The Cradle of Knowledge: African Journal of Educational and Social Science Research
AJESSR - ISSN 2304-2885-p, 2617-7315-e
Volume 12, Issue 4, 2024
P.O. Box 555 (00202) Nairobi. Kenya
editor@serek.or.ke

SOCIETY OF EDUCATIONAL RESEARCH AND EVALUATION IN KENYA

Enhancing Competency-Based Education Training in Dar Es Salaam, Tanzania, With Augmented Reality and Virtual Reality Technologies

Lazaro Inon Kumbo, Victor Simon Nkwera, Rodrick Frank Mero, Robert Michael Sikumbili & Martin Ludovick Mushi
Department of Computing and Communication Technology, National Institute of Transport
Email: lazaro.kumbo@nit.ac.tz, victor.simon@nit.ac.tz, rodrick.mero@nit.ac.tz, anibilivabo.rs@gmail.com, martin.mushi@nit.ac.tz

Abstract
Augmented Reality (AR) and Virtual Reality (VR) technologies have revolutionized education by offering immersive and interactive experiences that enhance student engagement and learning outcomes. Traditionally, education relied on face-to-face instruction and teacher-centric methods, limiting learning to physical classrooms and printed resources. This approach is efficient when small class sizes but struggles to address larger groups and diverse learning needs. AR and VR technologies have transformed this landscape, addressing these challenges by enabling personalized and scalable learning solutions. This paper adopts a qualitative research methodology grounded in a constructivist philosophical paradigm to explore the integration of AR and VR in education. It analyzes real-world examples to examine their application in Competency-Based Education and Training (CBET) environments. The constructivist approach underscores the importance of experiential and contextualized learning, aligning seamlessly with AR and VR's capacity to provide hands-on, learner-centric experiences. The practical benefits of these technologies are illustrated through case studies. For instance, Stanford University has used VR to provide realistic simulations in medical training, enhancing surgical skills and decision-making. Similarly, The Hong Kong Polytechnic University has applied AR to create interactive experiences in language learning, improving language acquisition. Additionally, the University of California, Irvine, AR, has facilitated understanding complex concepts via 3D visualizations and simulations in STEAM education. These examples highlight AR and VR's ability to support diverse learning styles, provide immediate feedback, and foster a culture of continuous learning. While challenges such as cost and the need for instructor training persist, AR and VR's potential to deliver tailored, engaging, and practical learning experiences is undeniable. By adopting these technologies, educational institutions can better prepare students for their future careers, aligning with the CBET approach of hands-on, experiential learning.
***Keywords**: Augmented Reality, Virtual Reality, Competency-Based Education and Training, Immersive Learning, Interactive Education, Experiential Learning.*

1. Introduction

In today's rapidly evolving digital age, integrating technology into education has become crucial in enhancing learning outcomes (Fauziningrum, E., Sari, M. N., Rahmani, S. F., Riztya, R., Syafruni, S., & Purba, P. M. 2023; Ningsih & Sari, 2021). As educational institutions strive to equip students with the necessary 21st-century skills, the role of technology in fostering education cannot be overstated (Wulantari, N. P., Rachman, A., Sari, M. N., Uktolseja, L. J., & Rofi'i, A., 2023).

This paper examines the impact of technology integration on practical-related modules among tertiary school students who are taught using competency-based education and training (CBET), highlighting both the potential benefits and challenges, Specifically the use of Augmented Reality (AR) and Virtual Reality (VR) technologies. On the other hand, in Tanzania, the other teaching approach is knowledge-based education and training (KBET).

AR and VR have transformed education, offering unique experiences that enhance student engagement and learning outcomes. These innovative tools go beyond the traditional classroom, creating interactive and immersive environments that cater to the increasing demand for experiential learning opportunities (Al-Ansi, A. M., Jaboob, M., Garad, A., & Al-Ansi, A., 2023). Prior to the rapid advancement of technology in recent years, education was primarily delivered through traditional methods that relied on face-to-face instruction and teacher-centric approaches, as noted by Wang, C., Chen, X., Teng, Y., Liu, Y., & Jing, Y. (2024). Learning was typically confined to physical classrooms, with teachers serving as the primary source of knowledge. Students relied on printed textbooks and other resources shared in the classroom, as pointed out by Nyabando and Evanshen (2021). The scope of information was primarily restricted to what was available through teachers, textbooks, and library resources. Assessments were primarily limited to written tests and oral exams, and student-teacher interaction was mostly confined to class or office hours, as highlighted by Xiao, M., Tian, Z., & Xu, W. (2023). Group projects and extracurricular activities were conducted in person, often after school hours.

Managing a class was relatively easy during this period, and implementing a specific training method posed a few challenges due to low enrollment numbers. In Tanzania, higher learning institutions adopted two training modes, CBET and KBET. CBET is the primary approach used in tertiary institutions. It is a student-centered approach in which a student is the center of knowledge, and an instructor guides the process. CBET requires students to acquire core components, such as knowledge, skills, understanding, and broader attributes, to complete a level. If students fail to achieve these attributes, they must repeat until they have acquired them all (Tambwe, 2017).

One of the most critical factors in achieving success in CBET is acquiring practical skills, typically developed during hands-on training sessions and practical attachments in the industry. Demonstrating these practical skills is a crucial component of CBET. However, classroom-based practical training can be challenging, and the effectiveness of such training largely depends on the number of students in the class. Smaller class sizes allow for more personalized attention and guidance, leading to better learning outcomes. Conversely, larger class sizes can make it difficult for instructors to provide individualized support and feedback to each student (Tambwe, 2017).

