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ORIGINAL ARTICLE

The Mobile Augmented Reality Application for Improving Learning of Electronic Component Module in TVET

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ABSTRACT – Teens and young adults may get training in anything from the basics to advanced skills in various workplace and academic settings at Technical and Vocational Education Training and Education (TVET) institutions. Some aspects of teaching and learning in TVET cannot be articulated clearly, and trainees cannot perceive how things fit together. The study was conducted to determine the optimal platform to develop mobile Augmented Reality applications for TVET trainees and, to assess the TVET trainee's readiness for AR-based mobile application training deployment. An online questionnaire was sent to trainees at Industrial Training Institute in Malaysia via the online system. A marker-based Augmented Reality application was created for the Basic Electronic Components module utilizing Unity software, the Vuforia engine, and C# script. Finally, the trainees were allowed to test the generated application. The trainees were interviewed to obtain data on their responses. The results indicate that 83% of the TVET trainees own and use android as the application platform. The results of the pre-test and post-tests used to gauge the success of the Augmented Reality application show that its usage in the sub-learning module significantly improved memory recalls for the TVET trainees. The outcomes showed that the Augmented Reality application suited the participants' learning needs and improved the effectiveness of their learning. The result from this project will serve as a pre-test for determining the most suitable platform to deploy the Augmented Reality application to be developed in the future.

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INTRODUCTION

Technical Vocational Education and Training (TVET) plays a crucial role in establishing high capabilities among the workforce that can raise the country's global competitiveness [1]. This is because one of the most important features of TVET is its orientation toward the work environment and the emphasis of its curriculum on the acquisition of employable skills [2].

Automotive, Building Construction, Welding, and Electric & Electronics are some of the courses among the long list of courses available on TVET [3],[4]. The trainees should complete their training within a stipulated time frame depending on their performance throughout the training. Within the training duration, they should attend industrial training for six months to gain more knowledge and skills in their field [1]. In contrast to a classroom setting, industrial training plays a significant role in educating trainees where the problems to be solved are real or live.

TVET is an essential arena that helps improve the quality of the workforce by improving their mobility, adaptability, and productivity [5]. TVET delivery systems are well placed to train a skilled and entrepreneurial workforce that some countries need to create wealth and minimize the poverty issues among the nations [6],[7]. TVET training comprises both theoretical studies and practical training. Heutagogy can help educators improve TVET by providing a more open and adult-friendly approach to learning [8].

Heutagogy encourages the growth of critical thinking skills and creativity in students by utilizing technologies like 3D printing, electronic publishing, games, and Augmented Reality (AR) [9],[10]. The effectiveness of teaching the trainees with interactive instructional media can be observed through the exam results. The usage of instructional media showed a positive effect on trainees' academic achievement. The trainees give a higher rating to lecturers who use a variety of interactive instructional materials compared to lecturers who use traditional lecturing methods [11]. As it has been documented in United Nations Educational, Scientific and Cultural Organization [12], a regulatory framework for blended learning is required for TVET.

Sutherland developed head-mounted display devices in 1968, which is when one of the technologies that make up AR first started. In terms of AR's development, it has quickly garnered attention in industries like business, logistics, gaming,

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manufacturing, retail, and education [13]. In AR, graphics are added to the environment that already exists in reality [14]. Industry players frequently use AR-based systems to obtain on-the-spot information (right in front of their eyes) to help them with their tasks [15]. As a result, even novices can become mechanics by following instructions provided by AR auto maintenance applications [16], such as 2D or 3D instructions on a mobile device [17]. AR can be utilized for a variety of reasons such as education, tourism, industry-related activities, and so on. AR can be used to introduce marine animals to the learners [18].

Virtual reality refers to the use of computer technology to create a simulated environment [19]. Virtual reality (VR) is a computer technology that simulates or replicates a physical world in order to give users the sensation of being there and physically interacting with it [20]. In virtual reality, the user will experience complete immersion in whatever activity they have chosen, such as playing a virtual golf game, virtually visiting a museum, or diving into a virtual sea environment [21].

Mixed Reality (MR) is a situation in which the real and virtual worlds merge, with the virtual augmenting the real and the real augmenting the virtual. In an MR experience, the user is immersed in an interactive context that is either real with virtual asset augmentation or virtual with real-world augmentation [3]. The three primary realities that comprise extended Reality (XR) are AR, virtual reality, and mixed reality [22]. A device that combines an AR-compatible device, a VR headset, and an MR headset is known as an XR device [23],[24].

