Empowering Skill-Based Learning with Augmented Reality and Virtual Reality: A Case Study

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***Abstract*— This paper presents a case study on the implementation of Augmented Reality (AR) and Virtual Reality (VR) technologies in skill-based learning. We discuss our experience in leveraging these technologies to create an immersive, interactive and engaging learning experience for skill-based learning that is not limited to laboratory setting and is able to reach a wider audience. Our findings suggest that AR and VR learning modules significantly enhance the understanding and retention of skills among learners. We also explore the challenges faced during implementation and provide insights into how they can be effectively addressed. Furthermore, we discuss the positive feedback received from both the instructors and the learners, underscoring the effectiveness of these technologies in enhancing learning outcomes and learner engagement. The paper concludes with lessons learned from our experience and areas of future work, contributing to the ongoing discussions on the use of AR and VR technologies in education.**

Keywords—augmented reality, virtual reality, extended reality, skill-based learning

I. INTRODUCTION

Skill-based learning refers to the acquisition and development of practical skills that are essential for various fields such as construction, manufacturing, engineering, and education. These skills are typically acquired through hands-on experience and practice. In recent years, immersive interactive technologies like augmented reality and virtual reality have been gaining popularity in skill-based learning. These technologies provide unique opportunities to enhance the learning experience and empower learners with practical skills [1].

The importance of skill-based education to the development of the country cannot be emphasized enough. Skills are the foundation of economic growth and innovation, and equipping individuals with relevant skills is crucial for their success in the workforce. Some of the examples are learning how to operate heavy machinery, performing complex medical procedures, troubleshooting electrical circuitry, mastering intricate design software, or acquiring expertise in a particular sport.

AR and VR technologies have the potential to revolutionize education by providing immersive and interactive learning experiences, as discussed by [1][2]. These technologies allow users to engage with educational content in a more intuitive and experiential manner, leading to deeper understanding and retention of knowledge especially on complex concepts [3]. AR and VR technologies can be particularly beneficial in skill-based learning as they offer a realistic and immersive simulation of real-world scenarios. For example, in the field of construction and manufacturing, AR and VR can be used to visualize and simulate complex processes, allowing learners to practice their skills without having to expose to potentially hazardous environments.

This paper presents a case study that focuses on the application of AR and VR in skill-based learning to teach basic mechanical and electrical skills, including handling tools, circuit analysis, and assembly. The organization of this paper is arranged into several sections to provide a comprehensive overview of our work. The paper begins with an introduction that sets the context and objectives of our case study. This is followed by a background section that provides a brief explanation of AR and VR technologies and their current state in education. The methodology section outlines the steps we took to develop and implement AR and VR content for skill-based learning. This is followed by user testing section. The results and discussion sections present the outcomes of our implementation from the perspectives of both the instructors and the students. The paper concludes with lessons learned from our experience and areas of future work.

II. BACKGROUND

Virtual Reality has the potential to transform knowledge work by extending displays into the third dimension, enabling new operations and interactions. For example, VR can allow for selecting overlapping objects or displaying additional layers of information, which can greatly enhance the learning experience in skill-based education. In addition, virtual reality technology is being actively used in science, engineering and technology education [4] to conduct virtual experimental teaching and establish virtual laboratories, providing students with hands-on learning opportunities without the need for physical resources or equipment.

Virtual reality has been extensively studied and implemented in skill-based learning scenarios. Researchers have explored the use of virtual reality in various fields, such as medical training, engineering simulations, and flight simulations. For example, in medical training, virtual reality can provide realistic surgical simulations where learners can practice procedures without the risk associated with real patient [5]. An example is the project called the Virtual Construction Simulator 3 game, which was developed to actively engage students through simulation of the planning and management of a construction project. Initial assessments of the VCS3 game have shown beneficial for both students' motivation and basic understanding of construction concepts [6]. For an example in electrical engineering, VR can be used to simulate electrical circuits and allow learners to practice troubleshooting and problem-solving skills in a safe and controlled environment [7]. Furthermore, augmented reality has also shown great potential in skill-based learning.

Extended Reality (XR) technologies, encompassing Augmented Reality, Virtual Reality and Mixed Reality, have demonstrated significant growth in the education sector, especially during the Covid-19 pandemic. They have been employed to improve understanding of theoretical concepts and practical procedures within education [8]. An example was carried out in using AR to make learning English [9][10]and mathematical concepts interesting [11].