There is an increasing need for technological solutions to address the challenges of larger class sizes. Using technology, instructors can provide students with more personalized feedback and support, even in larger classes (Liono, R. A., Amanda, N., Pratiwi, A., & Gunawan, A. a. S., 2021). This can help ensure that every student has the opportunity to acquire the practical skills they need to succeed in their future careers. Technological tools such as AR and VR can play a crucial role in providing personalized learning experiences and immediate feedback, helping to bridge the gap created by larger class sizes. According to Zhao, X., Ren, Y. Z., & Lee, K. C. S. (2023), AR and VR technologies enable students to engage with content in meaningful, contextualized settings, fostering a more profound understanding and application of knowledge. AR enriches physical experiences with information and interactivity by integrating digital elements with the real world. Conversely, VR creates entirely virtual environments that immerse students in scenarios where they can experiment, explore, and apply their learning (Al-Ansi et al., 2023).

One of the most significant advantages of AR and VR in education is their capacity to provide tailored learning experiences. These technologies are not restrictive but accommodating, adjusting to various learning styles and preferences. They ensure that all students, irrespective of their learning style or preference, can access and benefit from the material in ways that suit them best (Kurni, M., Mohammed, M. S., & Srinivasa, K. G., 2023). For example, a visual learner can utilize AR to view a 3D model of a molecule, while an auditory learner can use VR to listen to a lecture in a virtual classroom. This customization can help surmount learning barriers and enhance student motivation and engagement (Liono et al., 2021). In the context of CBET, AR and VR are instrumental in helping students acquire knowledge, develop essential skills, and foster broader attributes such as critical thinking, creativity, and collaboration. For instance, medical students can practice complex procedures in a safe virtual environment, while engineering students can simulate and test designs. This practical approach allows students to build confidence and proficiency in their fields, demonstrating the tangible benefits of these technologies in education.

Furthermore, Zhao et al. (2023) pointed out that AR and VR provide immediate feedback, enabling students to assess their performance and make real-time adjustments. This iterative learning process, facilitated by these technologies, helps students reflect on their progress and identify areas for improvement. It cultivates an evolving culture of growth and learning, where educators, administrators, and stakeholders play a vital role in shaping and inspiring the journey. In light of this attention, this paper aims to explore the possible application of AR and VR technology integration in tertiary education, identify best practices, and offer recommendations for overcoming the barriers to effective implementation.

VR and AR are expanding in Tanzania, particularly in education, vocational training, and storytelling. VR has been piloted in vocational programs such as electrical engineering, where students practice installations in simulated environments, overcoming challenges like limited resources and infrastructure (Skills training in Virtual Reality pilot test with students in Central Tanzania, 2022, July 20). Similarly, OnaStories uses AR and VR for immersive storytelling, including virtual Serengeti tours and 360-degree advocacy videos, enhancing cultural preservation and public awareness.

Other significant strides have been made through initiatives like HakiElimu's pilot project, funded by the Finnish government, to enhance teachers' professional development using Virtual Reality (VR). This collaborative effort, involving Häme University of Applied Sciences (HAMK) and 3D Bear Oy, equips educators with modern simulation tools to transform teaching practices (Prosper, J., 2024, September 16). Another notable initiative, the EU-funded TVET@WORK project, led by HAMK in partnership with the Vocational Education and Training Authority (VETA), 3D Bear, and HakiElimu, supports teachers' training and provides VR tools for institutions such as Mwanza Teachers Training College (MVTTC). Godfrey Boniventura, Head of Programmes at HakiElimu, emphasizes that these projects aim to revolutionize Tanzania's education system by adopting cutting-edge simulation technologies and fostering more interactive and practical learning environments (Prosper, J., 2024, September 16).

These technologies offer cost-effective solutions to educational gaps, fostering creativity and accessibility. However, widespread adoption faces challenges, including high hardware costs and limited local expertise. Efforts to develop affordable technologies and localized content show promise for broader integration. By examining the role of technology in enhancing educational outcomes, this study seeks to contribute to the ongoing discourse on educational innovation and improvement.

From the literature review and Case studies, the study aimed to answer the following research question:

> *How can Augmented Reality and Virtual Reality (technologies enhance practical skills acquisition and overall learning outcomes in Competency-Based Education and Training (CBET) for tertiary students?*

Tanzania is not the only African country seeking to acquire competence for graduates; valuable insights can be gained from Kenya's Competency-Based Curriculum (CBC) framework and South Africa's implementation of technology-enhanced learning models. In Kenya, the CBC emphasizes experiential learning, practical skills development, and learner-centric approaches, aligning seamlessly with the capabilities of AR and VR technologies. In Kenya, the CBC emphasizes experimental learning, practical skills development, and learning that aligns with the job market. For example, in vocational training under CBC, AR can overlay step-by-step instructions for plumbing repairs, allowing students to practice virtually before handling actual equipment (Akala, 2021).

Similarly, VR can immerse students in simulated industrial environments, such as a welding workshop, where they can safely hone their skills without injury. In South Africa, technology-enhanced learning has been instrumental in addressing educational disparities, particularly in under-resourced areas. For instance, Virtual Laboratory (VL) is being piloted in rural schools to teach science subjects like biology, where students can virtually dissect a frog or explore human anatomy in 3D, compensating for the lack of physical laboratory facilities (Shambare & Jita, 2024). These examples illustrate how AR and VR technologies can address CBET challenges, such as large class sizes, resource constraints, and the need for tailored learning experiences, while advancing educational outcomes in Kenya and South Africa.