AR is still being developed and expanded in order to meet the requirements of various streamlining [21]. AR can be divided into four kinds. These are marker-based AR, marker less AR, projection-based AR, and superimposition AR [25]. the researchers [26], created an AR application for an automotive instruction system. They installed Unity 3D and Vuforia on a Samsung Galaxy A Tablet. The investigation reveals that adopting AR-based teaching reduces Task Completion Time and error counts by 10.27% and 42.86%, respectively.

RELATED WORK

The most popular computing device for users to enjoy mobile AR is a smartphone. Despite this, mobile AR on smartphones has some set back due to the extensive functionality that causes concerns about thermal dissipation and battery life. Power characterization shows that mobile AR apps use more energy than other non-mobile AR apps due to camera usage [27]. AR is an approach that uses mobile technology to access to contextual knowledge in a variety of ways. The combination of Mobile device and virtual reality results in accessible, inexpensive, and high-quality education [28].

AR has advanced from cutting-edge research to a wide range of applications in entertainment, wellness, industry, tourism, and education. AR games, like Pokémon Go, have helped the general public grasp the technology. Mobile AR apps have evolved as a result of the proliferation of modern phones and tablets with huge displays, cameras, and high computing capability, which may provide users with context-sensitive information while allowing them to explore the context [29].

There are several AR applications that have been developed especially for android smartphones. The smartphone will identify markers using a tracking device, and once the markers have been identified, the object model in the space's structure will appear above the marker as if the object model has been reassigned [30]. An immersive mobile AR application was developed using eXtreme programming (XP) for a tourist destination in Central Java's Purbalingga area. In this study, the Android platform is utilised to display interactive tourism promotion brochures that incorporate 3D models and graphics [31].

AR technology is also used to assist students who are having difficulty explaining textbook subjects. A sign is scanned using an Android device's mobile app to reveal an AR technology-based illustration. In comparison to the actions of students searching for animations or photos, the time spent on this scan demonstrates that AR technology is more efficient [32]. An Android-based AR application was created with the notion of molecular geometry in mind. The research was carried out in stages, beginning with concept creation and progressing to application development on the Android operating system [33].

Several studies have been taken place by using iOS mobile devices. Clinical research integrated smartphone VIP iOS software into orthopaedic and neurosurgery care. This study used iOS mobile AR [34]. ARmedViewer is an iOS app that lets users quickly choose from a list of 3D images with digital images and header information. The data, which can be put on top of a real person's body, is put where the user wants it to be [35]. One way in which smart mobile devices are becoming more advanced is through mobile AR [36].

The term "mobile AR" (MAR) refers to a real-world setting that has had digital information and visuals superimposed on top of a mobile device namely the hand held type. MAR have successfully combined the physical and digital worlds [37]. Digitization in all areas of life poses a challenge to vocational training because it changes the way people work and how they need to be certified. It also gives a lot of chances to improve the quality of training. MAR makes it possible to learn and master intricate processes in a risk-free manner [38]. MAR appears to improve engineering learning. In their introduction to Mobile AR (MAR), the authors note that the dramatic advancement of mobile devices allows to enhance AR by providing an easier and more alluring access to this tool [39].

In recent years, numerous literature reviews on MAR have been released. Unfortunately, there has been a dearth of articles on the best platform for creating AR apps focusing on mobile devices. This study examined the best platform for developing mobile AR applications focusing on Electronic Component Module to help TVET trainees better comprehend, learn, monitor, and visualise their lessons. The TVET trainees were also assessed on the readiness for AR-based mobile application training deployment as it will be a game changer for the future trainees..

METHODOLOGY

In order to acquire the results, a combination of qualitative and quantitative approaches was utilised. This research includes techniques such as gathering some information concerning the assessment of Mobile AR compatible gadgets currently being used by TVET trainees. This methodology assists to identify the mobile application platform that is best suited for use in TVET-related AR apps. It also helps to determine whether or not TVET trainees are prepared to adapt themselves with AR-based training. Followed by design of AR apps that may be tested with TVET trainees in Malaysia.