Immersive XR technology has been investigated in engineering education for its potential benefits and challenges. Research has delved into the factors that impact instructors' acceptance of and intention to persist in using XR for teaching [12].

Additionally, research has demonstrated the effectiveness of XR in enhancing conventional teaching methods. In higher education, the field of XR has experienced significant growth, offering distinctive hands-on experiential learning experiences and driving student motivation to acquire essential skills and knowledge [13]. One such application of XR in education is the use of immersive VR technology to create virtual laboratories and experimental teaching scenarios, for example teaching two-strokes engine [14].

These investigations suggest that XR technologies show great promise for skill-based and technical education by offering immersive, interactive experiences that have the potential to improve learning results. By providing a simulated environment, learners can engage in hands-on practice and gain practical experience without the constraints of physical resources or real-world limitations. This approach not only fosters skill development but also increases learners' confidence in applying their skills in real-world settings. Nevertheless, additional research is necessary to tackle the difficulties and maximize the utilization of these technologies in educational environments [2].

III. Methodology

The methodology used in this case study involved designing and implementing an AR and VR platform for teaching basic mechanical and electrical skills, in accordance to the Malaysian Skill Certificate (Sijil Kemahiran Malaysia – SKM). Design and development involve identifying the specific skills to be targeted, creating realistic virtual simulations of handling mechanical and electrical tools including the safety procedures, electrical circuits, and integrating interactive elements for learners to practice tools handling, circuit analysis and also troubleshooting. Therefore experts in the field were involved in these stages.

Our methodology for developing AR and VR content for skill-based learning comprised of the following stages:

A. Identifying and Understanding Learning Objectives

In this stage, the researchers identified the specific skills that needed to be taught and understood in order to design the AR and VR content effectively. We engaged with the instructors of one of the local technical and vocational institution (Institut Kemahiran MARA Johor Bahru – IKM JB) to understand the specific learning objectives and requirements of teaching basic mechanical and electrical skills. Figure 1 shows a session with an instructor sharing the module of basic electrical circuit in the real workshop environment while Figure 2 shows another session for welding module (part of mechanical skills modules).

Fig. 1. An instructor sharing hands-on activities based on a module of electrical circuit.

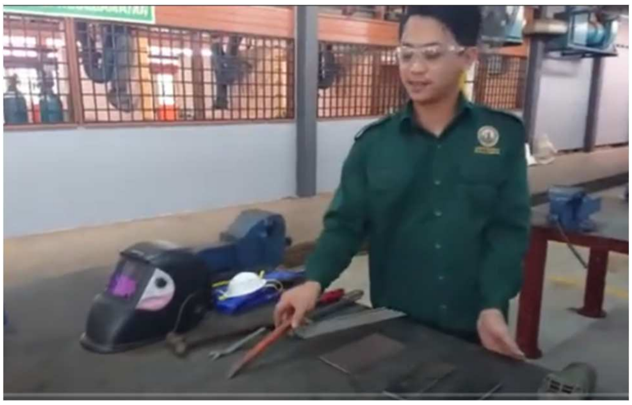

Fig. 2. An instructor sharing the tools and preparation for welding.

B. Storyboarding and Design

Once the learning objectives were clearly defined, the researchers proceeded to storyboard and design the AR and VR content. This required creating a visual representation of the virtual environment and planning the learner's journey within it. The design was checked and approved by the instructors consulted in the earlier stage. Once approved, it was at this stage that we began incorporating gamification elements, such as points and rewards, into the learning experience to enhance learner engagement and motivation.

C. Development

The development stage involved creating the virtual simulations of mechanical modules and electrical circuits emphasizing the interactive elements for learners to practice their skills. The modules were divided into AR application and mobile VR application. In order to reach a wider audience, the researchers decided to develop the AR and VR content targeted to be deployed on mobile devices such as smartphones and tablets. The researchers utilized software development tools and programming languages such as Unity3D and C# to create the immersive AR and VR experiences.

D. *Integration of Educational Content*

The next step involved integrating the educational content into the AR and VR experiences. This included creating interactive tasks and challenges that aligned with the learning objectives. We continued to use gamification strategies in this phase by designing the tasks as ‘missions’ or ‘quests’ that learners had to complete. A handbook outlining the modules involved were produced. This handbook also contains important information along with required markers, intended to be used with the AR modules and as guidelines for the VR modules.