1.1 Practical Application Learning Through Technology

Tools like smartboards, educational software, and digital textbooks engage students more effectively than traditional methods by making learning more interactive and relatable. Interactive simulations and gamified learning platforms enhance enjoyment and comprehension. Adaptive learning systems assess students' strengths and weaknesses, providing tailored content to meet individual needs and ensuring students learn at their own pace. Online libraries, educational websites, and academic databases democratize education by making high-quality resources accessible to everyone, regardless of location. Online collaboration platforms such as Google Classroom, Microsoft Teams, and

Zoom facilitate seamless collaboration, enabling group work and peer reviews even across distances. Educational institutions utilise data analytics to monitor performance, identify trends, and improve curriculum design based on data-driven insights. E-learning platforms expand access to education beyond traditional classrooms. Massive Open Online Courses (MOOCs) and online degree programs offer quality education to learners worldwide, mainly benefiting those unable to attend physical classes due to geographical or financial constraints.

While technology offers numerous benefits, it also exacerbates the digital divide. Not all students have equal access to devices and high-speed internet, so addressing this inequality is crucial to ensure all students benefit. Excessive screen time can negatively affect students' health, including eye strain and reduced physical activity, necessitating a balance between digital learning, traditional methods, and physical activities. The use of technology in education also raises concerns about data privacy and security, making it critical to protect student information and ensure secure online environments. Effective technology integration requires adequate training and support for educators, who must be proficient in using new tools and platforms to enhance their teaching methods.

Every country has different strategies to overcome the challenges. In Tanzania, the adoption and integration of ICT in education are guided by several foundational principles, drawing from innovation diffusion models (Zlotnikova, I., Patrick, K., Bada, J., & Khamisi, K., 2016). Everett Rogers' Diffusion of Innovations Theory emphasizes how technology spreads through different adopter categories: innovators, early adopters, the majority, and laggards. ICT in Tanzanian education means understanding how schools and teachers adopt digital tools, from initial experimentation to widespread use (Mbatha, 2024). Tanzania's ICT adoption follows Rogers' diffusion of innovations theory, which is progressing in stages. Early adopters will lead the way, while laggards may resist, requiring firm policy and infrastructure support. Overcoming barriers like limited access to technology and internet connectivity will be crucial. The success of this integration will depend on addressing these disparities and focusing on ongoing teacher training and digital literacy to foster inclusivity in education.

Essential blueprints for ICT adoption in Tanzania include government policy frameworks such as the National ICT Policy for Education, which provides a strategic vision for integrating technology into classrooms (Oreku, 2022). This policy outlines initiatives for providing access to digital tools and the internet, which is crucial for bridging the digital divide. Additionally, teacher training is a priority, ensuring educators possess the skills necessary to use ICT effectively in teaching and learning. Infrastructure is a significant challenge, as widespread access to reliable internet and modern devices remains limited, particularly in rural areas (Granić, A., 2022). The government and international partners have focused on improving ICT infrastructure and digital literacy, recognizing that both are essential for successful integration (Zlotnikova, I., Patrick, K., Bada, J., & Khamisi, K., 2016). This aligns with the Technology Acceptance Model (TAM), which suggests that technology's perceived ease of use and usefulness are critical for widespread adoption. Moreover, adaptive learning systems and e-learning platforms are becoming central in Tanzania’s education system, offering flexible and inclusive learning opportunities. As the country expands access to digital tools, the digital divide must be addressed to ensure equitable access to educational resources.

1.2 AR and VR Technologies in Education

AR is a technology that enhances real-world environments by overlaying digital elements, such as text, images, or 3D models, onto physical surroundings. This combination of virtual and physical worlds enables users to interact with their environment innovatively, providing additional information and context to enhance experiences. AR can be accessed using smartphones, tablets, or AR headsets, giving users flexible options for engaging with the technology (Al-Ansi et al., 2023). Zhao et al. (2023) observed that VR creates a fully immersive, computer-generated environment that students can explore and interact with as if it were real. To experience VR, users wear a headset that transports them into a virtual world, allowing them to engage with simulated scenarios and activities. This immersion provides students with unique opportunities for experiential learning and practice. AR and VR have transformative educational potential by offering interactive and engaging learning experiences beyond traditional classroom methods. AR can enhance physical learning spaces with digital content, while VR allows students to safely practice and experiment in virtual environments. These technologies provide valuable opportunities for students to acquire knowledge, develop skills, and gain a deeper understanding through practical, hands-on learning experiences (Al-Ansi et al., 2023).

In Africa, VR in education has yielded significant positive outcomes across education and social issues. A VR model addressing basic hygiene in Uganda, piloted at the Nakaseke Telecentre, enhanced community awareness of sanitation and disease prevention (e.g., malaria and cholera). The Naledi3d Factory in Pretoria trained Ugandan VR developers (Lockwood, D., 2004 This resulted in educational tools like "DC Motors" and "French for Ugandans," improving science and language learning in schools such as King's College Budu and St. Henry's Kitovu. In Kampala, a VR Committee was formed to unify initiatives across universities and educational bodies. Ethiopia leveraged VR to strengthen HIV/AIDS education by addressing its social and cultural dimensions, while in Johannesburg, VR programs helped youth acquire job skills and entrepreneurship knowledge, fostering employability and self-reliance (Lockwood, D., 2004). These examples demonstrate VR's capacity to address diverse regional challenges effectively.