Research Design

The findings of this study are going to be presented in two parts. The first part of this research will be to gather informations related to the accesibility of trainees to mobile devices, including the type, model and platform that the device works on. The next step will be to determine the suitable subtopic to be converted into mobile AR, to perform pre-test using questionnaire, go ahead with development of application using Unity3D and Vuforia. The application was distributed and tested among the trainees before they share their inputs on the applicability af the application. As for intervention before the post-test is given, the trainees were given an online briefing on how to use the application. This is followed by analysis of the results using IBM SPSS Statistics 20 software to conduct paired t-test. Figure 1 shows the flow chart of this study's research design.

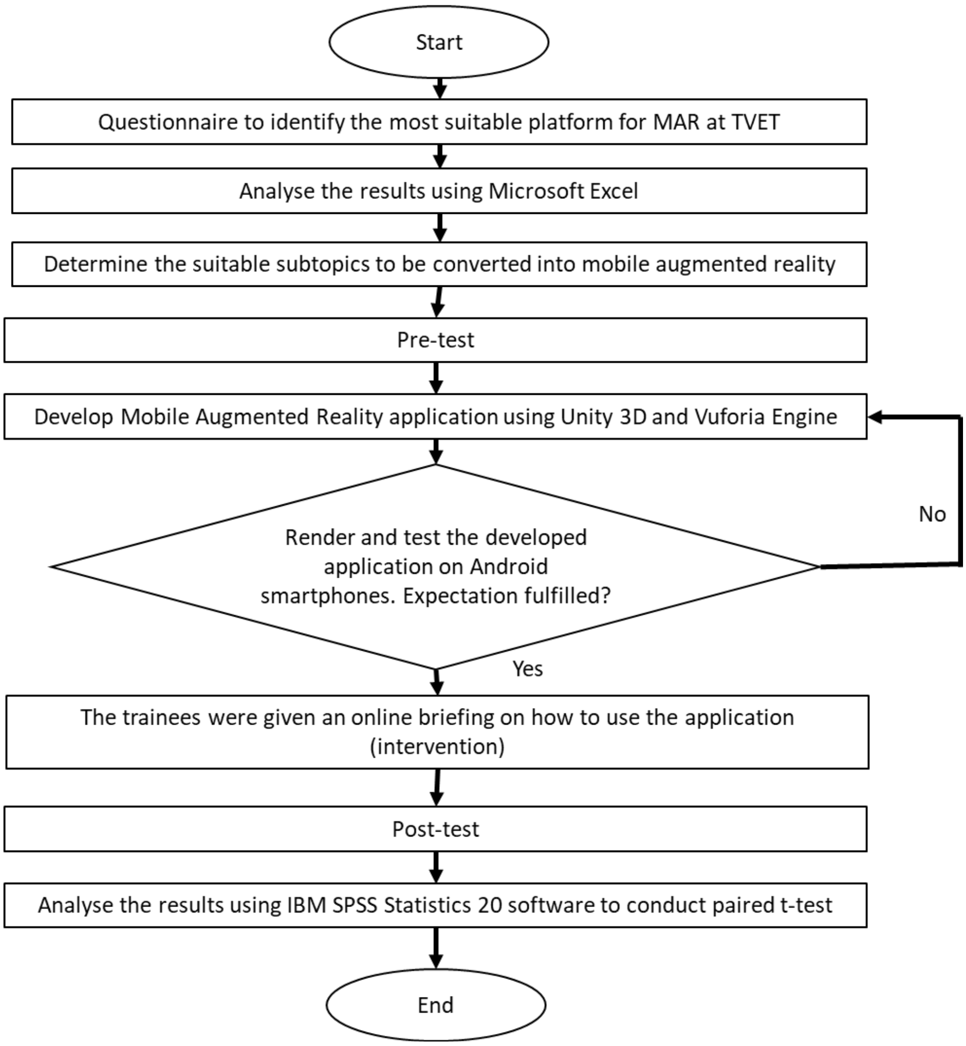

Figure 1. The flow chart of research design.

Research Sample

Twenty-three trainees from an Industrial Training Institution (ILP) under the Manpower Department, Ministry of Human Resources, Malaysia were involved in the first part of the project. In the second part, there are fourteen students from the same educational establishment participating. The instruments that were utilised include an online questionnaire that was created using a Google form and online interviews that were conducted using the WhatsApp platform [40].

Research Instruments

The purpose of the first part of this research was to identify the most suitable platform for establishing TVET-specific mobile AR applications. A questionnaire was prepared and distributed via the online system and sent to the trainees. The selected medium for the online system is Google Forms. The TVET instructor validated the questionnaire before it was distributed to the trainees [36]. The questionnaire has been constructed and written in two languages, Bahasa Malaysia and English. It is written in two languages so that TVET trainees may understand the questions and respond accurately.

