts suggested that while the developed product was largely practical, it required refinement and the addition of certain accessories, as indicated by responses to a distributed questionnaire. For example, a pressure switch was recommended to safeguard the compressor from excessive pressure.

Despite encountering financial constraints that limited the procurement of high-quality safety components, necessitating a focus on essential elements and functions for the study's aims, the product development process proceeded with functionality testing conducted in two distinct phases. The cooling system's performance was initially assessed by developing a Mollier chart cycle graph. Subsequently, a three-dimensional display was generated on smartphones via a unique QR code linked to the product's main component. Sensors meticulously collected performance data relayed it to a control board, and transmitted it to the Blynk server, enabling access to the information through smartphone-installed applications. The positive feedback from questionnaires unequivocally confirmed that the product achieved the research objectives, enhancing the teaching process and contributing significantly to the successful completion of the study.

Building upon the successful development and testing of the product, subsequent analysis focused on evaluating the perceived usefulness of augmented reality (AR) technology in chiller simulation systems for educational purposes. The findings reveal a pronounced appreciation for AR technology among students, with an average mean value of 4.34 across various items assessing its impact on learning efficacy, motivation, and comprehension of concepts. This high level of student endorsement underscores the view of AR technology as a substantial enhancer of the educational experience. The literature supports this positive reception; studies by Zambri et al. (2022) and (Sirakaya and Cakmak n.d.) have emphasised AR's role in making learning more engaging and effective, particularly in technical education fields such as chiller system training. Notably, the highest mean score related to improving performance on chiller topics illustrates the significant contribution of AR technology's interactive and immersive nature to enhancing learning outcomes.

Conversely, perceived ease of use also received a high average mean score (M=4.36), indicating that students found AR technology beneficial and user-friendly. The item receiving the highest mean value pointed out that AR technology is easy to understand, an essential factor for its effective integration into educational settings. This finding is supported by Delello et al. (2015), who noted the quick adaptability of students to AR technology. However, challenges such as device compatibility and the stability of marker-based AR, highlighted by the lowest mean value item, suggest areas for technological improvement to ensure AR's broader applicability and effectiveness.

In conclusion, the overarching positive attitude toward AR technology, with an average mean value of 4.25 for its integration into the learning process, underscores a consensus on its value in education. The enthusiasm for AR's application across various subjects and its capacity to increase motivation and interest in learning suggests a promising avenue for educational innovation. Despite the noted challenges, the findings advocate for the continued exploration and integration of AR technology in education, emphasising its potential to transform traditional learning environments into more engaging, practical, and interactive experiences.

5. Conclusion

Teaching aids are crucial in skill-based subjects that pose comprehension challenges for students. Teaching aids enable educators to refine their instructional strategies and effectively achieve learning objectives. Specifically, the Chiller Simulation System is invaluable, facilitating instructors in delivering subject content smoothly and efficiently. This product has been successfully developed, fulfilling all predefined objectives, encompassing the design phase, development, and testing of the product's functionality.

The deployment of the chiller simulation system represents a significant advancement in educational technology, enabling teachers to deliver content more effectively without the logistical challenges of gathering students around a physical chiller system. By incorporating features of effective teaching aids, such as enhancing the comprehension of system operations and offering a compact design for easy storage, this system not only facilitates an improved learning environment but also ensures the durability of the educational tool.

Building on this system's successful development and implementation, the subsequent evaluation of its effectiveness, as framed by the technology acceptance model (TAM), reveals a notable impact on student engagement and learning outcomes. Students from Kolej Vokasional Batu Pahat, Kolej Vokasional Kluang, Kolej Vokasional Muar, and Kolej Vokasional Segamat reported a high level of perceived usefulness, ease of use, and positive attitudes towards the integration of AR technology within the chiller simulation system. This feedback underscores the significant enhancement of students' learning experiences through AR technology, which not only meets but exceeds expectations regarding user-friendliness and minimal effort required from users. Importantly, students willing to engage with new, AR-enhanced learning environments showed a more profound commitment to mastering the subject. These findings validate the effectiveness of the chiller simulation system and suggest the broad applicability of AR technology in educational settings. Future research should delve into the dynamics between various TAM components to further elucidate how these factors contribute to innovative educational technologies' successful adoption and impact.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***introduction:*** *Muhammad Zuhairi Abdul Jalil,* Nizamuddin Razali ***literature review:*** *Muhammad Zuhairi Abdul Jalil;* Nizamuddin Razali; Khairul Anuar Abdul Rahman; ***methodology:*** *Muhammad Zuhairi Abdul Jalil;* Nizamuddin Razali; Mohd Bekri Rahim ***result and discussion:*** *Muhammad Zuhairi Abdul Jalil,* Nizamuddin Razali; Mohd Bekri Rahim ***conclusion:*** *Muhammad Zuhairi Abdul Jalil,* Nizamuddin Razali; Noorazman Abd Samad. *All authors reviewed the results and approved the final version of the manuscript.*

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