In Nigeria, The African University of Science and Technology (AUST), Abuja, has effectively incorporated VR simulations into its engineering curriculum, significantly enhancing practical learning opportunities and student engagement. Similarly, the Lagos State Technical and Vocational Education Board (LASTVEB) employs AR technology in vocational training, allowing students to interact with simulated real-world environments, such as automotive workshops and construction sites. This approach has increased student enrollment and higher program completion rates (Writer, G. (2024, April 9). These initiatives underline VR's potential to address diverse educational and societal needs across Africa, albeit requiring sustainable support and infrastructure development.

1.3 Applications of AR and VR On Practical-Oriented Modules

AR and Virtual VR transform education by providing students with more immersive and interactive learning experiences. One of the main benefits of AR and VR is their ability to offer hands-on training in practical skills, such as medical procedures or engineering designs. This allows students to achieve mastery through practice, a more effective and engaging way of learning (Al-Ansi et al., 2023). In addition to skill development, Yazdi (2024) observed that AR and VR can create simulations and case studies that recreate complex scenarios for students to analyze and solve. This fosters critical thinking and problem-solving skills, crucial in today's rapidly changing world. Another benefit of AR and VR is their ability to immerse students in different cultures and historical events. Through AR and VR, students can experience different cultures and historical events, promoting a more comprehensive understanding and empathy. This is particularly important in today's globalized world, where diversity and inclusion are essential (Zhao et al., 2023).

Moreover, AR and VR can also simulate work environments and tasks, helping students gain experience and prepare for their future careers. This type of training is beneficial in fields such as healthcare, engineering, and aviation, where practical experience is essential (Xiong, J., Hsiang, E., He, Z., Zhan, T., & Wu, S. 2021). In addition to simulated work environments and tasks, AR and VR can provide students with immediate feedback, enabling them to reflect on their performance and improve. This feedback and assessment are crucial in helping students identify their strengths and weaknesses and develop a growth mindset (Cao & Yu, 2023).

1.4 Challenges and Considerations of AR and VR in Education

Augmented Reality (AR) and Virtual Reality (VR) technologies have been gaining popularity in the education sector due to their ability to enhance the learning experience and engage learners in a more immersive and interactive way. However, as with any technology, several challenges must be addressed before integrating AR and VR into educational settings. One of the most significant challenges is the cost of equipment. AR and VR technologies require specialized hardware, such as headsets and sensors, which can be expensive and difficult to procure. Additionally, these technologies must be updated regularly to keep up with the latest advancements, which can further increase the cost (Xiong et al., 2021). Another challenge is the need for instructor training. Educators must be trained to use AR and VR technologies effectively in their teaching practices. This can be time-consuming and require additional resources (Bećirović, 2023). Finally, there is the potential for technology to distract from learning. While AR and VR can be engaging, they can also be overwhelming and detract from the learning experience if not used appropriately. Careful planning and thoughtful implementation of AR and VR in educational settings can help mitigate this risk (Alkhabra, Y. A., Ibrahem, U. M., & Alkhabra, S. A., 2023).

1.5 Theoretical review

The cognitive load theory is a well-established concept in educational psychology that explains how the brain processes and retains information (Sweller, 2011). It holds that when an individual learns, they need to manage the mental effort they apply to the task, called cognitive load. AR and VR technologies can transform education by optimizing cognitive load, that is, by making learning more effective and efficient for students. AR and VR technologies offer interactive and immersive environments that can manage cognitive load in several ways. Firstly, these technologies create engaging and contextualized experiences that align with students' existing knowledge, helping them integrate new information more efficiently. For example, AR can superimpose digital overlays on physical surroundings, enabling students to relate new concepts to familiar contexts and reducing extraneous cognitive load. Secondly, AR and VR technologies can segment and scaffold information, breaking down complex topics into manageable parts.

This approach helps manage intrinsic cognitive load, enabling students to engage with the content progressively and avoid cognitive overload. Students can understand and retain more information by presenting information in a structured and organized way. Lastly, AR and VR technologies offer personalized and adaptive learning experiences that can tailor learning pathways to individual students' needs. By analyzing students' progress, these technologies can adjust the challenge, pacing, and feedback level, aligning with adaptive cognitive load management. This approach helps students focus on specific skills and concepts, fostering more profound understanding and retention. Cognitive Load Theory provides a solid theoretical framework for understanding how AR and VR can improve student engagement, knowledge acquisition, and learning outcomes while effectively managing cognitive demands.

AR and VR technologies create highly engaging and contextualized learning experiences that align with learners' prior knowledge, facilitating the integration of new information. For example, Al-Ansi et al. (2023) research demonstrated that AR applications improve conceptual understanding by providing contextual overlays. By superimposing digital information on physical surroundings, AR reduces extraneous cognitive load, allowing students to focus on the core learning material. In addition, AR and VR support intrinsic cognitive load management by segmenting complex topics into manageable parts and scaffolding information. Studies by Petersen, G. B., Petkakis, G., & Makransky, G. (2022) found that VR simulations in STEM education enhance students' ability to grasp intricate concepts by breaking them down into sequential steps. This structured approach prevents cognitive overload and ensures progressive engagement with the content.

Furthermore, empirical findings indicate that AR and VR enable personalized learning experiences. A study by Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023), highlighted how AR applications adapt instructional material to meet individual students' needs, facilitating adaptive cognitive load management. AR and VR platforms adjust pacing and challenge levels by analyzing learners' progress, promoting more profound understanding and sustained knowledge retention.

Cognitive Load Theory emphasizes reducing unnecessary mental effort and focusing on content that fosters meaningful learning. Supported by evidence from educational psychology, AR and VR technologies provide learners with the tools to manage cognitive demands effectively. These tools enhance student engagement, improve knowledge acquisition, and lead to better learning outcomes, making AR and VR valuable assets in Competency-Based Education and Training.

