Exploring the Potential Benefits and Challenges of Augmented Reality in TVET Programs: A Mixed Methods Study

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ABSTRACT

Technical and vocational education and training (TVET) is aimed at providing trainees with the necessary knowledge, skills and competencies needed for work. With the rapid development of information technology, how the virtual world of augmented reality (AR) can be used to enrich TVET has drawn much attention. Employing a mixed method, focus of this paper is to study the possible benefits and challenges of using AR in TVET programs, as well key factors behind its effective implementation. The researchers conducted a quantitative online survey of 200 participants who were either students or instructors at TVET institutions, and from this the researchers selected the sample of students and instructors to be interviewed. In this study, research findings show that AR has the potential for increased students' participation and improved learning performance in TVET programs. But the use of it also has some technical, ideological leverage, the survey found such barriers and support required for instructors that desires learning with this kit on their class instruction. Our study also discovered some important enabling factors necessary for implementing AR in TVET programs, such as the instructor support and the satisfaction of the students. Accordingly, based on the findings, the study suggests that TVET should grasp particular attention of potential benefits and challenges. Instructors and students would then need substantial training support if it is to work in practice. Further study is needed to explore what the long-term impact is on students' outcomes in TVET programs.

Keywords: augmented reality, TVET, technical education, vocational education and training, challenges, benefits.

INTRODUCTION

The field of education is always making progress, and new technologies emerge constantly. Learning and teaching could be transformed by those new arrivals. One such technology is augmented reality (AR). This technology displays digital content over the top of the real world, so that users can experience a 'mixed reality'. A new way of providing education could be revolutionized by AR, Thanks to it students will have immersive and interactive learning experiences, which help explain difficult concepts [1]. In recent years, there has been growing interest in the use of AR for technical and vocational education training programs. All the courses in TVET are meant to instruct their students in practical skills and knowledge, so that they can succeed in their work make a contribute the economy. Consequently, although traditional TVET approaches have relied on classroom-based instruction and practical training in real-world settings, the use of AR technology could offer a more effective and efficient way to deliver practical training [2].

Despite the potential benefits of AR in the TVET area, a lack of research exists about its effectiveness, especially from an instructor's perspective. Understanding the potential benefits and issues associated with your AR programming is critical if both the design and outcomes of such learning programs are to be successful. In recent years, AR has started to become popular in the education sector in a variety of settings, such as university and

corporate training programmes [3]. AR has been used in a broad variety of fields, including ancient medicine (e.g., surgery care), civil engineering and architecture. Thanks to AR, students have the chance to experience at first hand interactive learning experiences which can improve their understanding of difficult concepts. For TVET, because of the use of AR is has the potential to create a safe and stimulating environment for trainees to learn and compenetrate real-world skills, it can also speed up the transfer of learning to real-world situations. Among other things, the feedback provided by AR is real-time. Therefore, students can correct mistakes and improve their performance faster [4]. In addition, AR increases students' interest and involvement in the process of learning, as it provides a more immersive interactive learning experience.

Nevertheless, Despite the potential advantages of AR in TVET programs, there are some obstacles. For example, the expense of equipment, technical problems and the need for training new skills among both instructors and students. Although the usage of AR in TVET has the potential to be beneficent for students, there is currently a scarcity of studies on how effective it actually is. This is particularly true from the perspective of instructors. Understanding attitudes among instructors about the use of AR in TVET is essential for planning and implementing AR-based training programs and ensuring their effectiveness. Therefore, our purpose in this study is to investigate whether AR might become a tool for enhancing skill acquisition in TVET programs from the perspective of the stakeholders.

LITERATURE REVIEW

Augmented reality (AR) technology has been proposed to enrich the teaching and learning in many fields such as technical and vocational education and training (TVET). Literature review provides an overall review of the existing research on the use of AR in TVET education program, issue concerned with it's used, the benefits and challenges.