The online questionnaire was distributed to the TVET trainees with the permission of their instructor. The selected medium for survey distribution is the WhatsApp application. The trainees answered the questionnaire once they receive it, and the response was monitored through the google form response page. Twenty-three online survey forms were distributed to the trainees. A total of twenty-three completed online surveys in the form of Google forms were received back from the TVET trainees.

Data collected from the questionnaire were analyzed using Microsoft Excel. The number of trainees who owned a mobile application platform for AR was calculated. For example, the number of trainees with Android and IOS will be determined and analyzed which one is the most owned among TVET trainees. Next, the type of smartphone used among trainees also will be selected. In all the above cases, quantitative analysis is used to develop complex data that leads to better decisions.

The next goal is to figure out how ready the TVET trainee is for AR-based mobile application training. The process begins with the development of an AR application and testing the functionality of the developed AR apps. The finalized AR apps that have gone through many phases of corrections were distributed to fourteen TVET trainees. The trainees were given pre-test and post-test to evaluate the extent of their understanding of the related topic. An interview was conducted after allowing the trainees to experience the developed AR app. Next, feedback about the developed AR application was received. Finally, the data was analysed.

The instrument used includes an AR application developed for the research purpose, a questionnaire using Google form, and an online interview via the WhatsApp platform. The survey was conducted using Google Forms and an online platform. Since this study was conducted during the Covid-19 pandemic time frame, the online method that best suited the situation was utilized.

The Mobile AR was created by using Unity software and Vuforia software. The AR application was built for android platform. AR camera was added and Vuforia license key was obtained in order to proceed with the application development. Since this is a marker-based AR project, database of target image was imported to the file project, followed by creation of virtual buttons. Figure 2 shows the creation of virtual buttons and the process of adding the image target using Unity software. The three virtual buttons were named as ‘Resistor’, ‘Potentiometer’ and ‘Switches’. Three videos were also inserted where each video provides basic information about resistors, potentiometer, and switches [41].