2.6 Conceptual Framework

This section provides a conceptual framework for immersive AR and VR learning experiences, outlining the key elements and their relationships within the learning process.

Immersive Learning Experiences

AR and VR technologies immerse students in interactive, realistic environments that bring abstract concepts to life. For example, history students can "walk through" the streets of ancient Athens using VR, experiencing its architecture, culture, and daily life firsthand. This dynamic approach helps learners connect emotionally and intellectually to the subject matter. Similarly, AR apps like Google Lens can overlay digital annotations on physical objects, such as identifying car engine parts in automotive training. This blend of theoretical knowledge and hands-on application enhances understanding and bridges the gap between learning and real-world skills.

Visualization and Simulations

- 3D Visualization: Using VR, educators can present complex topics such as anatomy, historical events, and scientific phenomena in three-dimensional formats that help students grasp intricate details and relationships.
- Simulations: These allow students to practice skills in hands-on scenarios without the risks associated with real-world applications, particularly in fields such as medicine, engineering, and aviation.

Virtual Field Trips

- Access to Distant Places: Students can virtually visit and explore faraway places or historical sites, gaining perspectives and insights they may not otherwise have access to.
- Enhanced Engagement: Such trips captivate students and make learning more dynamic and memorable.

Interactive Content

- Interactive Content: AR and VR can transform static content into engaging and interactive learning materials, offering a more stimulating educational experience.
- Gamification: AR and VR increase motivation and engagement in learning activities by introducing scoring systems and challenges.

Accessibility and Inclusion

- Customized Learning: AR and VR technologies offer personalised educational content tailored to different learning styles and paces.
- Inclusive Education: These tools can create accessible learning environments for students with various disabilities, ensuring equitable opportunities for all.

Practical Applications

- Lab Experiences: Virtual labs allow students to conduct safe scientific experiments and practice practical skills in a controlled setting.
- Professional Training: Real-world work environment simulations prepare students for professional scenarios, enhancing their readiness for the job market.

Collaboration and Communication

- Virtual Classrooms: These connect students and teachers globally, breaking down geographical barriers in education.
- Group Projects: Collaborative platforms facilitate group work across distances, enabling students to engage in teamwork and shared learning experiences regardless of location.

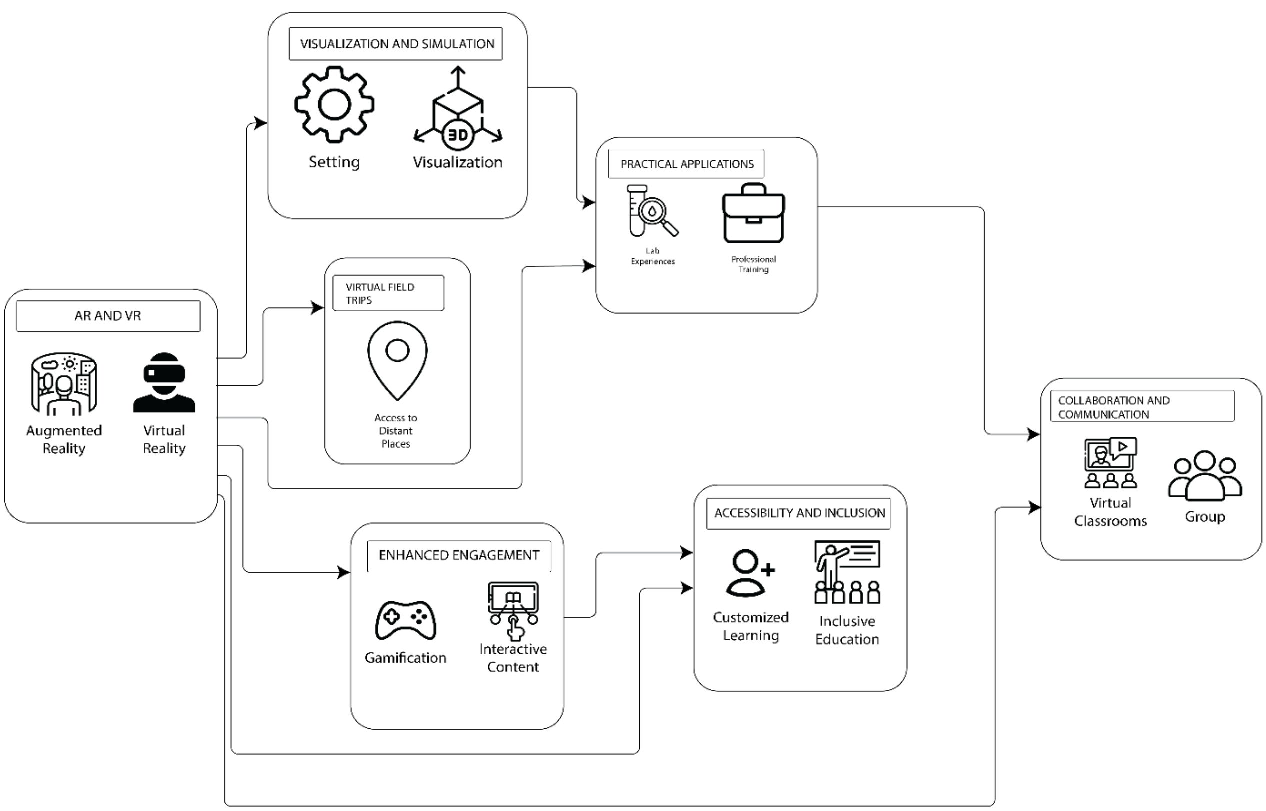

Fig. 1: A conceptual Diagram for immersive AR and VR learning experiences

In the conceptual model (Fig. 1) of immersive AR and VR learning experiences, the flow begins with the core technologies (AR and VR) creating engaging, interactive learning environments. This leads to key learning outcomes, such as enhanced visualization through 3D models and simulations, which help students understand complex topics. Virtual field trips extend access to remote locations, enriching learning. Interactive content and gamification increase engagement and motivation. These tools cater to different learning styles, promote inclusivity, and offer practical applications like virtual labs and professional training. The model also highlights the role of collaboration and communication through virtual classrooms and group projects.