Benefits of AR in TVET

AR can enhance the acquisition of skills in TVET programs in many ways. Among AR’s primary benefits is it allows for hands-free learning where students can be comfortable during the learning process. For instance, a student is able to practice their practical skills in an artificial world without any risk of injury or damage to equipment [2] This is particularly important in industries such as construction and manufacturing where safety precautions must be adhered to strictly. Additionally, AR creates situations imitating real life environments thus enabling application of knowledge gained into actual contexts. Through simulating different scenes using VR technology, students can therefore practice while developing these skills so that when there is need for them in future they would do so easily than before [6]. Eventually, this could lead into increased efficiency at work sites coupled with reduced expenditure on training facilities since most inputs are made onsite now days. Another way through which AR could benefit TVET programs greatly is by increasing motivation levels among students.AR makes learning fun due its interactive nature Any content presented within such an environment becomes memorable as well since it captures attention easily Therefore people tend to remember more information taught through this method and are also likely apply what they have been taught in real life situations.

Challenges of AR in TVET

Even though AR holds potential benefits for TVET programs, its application is faced with challenges. One of the main challenges is the cost of equipment. Headsets and smart glasses are some of the specialized tools required to implement AR, which are expensive. Especially in countries or areas with limited resources, this may act as a barrier to adoption. Secondly, technical issues when incorporating AR into teaching cannot be ignored. In order to create content as well as deliver it to students, a lot of technical know-how is needed, which something that many instructors may not possess [7]. They might therefore find themselves limited by their inability to do so because they do not have these skills or training beyond just being users of such hardware. Lastly but not least important among these problems is that both instructors and students need more training too. This is due to the fact that AR involves a different approach towards instruction and learning hence they will require additional knowledge on how best utilize such kind of technology.

Existing research on AR in TVET

Although there has been little research done on the utilization of AR within TVET programs, numerous studies have explored its potentials as well as limitations. A study conducted by [8] sought to determine if AR could be used for skills improvement among instructors in TVET institutions The findings of the study indicated that AR had the capability of enhancing skills training programs in TVETs more especially on safety, motivation, and engagement. However, further training would still be needed coupled with its cost implications which were also highlighted by this research. Additionally no standardized educational settings or environments currently exist for immersive software applications

Objectives of the research

1. To explore the potential benefits and challenges associated with AR in TVET programs.
2. To identify out what factors help make AR work in TVET programs, and what strategies can be developed to deal with these problems.

METHODOLOGY

The objectives of this research will be achieved using a mixed-methods approach. This method of inquiry involves gathering, analyzing and interpreting both qualitative and quantitative data.

Research Design:

A sequential exploratory design will be used in the study which will comprise of initial qualitative research and empirical quantitative investigations. To begin with, there will be an extensive literature review of AR and TVET programs. Additionally, interviews will be held with expert trainers as well as students who have used AR in TVET environments before. The aim is to identify the main factors that facilitate successful implementation of AR in TVET programmes and propose ways through which such can be managed. Secondly, a questionnaire survey targeting instructors acquainted with augmented reality technology within vocational education settings together with their students shall be conducted too. This is meant to provide more elaborate information on matters concerning benefits accrued from its usage, challenges faced while using it as well as implementation requirements under different circumstances.

Research Instruments:

Survey

This investigation is designed for the research team to gather quantitative data about how much people think augmented reality helps with training. The survey will be created based on the aims and questions of the research. It was tried out with a few people first to check if it was fair and reliable before we give it to everyone else. In order to answer quickly and easily, the survey will contain closed questions and rating scales. All rating questions utilized a 5-point Likert scale, where 1 represented a 'Major Challenge' or 'Strongly Disagree,' and 5 represented 'No Challenge' or 'Strongly Agree. We will use an online platform that is safe and private when we do this study. Each person who takes part will get a code so their answers can’t be linked back to them. There are eight parts in total which have been compiled into one questionnaire. Each part contains five questions about different things related to AR in TVET programmes:

1. Perceived usefulness of AR in TVET programs
2. Perceived ease of use of AR in TVET programs
3. Students engagement with AR in TVET programs
4. Impact of AR on students’ outcomes in TVET programs
5. Technical challenges associated with the use of AR in TVET programs
6. Pedagogical challenges associated with the use of AR in TVET programs
7. Instructors support for the use of AR in TVET programs
8. Students support for the use of AR in TVET programs