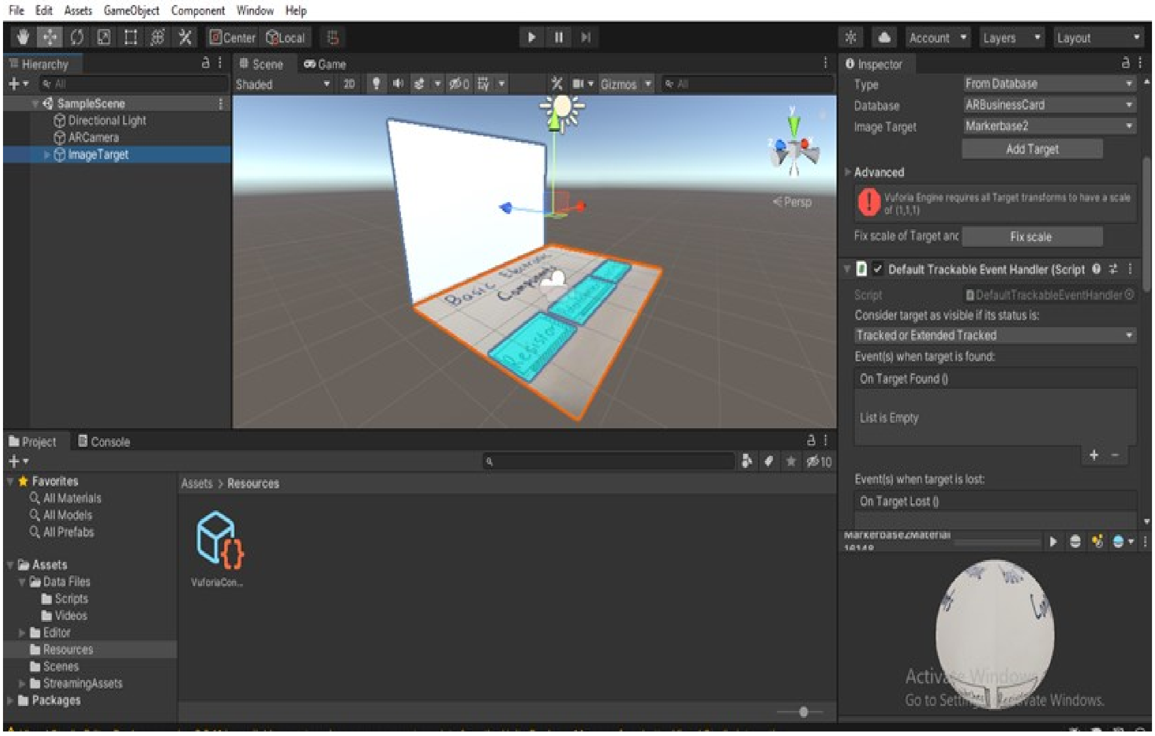

Figure 2. The creation of virtual buttons and the process of adding the image target using Unity software.

The video used was from YouTube [42]. Three planes were inserted for each video to display. Next, the programming code for the three virtual buttons was created. When the Resistor button was pressed, the resistor's video will display, and the other two videos will turn off. Instead, when the Potentiometer button was pressed, the video about the potentiometer will be displayed, and the other two videos will turn off. The APK file for this AR app will automatically be downloaded once it has been developed. The APK file must then be copied and transferred to the smartphone as the next step. Install the AR app on your smartphone to complete the development process and proceed to use the application.

Research Procedure

A video was produced to demonstrate how to utilize the AR application, and the trainee's reaction was gathered through an interview. In the video, several steps have been explained. The output of developed AR can be experienced by following the steps as mentioned below:

1. When the APK file of the developed application has been downloaded by the trainees, they need to transfer the file and install it on their respective smartphones.
2. After installing the APK file, the AR apps icon will appear on their smartphone and it can be opened for usage. Figure 3 shows the image target that have been used for this research.

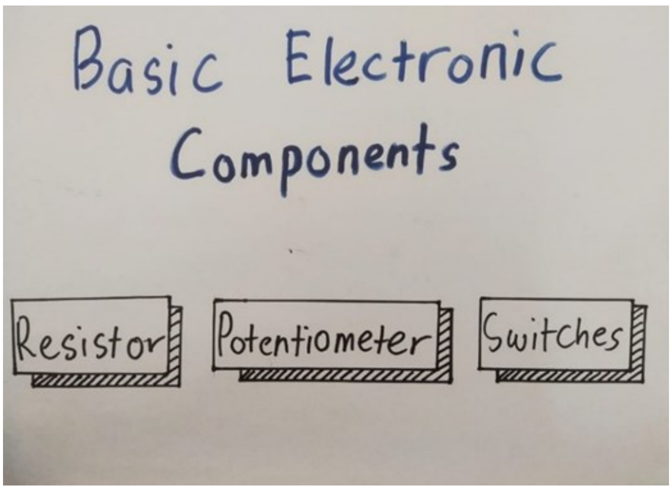

Figure 3. The image target for Basic Electronic Components.

3. Next, the trainees need to hold the smartphone with AR apps on the Marker base to scan it as shown in figure 4.

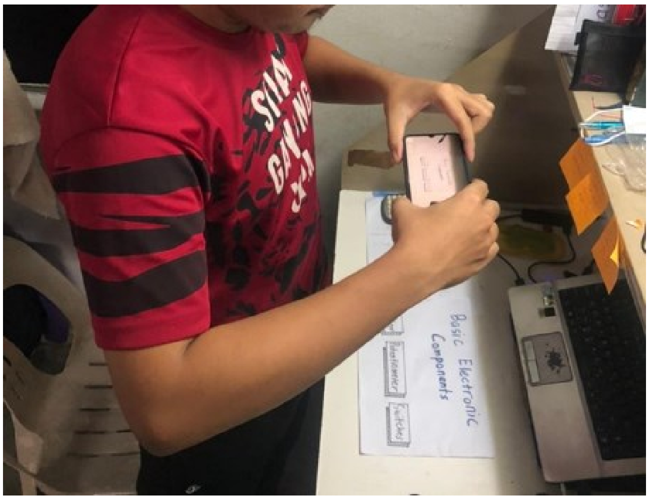

Figure 4. The trainee holding the smartphone with AR apps on the Marker base to scan it.

4. The trainees need to press the virtual resistor button on the Marker-base. Once the Resistor button is pressed, the information about the resistor will pop up and be displayed as shown in figure 5. The process goes on for potentiometers and switches.