2.0 Methodology

The study involved case studies on a particular educational environment or program incorporating AR or VR technologies. These case studies provide a thorough analysis of the impact of these technologies and offer a comprehensive understanding of how these technologies are utilized in real-world educational settings. The study employed a literature review to analyze and synthesize existing scholarly works, empirical studies, and theoretical articles on integrating technology in senior high school English language education (Zed, 2008). The goal is to provide a comprehensive understanding of the current landscape, identify patterns, draw insights, and highlight gaps in the existing research. The study begins with a systematic search of academic databases such as Google Scholar, JSTOR, and ERIC, using keywords like "technology integration," "Augmented Reality," "Virtual Reality," "learning tools," " Knowledge-Based Education and Training, " and " Competency-Based Education and Training " Selection criteria include peer-reviewed journal articles, books, conference papers, and reputable reports from the last decade, covering both qualitative and quantitative studies.

The next step involves critically analyzing and categorizing the selected literature and evaluating research designs, methodologies, sample populations, and critical findings. The focus is on understanding the impact of technological tools on English language proficiency, specific language learning aspects they influence (vocabulary, grammar, pronunciation, comprehension), and contextual factors affecting their effectiveness.

The review identifies recurring themes and trends, compares interactive language learning apps to traditional methods, and examines the role of multimedia resources and virtual exchanges. It highlights best practices and successful case studies. Challenges such as the digital divide and the need for teacher training are also addressed, with proposed solutions and strategies. The study maintains an objective perspective, presenting contradictory findings to offer a nuanced understanding. The ultimate goal is to compile a comprehensive body of knowledge to inform educators, policymakers, and researchers on effectively integrating technology into tertiary students.

3.0 Results

The following sections explore AR and VR in greater detail, shedding light on best practices and case studies that exemplify their successful implementation. Educators can be optimally utilized in education by understanding and adopting these opportunities. The section also discusses some exemplary case studies and best practices demonstrating how technology can be leveraged to create a truly immersive, engaging, and fruitful learning environment for students to accommodate the CBET approach. Using Empirical evidence, the study was guided by the following research question:

> *How can Augmented Reality and Virtual Reality technologies enhance practical skills acquisition and overall learning outcomes in Competency-Based Education and Training (CBET) for tertiary students?*

3.1 Practical Application of AR and VR in Different Fields

AR and VR have significant potential to enhance practical-related subjects by creating immersive, interactive, and engaging learning environments. These technologies can transform traditional teaching methods, offering hands-on experiences that are often challenging to replicate in a standard classroom setting.

3.1.1 Medical and Health Sciences

AR applications in medical education offer transformative benefits, particularly in anatomy lessons and surgical simulations. AR enables the overlay of 3D human anatomy models onto real-world objects, facilitating detailed visualisation and interaction with anatomical structures like organs and muscles. This capability enhances spatial understanding and anatomical knowledge crucial for surgical fields, radiology, and physical therapy (Bölek, K. A., De Jong, G., & Henssen, D., 2021). Additionally, AR guides medical students through surgical procedures by overlaying step-by-step instructions and real-time data onto patients or mannequins. This immersive approach aids in precise execution, reduces procedural errors, and provides a safe environment for students to practice before treating actual patients. In contrast, VR complements these benefits by simulating diverse patient scenarios and emergencies, fostering clinical skills such as diagnosis, patient interaction, and crisis management. AR and VR technologies enhance learning experiences with interactive elements and offer risk-free environments for skills development, making them indispensable tools in advancing medical education globally across various specialties and educational levels (Mühling, T., Späth, I., Backhaus, J., Milke, N., Oberdörfer, S., Meining, A., Latoschik, M. E., & König, S., 2023).

3.1.2 Engineering and Technical Education

In mechanical maintenance, AR revolutionizes training by directly overlaying technical diagrams and instructions onto machinery, guiding students through complex maintenance and repair tasks with unprecedented clarity. For instance, AR glasses can project real-time information onto a car engine, highlighting specific parts to inspect, tighten, or replace, facilitating intuitive learning (Yazdi, 2024). This technology significantly reduces the risk of errors during tasks by ensuring students follow precise procedures, as they can compare the virtual overlay with the actual equipment in real time. This enhances safety and accelerates learning by providing a hands-on, immersive experience crucial for mastering intricate mechanical procedures effectively. On the other hand, in Engineering and Technical Education, VR offers transformative benefits by creating immersive, interactive learning environments that enhance understanding and practical skills. VR simulations allow students to practice mechanical maintenance, civil and structural engineering, electrical and electronic engineering, aerospace engineering, and robotics in virtual settings, replicating real-world scenarios (Oje et al., 2023). These simulations enable students to perform complex tasks, diagnose faults, and understand intricate systems without the risks associated with physical equipment. This hands-on, safe, and controlled environment fosters confidence, competence, and innovation, making abstract concepts tangible and preparing students for real-world challenges.