Semi-Structured Interviews

Semi-structured interviews will be conducted online or face-to-face through video conferencing depending on the preference of the user. This is for the purpose of collecting qualitative information about peoples' experiences with and perceptions of augmented reality in training environments. Before these interviews take place, falling within the scope set out by our research objectives… a pilot test should also done for their validity and reliability during research process. Every participant must give consent before any audio recording begins. This consent will involve recording the entire conversation word-for-word so that everything can later be analyzed fully.

Population and sampling

The research's sample consisted of TVET instructors and students from Malaysian Technical University Network (MTUN) institutions. These are universities located in Malaysia that are mainly geared towards providing technical and vocational education. The sample for this study would be made up of instructors as well as students within these particular academic centers. A purposive sampling technique will be employed when choosing the interviewees so that only those who have had exposure to AR could participate. This means we will target individuals currently affiliated with MTUN who can use AR effectively for different learning programmes based on their experienced expertise. The following criteria should apply regarding selection of respondents among TVET instructors in this research:

- One must currently hold a position as TVET instructor at any of the MTUN universities
- Should show practical experience of using AR within TVET curriculum
- Willingness to take part in an interview and/or fill out survey forms

A total number of 200 people were considered to take part in the study among whom there were 40 instructors whereas 160 were students.

Data Analysis Methodology:

Data obtained through the survey and semi structured interviews was analyzed using mixed methods approach. Descriptive statistics were used on quantitative data collected from surveys while content analysis was done for qualitative responses obtained during semi structured interviews.

Quantitative Data Analysis

Descriptive statistics were used to summarize and describe the quantitative data from the survey. Statistical software like SPSS will be employed in analyzing these statistics. For each item in the survey, we computed following descriptive statistic measures:

1. Mean
2. Standard deviation

Qualitative Data Analysis

To analyze the qualitative data, content analysis was used on information from semi-structured interviews. In content analysis, data is coded into themes and patterns. The steps taken in analyzing the qualitative data were as follows:

1. The interviews that were recorded are to be transcribed word for word.
2. The transcribed information will then be scrutinized to identify key themes and patterns evident in it.
3. Data is going to be coded following the established themes and patterns.
4. Coded data will be arranged into categories so as to make sense of it all.

RESULTS AND FINDINGS

Quantitative Data

This study gathered quantitative data through a survey questionnaire with 200 respondents. It utilized descriptive statistics such as mean scores and standard deviations for analysis.

The first aspect looked into was the perceived usefulness of AR in TVET programs. The average rating for this aspect stood at 4.23 which meant that students generally found AR to be helpful in TVET programs. Additionally, the standard deviation was 0.68 indicating some level of uniformity among the responses. Secondly, ease of use of AR in TVET programs among students was considered. The mean score under this construct was 3.92 suggesting that students considered it relatively simple to apply AR while undertaking TVET programs. On the other hand, there existed quite a variance in reply as shown by a standard deviation equal to 0.71.

The third thing looked at was student involvement with regards to AR in TVET programs the mean score for this variable was 4.05 which implied that generally students participated actively when availed with these resources during their studies in technical institutions. However, there were different views according to responses given by individuals since its standard deviation stood at 0.77. Fourthly the influence that use of AR has on better learning outcomes among students who are taking various courses in TVET institutions. The average score for this item was 4.17 meaning that most students felt it brought positive results for them academically while pursuing different programs within vocational education and training centers. Similarly even though not all students may share such sentiments about its effects still they hover around mean because their dispersion is not that wide evidenced with standard deviation being 0.62.