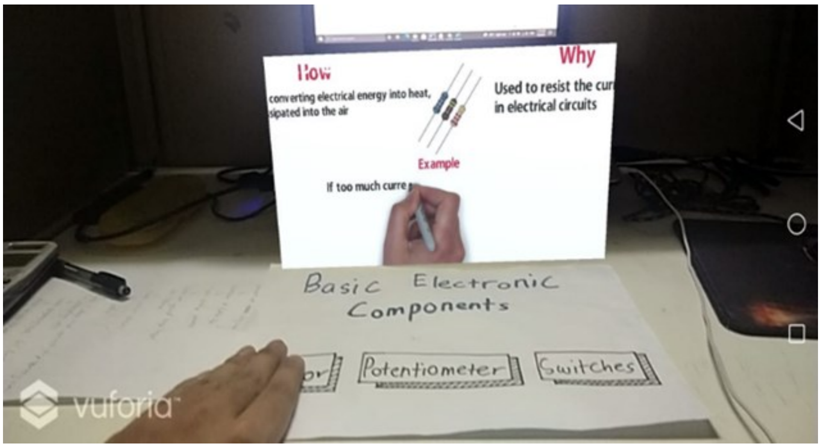

Figure 5. The trainee holding the smartphone with AR apps on the Marker base to scan it.

5. These steps can be repeated until the TVET trainees fully understand the essential electronic components' functionality.

EXPERIMENTAL RESULTS

The response rate is 100%. All twenty-three respondents who are TVET trainees replied to the study and were highly cooperative throughout the research. There are around 78% of male TVET trainees among the respondents, whereas there are only 22% of female TVET trainees among the respondents. The majority of the respondents are male TVET trainees. Due to the fact that the courses that were provided at the Industrial Training Institute were appropriate for and more pertinent to male trainees.

Every single TVET trainee that participated in this research owns and uses a smartphone. That accounts to 100% of smartphone usage by the trainees. When it comes to the choice of smartphone manufacturer, opinions between trainees vary widely. Table 1 provides a summary of the trainee's choice of smartphone manufacturers, which was acquired through the study. The Oppo and Vivo brands of smartphones offer top-notch quality at entry-level prices, with impressive features and the newest processors. Taking this into consideration, Oppo and Vivo accounted for 26% each of all smartphone users. Next, 18% of respondents use Apple devices, while 9% use Realme and 5% prefer Neffos. Samsung, Yes, Xiaomi and Huawei stand at 4% each.

Table 1. Choice of smartphone manufacturers.

Smartphone manufacturer	Percentage of trainees that own
Oppo	26%
Vivo	26%
Apple	18%
Realme	5%
Neffos	4%
Samsung	4%
Yes	4%
Xiaomi	4%
Huawei	4%

The trainees have listed down 20 different smartphone models that are being used by them. It depends on how affordable they are. The majority of trainees owned the Vivo 1718 and Realme 5i models since they featured Qualcomm Snapdragon 450 Octa Core processors set at 1.8 GHz and 4GB of RAM. It performs better and does not lag. It has 32GB of internal storage which is extremely large, and it also supports memory up to 256GB of storage. Trainees can save numerous files without worrying about their memory becoming full. Figure 6 shows that the TVET trainees with the android platform for their mobile phones account for 83% of the overall sample size whereas balance 17% of the trainees use the iOS platform.

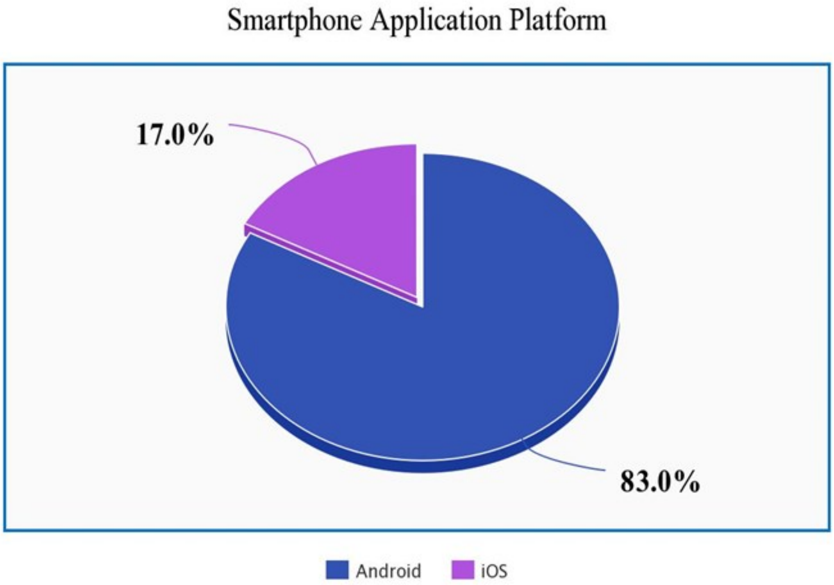

Figure 6. Comparison of the smartphone application platform prefered by TVET trainees.