E. *Testing and Iteration*

Once the AR and VR content was developed and integrated with the educational content, we conducted a series of testing sessions with the instructors and learners from the target institution. Four IKM instructors were involved to verify the AR and VR contents, including the Head of the Department. We managed to engage 26 IKM students for user acceptance test. During these testing sessions, we collected feedback from the learners regarding their experience with the AR and VR content. Feedback obtained from the learners during the testing sessions provided valuable insights for iteration and improvement of the AR and VR content.

F. *Application Deployment*

After iterating and improving the AR and VR content based on learners’ feedback, the final step was to deploy the technology for the general public. The application was deployed via Google Playstore and can be downloaded to users’ own device. The deployment phase involved ensuring that the AR and VR technology was accessible to a wide range of users.

Incorporating gamification at various stages of this process not only made the learning experience more engaging but also allowed us to provide immediate feedback and recognition, which are key factors in skill acquisition.

IV. User Testing

User acceptance test was done for the targeted users from IKM JB, before final preparation for public deployment. 26 students were selected by the instructors from various courses that involve basic mechanical and electrical skills. In summary, the majority are male students (minority female) from both Certificate and Diploma levels involving courses from Welding Technology, Electrical Engineering (Power), Welding Competency, Mechanical Engineering (Industry) and Industrial Maintenance, with little or no experience using AR or VR mobile applications.

These are the steps conducted during user acceptance testing for the targeted users:

A. *Equipment Setup*

We started by setting up the necessary AR and VR on the device to ensure that the application was properly calibrated and tested before use.

B. *User Orientation*

Before starting the learning sessions, we conducted an orientation program for the learners. This helped them understand how to use the AR and VR equipment and what to expect from the learning experience.

C. *Learning Sessions*

We then conducted the learning sessions. Each session was designed to focus on a specific skill. The learners interacted with the augmented reality and virtual reality contents and completed various tasks and challenges that were designed to help them acquire the target skills.

D. *Feedback*

We collected user feedback based on questionnaires for insights and improvements. (Note that for general users, we use online questionnaires to get insights on user satisfaction and acceptance during deployment.)

V. Results

The implementation of our AR and VR experiences was not without challenges. However, through careful planning and continuous iteration, we were able to overcome these challenges and create an effective and engaging learning experience. Figure 3 – 4 show some example from our developed application. Our implementation of AR and VR for skill-based learning yielded positive outcomes, as observed from the perspectives of both the instructor and the students involved in the testing.

Fig. 3. Sample AR content.

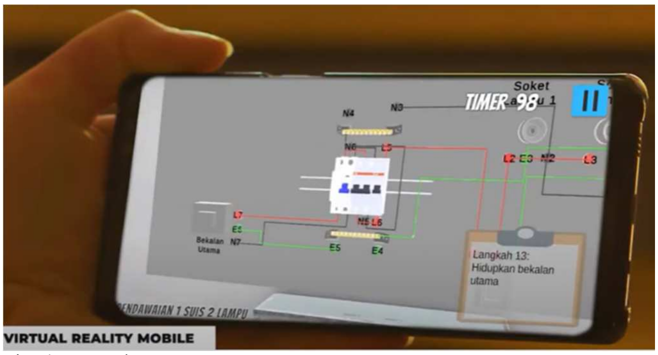

Fig. 4. Sample VR content.

A. Instructors' Perspective

The instructor reported that AR and VR technologies significantly enhanced the teaching process, especially after the pandemic. The immersive nature of these technologies allowed for a more engaging and interactive teaching experience. The instructor was able to provide real-time feedback to students, which improved the learning process. Furthermore, the gamification elements increased student participation and motivation. The instructor also noted an improvement in students' understanding and retention of the skills taught.

B. Students' Perspective

From the students' perspective, the use of AR and VR made learning more enjoyable and engaging. They reported that the immersive and interactive nature of these technologies helped them understand and remember the skills better. The real-time feedback provided during the learning sessions was particularly appreciated, as it allowed them to understand their mistakes and improve immediately. The students also enjoyed the gamification elements, which added an element of competition and fun to the learning process.

Overall, the results of our case study suggest that AR and VR technologies have the potential to significantly enhance skill-based learning. These technologies show the potential in providing an immersive and interactive learning experience, which further can improve understanding and retention of skills. Furthermore, the use of gamification elements increases student engagement and motivation.