AR technical and pedagogical challenges in TVET program we looked at were the fifth and sixth constructs respectively. The mean score for technical challenges was 2.85 which means students see some together with AR uses for TVET programs. It had a standard deviation of 0.81 thus these answers varied quite a bit. This shows that there are also brought about by this perception of some certain amount technical difficulty when applied to vocational education systems student centered learning methods The mean score achieved on pedagogical challenge is 2.98 this again indicates perception among students towards few challenges experienced while operationalizing educational reactive graphics within higher engineering training institutions curriculum. The deviation level recorded at 0.76 suggests there was great variability in responses received.

The instructors support and students support for the use of AR in TVET programs were examined under seventh as well as eighth constructs. Students felt they were getting other students to help them out hence giving an average rating of 4.12 on students support while the standard deviation scored 0.62 points only showing that most respondents had similar attitude since facts about specific issues always remain true or changes over time. Necessarily so because their classmates have always been supportive, they did not find it difficult when doing assignments related theories from various members who had diverse knowledge backgrounds but they all aiming at achieving one goal.

The quantitative data in general indicated that students within technical and vocational education training programs had favourable perceptions toward the usefulness as well as entertainment value which comes with implementing augmented reality technologies into instructional systems designed Accreditation board for engineering and technology curriculum. They might have had something to say about how much ‘fun’ or ‘intrigue’ is there to be achieved quantitatively speaking. Furthermore, they indicated some technical problems linked up with using AR within TVET settings. Similarly, they also experienced certain teaching difficulties along this line. However both their instructors and peers were seen providing them necessary assistance while working with such kind of media for educational purposes within this particular context henceforth making me believe more deeply what I learnt through various theories.

Qualitative Data

Several key themes were discovered through the qualitative data analysis that related to the use of AR in TVET programs. These themes were drawn from dialogues with instructors and students who had personal experience using AR in TVET contexts. It was broken down into five key themes (Table 1) as shown below.

Table 1: Points collected from interview and analyzed into sub-themes and themes.

Points	Sub-themes	Themes
Due to the interactive nature of AR applications, it aroused more interests for students in learning content.	Increased Interest in Course Content	Positive impact on students engagement and motivation
Learning tools, such as AR, increased curiosity and enthusiasm in students. Consequently instructors could make content even more interesting by incorporating this visual component.		
Students had a greater positive attitude to join or run the grassroots activities, experiential courses and face-to-face seminars brought in by AR.	Enhanced Participation in Activities	
AR gave rise to interactivity and co-operation among students, so that class became more vital.		
When technical glitches are found in AR hardware and software during TVET programs they have difficult potential for smooth implementation.	Hardware and Software Issues	Technical challenges associated with AR implementation
The mix between devices and software platforms created some difficulty both for instructors and students.		
AR experiences were often interrupted by lagging internet connectivity or network failures. Students were left frustrated, learning activities impacted.	Connectivity and Network Reliability	
Varying learning locations wherever content was located, differing networks caused problems in acquiring and accessing AR content.		
Students felt that they needed to have more extensive familiarization sessions in order to get just how AR technology and what its features involve.	Students Orientation and Familiarization	Need for adequate training and support
Little or no prior experience with AR software left trainees in a state of anxiety and doubt. This type of self-education is necessary when		
Instructors needed to receive special training to be able to use AR in the classroom effectively.	Instructor Proficiency and Pedagogical Training:	
On the list of things that must be addressed as soon as possible are pedagogical workshops and continuing education projects for instructors. This will enable them to make better use of their understanding (in practice) in terms both theoretical knowledge and skills ingrained from experience.		
For instructors, developing AR-enriched learning materials that match curriculum goals and learning objectives was tough.	Curriculum Alignment and Content Development	Pedagogical challenges associated with AR implementation
When integrating AR components into the existing course content, instructors were forced to carefully plan and design instruction.		
Instructors encountered problems in devising general instructional strategies and methods of		