Android was favoured by TVET trainees since it is less expensive than Apple's iOS. In addition to its popularity, Android's widespread availability of features and its versatility has contributed to its widespread adoption among TVET trainees. Android's interface is easy to use. On Android devices, the Quick Settings panel acts as a quick launch pad to the full Settings menu, as well as other customization choices. TVET trainees are ready to adapt to AR based training using mobile applications. Due to the Covid-19 pandemic, they cannot learn face to face. So, using this new learning method will ease them to understand the lessons.

TVET Trainee's Readiness For AR-Based Mobile Application Training.

The results from the questionnaire related to the readiness of TVET trainees to adapt to AR-based training using mobile applications is shown in Table 2.

Table 2. Readiness of TVET trainees to adapt to AR-based training using mobile applications.

Question posed to trainees	Percentage of response	
	Yes	No
Do you have a smartphone?	100%	0%
Does your smartphone support the AR application?	57%	43%
Do you know about AR term?	13%	87%
Do you have any experience with AR?	9%	91%

Do you know that Pokemon Go is one of AR?	30%	70%
Do you think AR can help you in education?	91%	9%
Do you think that mobile AR is a good idea?	83%	17%

In this study, the researcher employed IBM SPSS Statistics 20 software to conduct paired t-test analysis. According to Table 3, the results of the paired t-test shows that learning performance achieved a significant difference level. The t-value is 5.48. The p-value is $< .05$. The result is significant at $p < .05$. This means that the learners who used the AR application could improve their knowledge of basic electronics. The results from the pre-test (Mean = 53.57, Standard Deviation (SD) = 9.45) and post-test (Mean = 84.29, Standard Deviation (SD) = 9.76) of the instructional effectiveness indicate that the presence of AR application in the learning of the sub-module resulted in an improvement in memory recall, $t(14) = 5.48$, $p = .0015$. The result is significant at $p < .05$.

Table 3. Results of the paired t-test of Instructional Effectiveness.

Variable	Pretest		Post test	
	Mean	SD	Mean	SD
Instructional effectiveness	53.57	9.45	84.29	9.76

This result is consistent with [43], in which intelligent feedback was a helpful strategy for novices. This research also proved that using mobile AR for teaching and learning can trigger problem solving ability and improve learning performance. Thus, the developed mobile AR apps fulfilled the learners' learning requirements and was a useful learning system.

Majority of the respondents, which contribute about 91% of the total respondents, agree that AR can help them in education. In comparison, only 9% of total respondents agree that AR can help them in education as shown in Figure 7. Learning using the AR method was new to the trainees. The TVET trainees were more engaged in their learning activities due to AR. Furthermore, the trainees tend to pay more attention during the teaching and learning process.

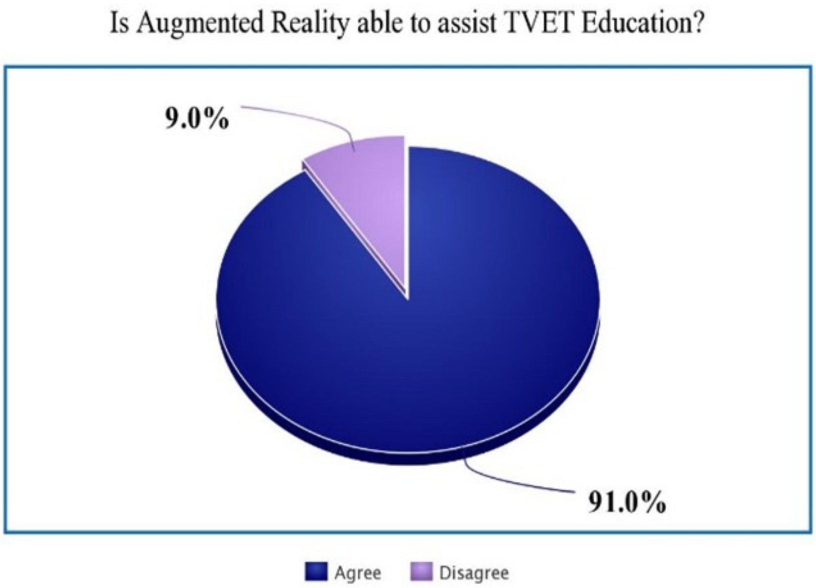

Figure 7. Trainees' opinions on the ability of AR to assist TVET education.