3.1.3 Vocational Training

AR and VR offer transformative benefits in vocational training by providing immersive, interactive learning experiences tailored to specific tasks and equipment. AR can project detailed visual guides and instructions onto real-world scenarios, such as demonstrating the correct welding technique or outlining precise plumbing or electrical work steps. This real-time instruction allows students to receive immediate feedback, highlighting areas for improvement and offering tips for refining their techniques directly within their workspace, making learning more interactive and engaging (Chiang et al., 2022). Moreover, AR enhances operational efficiency in equipment training by directly overlaying real-time guides and safety protocols onto the equipment, promoting safe usage, and reducing downtime by enabling prompt troubleshooting (Ravichandran & Mahapatra, 2023).

VR complements AR by creating fully immersive environments where students can practice tasks in a virtual setting, replicating real-world scenarios. VR simulations allow students to navigate and interact with virtual equipment and practice tasks such as disassembling components, diagnosing faults, and performing repairs without the risks associated with actual equipment. This safe, controlled environment helps students build confidence and competence in their vocational skills, from mechanical maintenance to electrical systems. VR enhances understanding, promotes innovation, and prepares students for real-world vocational challenges by providing a realistic, risk-free platform for experimentation and learning (Zhao et al., 2023).

3.1.4 Science and Environmental Studies

AR and VR enhance fieldwork and laboratory experiments in educational settings by leveraging real-time data and interactive capabilities (Pang & Cai, 2023). During field trips, AR enriches learning by providing instant information about the environment, such as identifying plant species or geological formations through AR-enabled devices. This feature allows students to engage deeply with their surroundings and comprehensively understand natural processes. Additionally, AR enables interactive exploration by overlaying historical data or environmental changes onto landscapes, facilitating a nuanced understanding of ecological dynamics and historical contexts (Koumpouros, 2024). In laboratory settings, AR augments experiments by overlaying data, results, and interactive elements onto physical setups. Students can visualize complex molecular structures in 3D, manipulate variables, and observe real-time changes, enhancing their comprehension of scientific principles in chemistry or physics. This visualization capability is particularly beneficial for grasping abstract concepts and phenomena that are difficult to perceive through traditional means. By seamlessly merging digital information with physical experiments, AR transforms learning experiences in fieldwork and laboratory environments, fostering deeper engagement and improving overall educational outcomes. VR complements AR by creating immersive, simulated environments for hands-on practice and experimentation, further enhancing educational experiences (Vats & Joshi, 2023).

3.1.5 Arts and Design

In Arts and Design education, AR and VR significantly enhance creative and practical skill development. AR overlays digital content onto physical artworks, enabling interactive art experiences (Serna-Mendiburu & Guerra-Tamez, 2024). For instance, scanning a painting with an AR app can reveal hidden details, provide artist commentary, or present historical context, enriching the viewer's understanding and engagement. This fusion of physical and digital elements encourages students to experiment with innovative techniques, leading to mixed-media projects that blend traditional and digital art forms, expanding the boundaries of creative expression. In design visualization, AR and VR allow students to see their projects in real-world contexts through 3D models and immersive environments. Fashion design students can visualize garments on virtual models, while interior design students can place virtual furniture in physical spaces to evaluate aesthetics and functionality (Korkut & Surer, 2023). This capability provides real-time feedback, enabling immediate adjustments and iterative refinement of designs. These technologies improve accuracy, quality, and efficiency in student work, driving innovation and excellence in the field by making abstract concepts tangible and interactive.

3.2 Case Studies

The case studies also proved the research question: *"How can Augmented Reality (AR) and Virtual Reality (VR) technologies enhance practical skills acquisition and overall learning outcomes in Competency-Based Education and Training (CBET) for tertiary students?"*

The critical analysis of the selected case studies provides an in-depth examination of the implementation and impact of immersive AR and VR technologies in educational settings. Each case study highlights different approaches and outcomes, offering insights into how these technologies are integrated into various learning environments. The analysis explores the effectiveness of these technologies in enhancing engagement, improving comprehension, and addressing accessibility challenges. By comparing successes and challenges across cases, the analysis offers a comprehensive view of the potential and limitations of AR and VR in modern education.

Case Study 1: Medical Training with Virtual Reality

Institution: Stanford University School of Medicine. This is found in the study by Pedram et al. (2024)

Background: Stanford University School of Medicine incorporated VR technology into its medical training program to provide students with hands-on, realistic simulations of medical scenarios. This approach aims to enhance the practical skills of medical students.

Implementation: In this program, students use VR headsets to immerse themselves in a virtual operating room environment where they practice medical procedures. They can interact with simulated patients and collaborate with peers and instructors in real-time.

Results: VR for medical training has yielded positive outcomes, such as improving students' surgical skills, decision-making, and teamwork abilities. The safe, controlled virtual environment has also boosted students' confidence in performing complex procedures and managing emergencies.

Case Study 2: Augmented Reality in Language Learning

Institution: The Hong Kong Polytechnic University; this is found in the study by Zhang, D., Wang, M., & Wu, J. G. (2020

Background: The university's Language Centre integrated AR technology into its language learning programs for students studying English and Chinese as second languages. This initiative aims to create more engaging and compelling learning experiences.

Implementation: Students use AR-enabled applications to interact with digital content, such as vocabulary lists and pronunciation guides, overlaid with physical objects and environments. This approach helps students learn language concepts in context and in an interactive manner.

Results: The AR language learning tools have proven to increase student engagement and motivation. Students reported improved language acquisition and retention rates due to AR technology's contextualized and immersive learning experiences.