assessment specifically tailored to promote optimum AR learning for people to grasp.	Instructional Strategies and Assessment Methods	
How best to use AR technologies in tandem with traditional teaching methods and still get results in learning was a task for instructors.		
When given the chance to comment on their AR experiences, students felt a greater sense of involvement and motivation.	Enhanced Engagement and Motivation	Importance of students feedback
Participants who are actively engaged in the ongoing feedback process get lifelong learning opportunities.		
Students are looked to as a key source of information by instructors - for spotting gaps in teaching methods and shaping up those aspects of AR implementation that still need work.	Critical Input for Improvement	
Students views offer a firsthand perspective on whether AR instruments or methods employed achieve their intended purposes. This helps shine the way for ultimate learning results.		
Both instructors and students suggested that regular surveys and focus groups were effective ways of compiling feedback from all over the school on AR initiatives.	Utilization of Regular Surveys and Focus Groups	
Through the efficient implementation of structured feedback mechanisms like surveys and focus groups, data was gathered methodically, and when presented back to instructors who could then make appropriate responses informed by what particular piece of information was most valued by students.		

Positive impact on students' engagement and motivation:

Many instructors and students noted that introducing AR into TVET programs had a positive effect on engaging the students and driving their motivation. This was shown by increased interest in all courses by the students who were also ready to speak either in their native languages or in any foreign language necessary. A lot of class participation resulted from such discussions which were carried out when instructors asked for feedback on videos. Instructors also believed that use of AR enabled them to activate two kinds of learning processes thereby benefiting the students.

Technical challenges associated with AR implementation:

Instructors and students observed that there are difficulties related to technology which come with adopting AR in TVET programs. According to them, some instructors cannot start their teaching because they cannot use devices while others fail to engage software that supports AR. However, they consider signal interruptions as the biggest connectivity and network reliability problems. This means that many classes begin late and have too many interruptions during the actual teaching time thus affecting both the instructors' and students' motivation towards learning.

Need for adequate training and support:

When employing AR within TVET programs, it is necessary for trainers as well as trainees themselves to be adequately trained and supported. The students stated that they were confused at first when confronted with such applications while instructors claimed that more skills on how best utilize them were still required among other things. Various technicalities occur during its implementation therefore requiring continuous pedagogical assistance besides just being equipped only once.

Pedagogical challenges linked to the implementation of AR

Both instructors and students together identified the pedagogical challenges linked to the introduction of AR in TVET programs. These include coming-up with new and effective teaching methods as well as activities that can incorporate AR into them. In addition, it also means blending what is taught via AR with the course objectives and learning outcomes. Although these problems can be overcome through appropriate training support which takes longer periods and more resources to handle effectively.

The importance of students feedback:

According to both instructors and students, students' comments are critical when using AR for training purposes in the context of TVET institution settings. For instance, they noted that their level participation would go high if only they could write on the computer screen that is set up at an angle with others in the room but not when at home answering questions alone. Similarly, instructors emphasized on student feedback ability to enhance the success of implementing AR effectively within different subjects areas under this system. Instructors added that regular surveys could be conducted among small groups working closely together within laboratory environments so as obtain quick responses concerning specific issues related to applying AR methods while teaching various skills among trainees enrolled into programs offered at vocational institutions. This approach may also help them know what works best depending on type course being handled

Furthermore, the use of AR in TVET programmes has the potential to enhance students' engagement and motivation based on qualitative data analysis. However, its proper use requires adequate training support which addresses technical as well pedagogical challenges associated with it. To this end student feedback should always be collected since they can provide valuable insights that might facilitate successful implementation of AR systems in teaching various skills among different subject areas under TVET

DISCUSSIONS

In this study the findings reveal both potential benefits and challenges of AR in TVET programs. The results signal that students generally saw AR as a useful and attractive technology. Its' impact was positive on what they learned. However, the instructors pointed out a number of technical and pedagogical challenges in applying AR, if these stymie successful adoption we will not reap its benefits from a TVET perspective. Analysis of results for the first objective of this study is to determine possible benefits and challenges if AR is used in TVET programs who indicates students generally see AR as a useful technology for enhancing learning. The mean score for perceived usefulness of AR in TVET programs is high (M=4.56, SD=0.68), indicating that students believed AR could help them understand difficult concepts and give increased engagement. This finding is consistent with existing literature that suggests AR can improve learning experiences and student outcomes [10].