Based on the interview conducted on 14 trainees upon trying out the developed mobile AR app, most respondents agreed that mobile AR is a good idea. Their reasons are that the application is easy to use, the application can ease them in education, it is easy to understand, visual images that pops out once the button is pressed keep them attentive and lastly the agree that AR application can help them in education by using a smartphone with the apps downloaded.

According to the findings, technical trainers continue to utilize teaching aids at a modest degree. Trainers require an assistive tool to enhance the trainees learning and training experience [44]. A tool that encourages trainees to reflect on the topics covered can significantly improve the quality of the teaching and learning process [20]. TVET can benefit from alternative e-learning platforms such as AR applications, Virtual Reality applications, and Mobile applications.

As written in [45], the TVET curriculum should be expanded to include multimedia and hypermedia in order to improve trainees' performance. As stipulated in the Education Agenda 2030, a new style of training is required. The survey completed during COVID-19 revealed that e-learning materials are insufficient for current TVET training centres [46]. Authors [47],[17] and [48] have also discussed this problem statement. Implementing e-learning will not only raise

TVET trainees' enthusiasm in studying, practising, and mastering knowledge and skills on their own, but it will also improve their understanding level.

CONCLUSION

All of the trainees at TVET are completely comfortable using smartphones. Based on the findings, the entire TVET trainees were found to be 100% smartphone-savvy. These findings supports the study where Mobile Augmented was chosen as the medium for alternative teaching and learning. It is possible to reach the conclusion that Android is the most suitable platform for the development of AR applications in TVET. This remark is supported by the findings of the poll, which indicate that Android users account for 83 percent of the whole sample size, whereas just 17 percent of the trainees choose iOS.

The mobile AR application that was developed and tested with TVET trainees provided the trainees with the opportunity to be exposed to AR and the benefits it may provide. It also gave the trainees an opportunity to discover about Mobile AR and its usefulness. According to the trainees' responses in the interview, they found the application to be appealing, attractive, help them in TVET learning and beneficial to their theoretical education. The trainees provided positive comments about the introduction to Mobile AR and the feedback was helpful to strengthen body of knowledge related to Mobile AR's application for TVET. The TVET trainee's readiness for application and usage of AR-based mobile application as part of teaching and learning was well established at the end of this study.

Researchers can consider building the AR application for the processes or elements that are difficult for TVET trainees to understand. Thus, the trainees will be able to see the techniques or elements and improve their understanding. AR applications with more graphics and illustration will encourage the trainees to pay more attention and learn more. An attractive AR application for TVET will attract and make the TVET trainees more focused while learning.

The learning technique used by TVET trainees is more to learning theory and conducting hands on activities. AR encourages technology-enhanced learning, which may offer an alternative solution to this conventional method. More AR apps are needed to be introduced in the TVET environment. AR will be able to provide flexibility for trainees to study and master technical skills at their own pace. As we know, every trainee has their learning capability. AR can help to simulate the real condition of an installation task or assembly task and assist trainees to get a better understanding before the trainee undergoes the practical training [24].

AR application is eco-friendly. It will not pollute the environment and furthermore, the application will also make the younger generation more creative, as AR deals with graphical images. AR is a learning method that is suitable for the future generation to promote an advanced society. There is a need to invest in the development and production of IR 4.0 solutions, such as AR and virtual reality. In order to obtain a highly trained workforce, substantial investment in infrastructure upgrades in TVET institutions is required in the emerging technological field such as AR and virtual Reality.

This study has the potential to be explored further through the development of TVET-related modules based on mobile AR. It is possible to incorporate evaluations and several other elements into the developed module in order to make it more streamlined. According to the findings of the research, the development of modules based on Mobile AR for TVET should take into consideration the Android platform and add on features that will incorporate more of the cognitive aspects.

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