Case Study 3: Science, Technology, Engineering, Arts, and Mathematics (STEAM) Education with Augmented Reality

Institution: Oxford; this is found in the study by Jesionkowska, J., Wild, F., & Deval, Y. (2020) and Zhang et al. (2020)

Background: The university integrated AR technology into its STEAM education programs to enhance students' comprehension of complex scientific concepts. This approach aims to provide students with a deeper understanding of abstract ideas.

Implementation: In physics and chemistry labs, students use AR applications to visualize and interact with 3D models of molecules, simulations of physical processes, and data visualization tools. This allows for a more hands-on, immersive learning experience.

Results: Students demonstrated a notable improvement in understanding abstract concepts, increased engagement in lab activities, and higher achievement on assessments compared to traditional teaching methods. This indicates the success of AR in STEAM education in promoting deeper learning and comprehension.

These case studies demonstrate how AR and VR technologies can successfully integrate into various educational settings to enhance student learning experiences, engagement, and outcomes.

4. Discussion

Integrating AR and VR in education has shown significant potential in enhancing student learning outcomes, particularly in competency-based education and training (CBET). The benefits observed in various case studies and literature underscore the transformative impact these technologies can have across different fields of study.

AR and VR have proven particularly effective in medical and health sciences, engineering, vocational training, and STEAM education. For instance, Stanford University School of Medicine's use of VR for medical training has improved students' surgical skills, decision-making, and teamwork (Bölek et al., 2021). The immersive virtual environments provide a safe and controlled space for students to practice complex procedures and manage emergencies, boosting their confidence and competence. This aligns with the CBET approach, which focuses on mastering specific competencies through repeated practice and feedback.

Similarly, in engineering and technical education, AR's overlay of technical diagrams and real-time instructions onto machinery has facilitated a more precise understanding and execution of maintenance tasks, reducing errors and enhancing safety (Yazdi, 2024). VR simulations in engineering education allow students to engage in hands-on practice without the risks associated with real-world equipment, preparing them for professional challenges (Oje et al., 2023). These technologies support CBET by providing realistic, practical experiences that help students develop and demonstrate their skills.

AR and VR technologies significantly enhance interactive and contextualized learning experiences, which are crucial CBET elements. At the Hong Kong Polytechnic University, AR-enabled language learning tools have increased student engagement and motivation, improving language acquisition and retention (Serna-Mendiburu & Guerra-Tamez, 2024). The ability to interact with digital content in real-world contexts helps students understand and apply language concepts more effectively.

In STEAM education, Oxford's use of AR applications in physics and chemistry labs has led to a deeper understanding of abstract concepts. Students have benefited from visualizing and interacting with 3D models and simulations, which make complex scientific phenomena more tangible and comprehensible (Pang & Cai, 2023). This method aligns with CBET's goal of fostering a deep understanding of subject matter through contextualized and experiential learning.

One of the significant challenges in CBET, particularly in settings with larger class sizes, is providing personalized attention and feedback to students. AR and VR technologies address this challenge by offering tailored learning experiences and immediate feedback. Zhao et al. (2023) highlight that these technologies enable students to engage with content in meaningful, contextualized settings, fostering a deeper understanding and application of knowledge. The personalized learning pathways and adaptive feedback mechanisms help manage cognitive load and enhance learning outcomes. This individualized approach is at the core of CBET, which prioritizes the mastery of competencies over standardized progression.

Despite the evident benefits, integrating AR and VR into educational settings comes with challenges, such as high costs of equipment, the need for instructor training, and potential distractions from learning (Xiong et al., 2021; Bećirović, 2023). Addressing these barriers requires thoughtful planning and investment in infrastructure and training. Ensuring equitable access to these technologies is crucial to avoid exacerbating the digital divide. Institutions must also balance digital learning with traditional methods and physical activities to mitigate the adverse effects of excessive screen time. These steps are necessary to fully realize the potential of AR and VR in supporting CBET objectives.

5.0 Conclusion

Integrating AR and VR technologies in tertiary education, particularly within CBET frameworks, offers immense potential to enhance practical skills acquisition, promote interactive learning, and address the challenges of larger class sizes. The successful case studies and literature review highlight the transformative impact of these technologies across various fields. However, overcoming the associated barriers and implementing best practices is crucial for realizing their full potential and ensuring equitable and effective educational outcomes for all students. By doing so, educational institutions can create a more engaging, personalized, and competency-driven learning environment that prepares students for the demands of the modern workforce.

6.0 Recommendations

To maximize the benefits of AR and VR in education, particularly within CBET frameworks, the following best practices and strategies are recommended:

- Comprehensive Training for Educators: Adequate training and support for educators are essential to effectively integrating AR and VR into their teaching methods. Educators should be well-versed in using these technologies to create immersive and competency-based learning experiences.
- Scalable and Sustainable Infrastructure: Investing in scalable and sustainable technology infrastructure can help manage costs and ensure long-term benefits. This infrastructure should support the widespread use of AR and VR in various educational contexts.
- Equitable Access: Addressing the digital divide by ensuring all students have access to the necessary devices and high-speed internet is crucial. This ensures that all learners can benefit from AR and VR technologies, supporting the inclusivity aspect of CBET.
- Balanced Integration: Combining digital learning with traditional methods and physical activities to maintain a holistic educational approach. This balance helps prevent the drawbacks of excessive screen time while leveraging the strengths of both digital and traditional learning methods.
- Data Privacy and security: Implementing robust data privacy and security measures to protect student information and create a secure online learning environment. This is essential for maintaining trust and ensuring the safe use of digital technologies in education.

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