The mean score for students engagement with AR in TVET programs was also high (M=4.45, SD=0.77), indicating students found AR to be an interactive and captivating technology that inspired them to learn. This finding is consistent with the existing literature: AR can raise students engagement and motivation [11]. The survey also found that the use of AR in TVET programs raises many technical challenges. However, when analyzing the responses from the 40 instructors surveyed, the mean score for technical challenges was moderate (M=3.25, SD=0.94), which indicates that instructors perceived several technical problems that might block the adoption of AR. These technical issues include the cost of AR devices and software, the necessity for technical support, compatibility problems between AR devices and existing software systems. These results also conform to the existing literature: it is suggested that if AR is to be implemented effectively in education, several technical issues (including cost, compatibility and support of the hardware) must first be addressed [12][13]. On top of this, the instructors also identified a number of pedagogical challenges associated with the use of AR in TVET programs. Similarly, data from the instructor surveys showed a moderate mean score for pedagogical challenges (M=3.40, SD=0.85). This shows the instructors found a number of pedagogical problems for themselves which might affect the successful adoption of AR in TVET.

These problems include the need for appropriate learning activities and assessment methods, the requirement of training and support for instructors, and the necessity of proper integration of AR into TVET curriculum. Again,

these results conform to existing Here literature material. It is suggested that to implement AR in a successful manner education requires paying attention to such pedagogical issues as appropriate learning activities and assessment methods, together with curriculum integration [14]. According to the results of the research, the potential benefits of AR for TVET courses outweigh the problems associated with its use. But then solving the technical and pedagogical problems engendered by AR in TVET is a prerequisite for employing this technology effectively in TVET programs. Therefore, based on the findings of this study, TVET institutions should provide support and education for instructors and students technical, operational training in handheld device operation, system compatibility of AR hardware and software with the existing educational systems, as well activities that suit TVET curriculum and test methods which are appropriate in order to fully realise the potential of using AR in TVET programs.

The second objective of the study was to investigate the faculties involving application of AR in TVET programs, from its literature review and advice given by instructors and students experienced in employing AR under TVET conditions directions were sought for dealing with these situations and offering practical solutions. This study based on quantitative and qualitative data analysis has yielded some valuable findings that touch on the constraints and opportunities for AR in TVET, how to improve its teaching effectiveness. Conclusion The quantitative data analysis from this study indicated that both technical and pedagogical issues were perceived as notable challenges by participants. While the mean scores for each were comparable, the qualitative findings further revealed that technical glitches and the need for instructor training are significant, immediate hurdles to successful AR implementation. This means that although the potential of AR for TVET programs is generally recognized, some technical problems still remain to be solved in order to make it reliable and efficient in use.

The nature and sources of these challenges were further explored during the qualitative data analysis, as well as strategies and conditions for making the effective implementation of AR a reality in TVET programs. Also the expert input gathered from instructors and students looked at several factors like availability and quality of AR content, usability and accessibility, relevance and alignment with TVET standards or TVET curricula plus support and training available for those who use AR. Not only are they consistent with the findings of previous studies into what makes technology enhanced learning successful in general, but also AR in particular [15]. This study's findings indicate that in order to address these challenges and implement AR effectively in TVET programs, several recommendations can be made although solutions for such problems are not yet fully developed. First of all, guaranteeing the availability and quality of AR content which is relevant to TVET students and meets the standards for authenticity as well as the requirements of TVET curricula and learning objectives—this is something that has to be informed by experience or monitored through quality assurance processes like TVET workshops. Such collaboration will involve subject matter experts and instructional designers working together with the developers of AR, together with feedback from TVET instructors and trainees.

Second, it is important to equip AR users with tools for easy use that can be accessed across different devices and operating systems, require no great technical proficiency and minimal support. This can be achieved by adoption of open formats and standard protocols for AR, such as WebAR or ARCore on the development and distribution of user manuals, tutorials and support services. Thirdly, AR should be used in TVET programs within the framework of sound pedagogical principles and practices, such as active and experiential learning-problem-based Reproduced Local Learning and Learning by Using Problems and practices Nevertheless, this calls for the cooperation and training of TVET instructors, instructional designers, educational technologists, as well as the opinion and contributions of TVET students, giving them space to speak.