VI. Discussion

This case study focused on empowering skill-based learning through the use of AR and VR technology. Instead of using high-end devices or relatively expensive head-mounted display, we chose to develop suitable mobile application that can produce the AR and VR experience in order to reach a wider audience. The approach to creating AR and VR content for skill-based learning was thorough, involving engagement with the instructors from a local technical and vocational institution. This collaboration provided valuable insights into the specific learning objectives and requirements for teaching basic mechanical and electrical skills, ensuring that the AR and VR contents were designed effectively to meet the educational needs of the students.

The incorporation of gamification elements, such as points and rewards, into the learning experience demonstrated a keen understanding of enhancing learner engagement and motivation. This approach aligns with contemporary educational theories that emphasize the importance of immediate feedback and recognition in skill acquisition. Furthermore, the decision to develop the AR and VR content for deployment on mobile devices, such as smartphones and tablets, reflects a forward-thinking approach to reach a wider audience of learners.

The iterative nature of the testing and iteration phase, involving feedback from both instructors and learners, highlights our commitment to refining the AR and VR content based on user experience. This user-centered approach to continuous improvement is a way to ensure that the technology is not only efficient, but also easy to use and readily accessible.

Overall, this case study shows that AR and VR technologies can effectively enhance skill-based learning by providing immersive and engaging experiences. We also discovered that these factors are crucial for successful technology-infused skill-based education:

- Interdisciplinary Collaboration - Incorporating insights and input from both educators and industry professionals ensured that the AR and VR content aligned with the specific learning objectives and requirements of the modules. The successful implementation of AR and VR in education requires collaboration between educators, technologists, and designers. Each brings a unique perspective and set of skills that are crucial for creating effective learning experiences. Support from the government and stakeholders is also essential to promote the integration of AR and VR in educational settings.
- User-Centered Design - The design of the AR and VR content prioritized the needs and preferences of the learners, and the correctness of the content. This user-centered approach involved conducting user research and gathering feedback throughout the development process to ensure that the content was intuitive, engaging, and aligned not only with learners' learning objectives, but also considers learners' learning styles and preferences.
- Continuous Iteration from Feedback - The iterative process of gathering feedback from instructors and learners during the testing phase was crucial in identifying areas for improvement and refinement. This commitment to continuous iteration based on user feedback not only enhanced the quality of the AR and VR content but also demonstrated a dedication to meeting the evolving needs of the learners.
- Accessibility and Inclusivity - Considerations were made to ensure that the AR and VR content was accessible to a broad range of users, including those with limited access to technology. Since this project was started during the onset of Covid-19 Pandemic, after careful considerations, we chose to use mobile-based AR and VR adaptation to the developed content so that the outcome could be used and beneficial to a wider audience. However, since technology continues to advance, the accessibility and affordability of AR and VR devices are likely to increase, opening up new possibilities for delivering immersive learning experiences to a broader audience. This presents opportunities for educators, technologists, and designers to collaborate on developing innovative and impactful educational content that leverages the potential of AR and VR technology.

VII. Conclusion

The utilization of AR and VR in skill-based learning presents a valuable opportunity to revolutionize the way practical skills are acquired and mastered. By addressing the initial challenges and leveraging the positive impact on learning outcomes, the incorporation of these technologies holds the potential to significantly advance skill-based education and empower learners with the necessary expertise for success in their respective fields.

In conclusion, our case study demonstrated the significant potential of Augmented Reality (AR) and Virtual Reality (VR) technologies in enhancing skill-based learning. Our implementation of AR and VR in skill-based education provided an immersive, interactive, and engaging learning experience, which improved the understanding and retention of skills among learners.

The positive feedback from both the instructor and the learners underscores the effectiveness of these technologies in enhancing learning outcomes and learner engagement. Furthermore, the deployment of our AR and VR experiences to the general public highlighted the transformative potential of these technologies in the broader educational landscape.

The lessons learned from our experience provide valuable insights for future implementations of AR and VR technologies in education. As we move forward, we plan to explore several areas of future work, including personalized learning, collaborative learning, assessment, and scalability. Through our work, we hope to contribute to the ongoing discourse on the use of AR and VR in education and to inspire further research and innovation in this exciting field.

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