Fourthly, it is obligatory for TVET programs implementing AR to receive the necessary institutional and organizational support in order to be successful this includes allocation of resources and infrastructure, recognizing rewarding innovative teaching practices, engaging stakeholders partners, etc. This requires the leadership vision of TVET institutions and policy-makers, as well as partnerships with industry community sectors, and so on. Another factor identified from this study, it is essential to offer adequate training and support for instructors. Participants agreed that instructors probably don't have necessary abilities or enough knowledge to reliably use AR in TVET programs, so many will need further training and help in order to rise above these challenges.

This is consistent with previous studies on technology in education, which have stressed the importance of providing instructors with appropriate training support in order to successfully integrate technology into their teaching practices [16]. It is also important to think about students 'perspectives and students when implementing AR into TVET programs. That seems to indicate that students are quite keen on AR in their learning experiences, yet they may also require some further study or guidance to fully engage and reap the benefits of these technologies. Previous research has emphasized the importance of involving students in product development and software engineering as well as affording them opportunities to provide feedback on their experiences and put forward advice [17].

To sum up, this study has found several key factors that can affect how well AR is incorporated into TVET programs. They include: reconciling technical and pedagogical limitations, offering support for both students and instructors, and ensuring the latter have received appropriate training to deliver the subject. These discoveries hold great significance for policymakers working within vocational education sectors as well as instructional staff themselves. Hence there is need continuous inquiry coupled with innovation in availing learning technology which would help improve quality of training offered in these areas However our current investigation also suffers from certain limitations. Consequently, other possible methodologies might yield different or more nuanced results regarding individual stakeholder experiences, depending on context where it is employed. A significant practical limitation of this research is its exclusion of a cost-benefit analysis. The high cost of AR hardware, software development, and maintenance represents a primary barrier to adoption for many TVET institutions, and this study did not explore the financial feasibility of implementing the technologies discussed.

CONCLUSIONS

In brief, this study was conducted to examine the current applications of AR in TVET, identify potential benefits and challenges associated with its implementation at present as well as determine some main conditions for successful integration of AR into TVET. To achieve these objectives, samples of TVET students were selected together with their instructors for data collection. Thus, both qualitative and quantitative methods were used in this research. For example, according to quantitative analysis it was found out that most students appreciate AR because it helps them understand the information better and apply them practically. Concerning the impact of AR on academic achievements, it yields moderate results. Furthermore, for successful implementation of AR into teaching and learning process within TVET institutions additional findings on technical and pedagogical challenges that may arise from its usage should be sought after. On the other hand, more robust conclusions about advantages and disadvantages which AR might bring into vocational education can be made through a qualitative inquiry. For instance, such issues like students involvement or support during AR activities need to be looked at closely. Hence, if full realization of AR's potential in TVET is to be achieved effective instructional strategies must also accompany its adoption. Consequently, based on the above results certain recommendations can be suggested for successful introduction of AR in TVET. Firstly, instructors need to be trained adequately on how to use these technologies in their teaching methods hence there is need for sufficient support system among them. Secondly, students should be provided with necessary materials and equipment which will enable them take part effectively in AR lessons. Thirdly, appropriate pedagogical practices should be developed and implemented which exploit advantages offered by AR tools within different vocational training programs rather than just depending on them as spectacles for viewing fictitious events. Lastly, further studies need to be done so as to unearth more about long term effects of augmented reality learning system in students' academic performance during instructional changeover periods. Crucially, we recommend that future studies conduct a thorough cost-benefit analysis of AR implementation in TVET. Such research would provide invaluable data for policymakers and institutional leaders, offering a practical framework for making informed investment decisions. [249] Additionally other educational institutions should also think of how they can incorporate such mechanism in their systems. In conclusion, all those involved with technical vocational education training should take note of these suggestions because they have potential of bringing significant political transformations.

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