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Introduction

To establish clear definitions, virtual reality (VR) is the use of computer modelling to simulate an artificial three-dimensional (3D) world (Lowood, 2025), while augmented reality (AR) is an enhanced version of the real world, achieved with computer-generated digital information (Hayes, 2024). Extended reality (XR) is the umbrella term for both VR and AR (VRAR). It was just a decade ago when these terms were not familiar by many. This was no longer the case with the advancement of VRAR, as shown with the releases of Oculus Rift (VR) or Pokémon Go (AR) where it brought the ground-breaking technology to the public's attention. VRAR main purpose is to provide immersive and interactive experiences to satisfy contemporary needs of industries, which include gaming, education, healthcare etc.

This documentation presents a comprehensive overview of VRAR application in the education and training sectors.

VRAR Software and Hardware

There are a plethora of hardware and software used to develop and utilise VR and AR applications that can be used for the education and training sectors. Technology implemented aims to create a realistic virtual environment, simulate real-world physics and track user movement accurately.

Hardware

One of the main pieces of hardware required to develop VRAR applications include smart devices (smart phones, etc.), VRAR headsets (alongside controllers), and AR glasses (or smart glasses) (Van Arnhem et al., 2018). They are crucial to run VRAR applications and display virtual assets. Regarding VRAR headsets, they can be categorised into standalone and PC-connected (for VR, commonly known as PCVR). Standalone headsets and glasses are able to run applications independently because they have their own processors and GPU; tethered or PC-connected headsets (PCVR) need a powerful computer to render 3D graphics, while the headset only serves as a display monitor (Grolleman, 2024). According to Ralston (2024), developing VRAR applications with standalone headsets is regarded as a popular choice among developers. This is due to the promising growth prospects of the standalone headset development ecosystem, all thanks to massive investments from tech giants like Meta and Apple. Nevertheless, there are other factors to consider when choosing between standalone headsets or PCVR (Ralston, 2024). For example, to maximise realism of training, development using PCVR is recommended for the best graphics. Additionally, for VRAR applications in education, standalone headsets should be adopted because students are likely to own affordable standalone headsets. Ultimately, the choice of primary hardware for VRAR development depends on the project requirements. Alongside it would be the use of computers with powerful processing speed and graphics performance (Ralston, 2024). The minimum specifications for processors are Intel Core i5 or AMD Ryzen 5. For graphics processing unit (GPU), Nvidia GTX 1060 (6GB) or AMD Radeon RX 580 or later generations are the minimum requirements (Dale, 2023).

Thanks to recent advancements, most middle and high-end VRAR headsets and smart glasses support high-resolution video quality like Viture Pro XR Glasses' 1920 x 1080 pixels per eye and Meta Quest 3's 2064 x 2208 pixels per eye (*Introduction to VITURE XR* Glasses, 2024; *Meta Quest 3*, 2024). Devices with crisp video quality are preferred for AR development, providing high-fidelity views of both real-world surroundings and AR objects. Similarly, high-resolution display is significant in VR for heightened realism. This is especially beneficial for the training sector because accurate real-world simulations allow workers to make use of the skills garnered in the virtual environment. Plus, the resolution of virtual assets can be flexibly scaled down for low-end hardware if digital content is readily high quality during development.

Other than that, sensors are essential in VRAR projects to translate user's motion perfectly into the virtual world. One of the key sensors is gyroscope sensor. It detects spontaneous movements, that being the device's rotation and change in orientation (Van Arnhem et al., 2018). Moreover, accelerometers are used to determine and calculate the velocity of user's movement. Aside from aforementioned sensors, magnetometer, altimeter, barometer, camera, GPS tracker, microphone, etc. are also used depending on the AR project's necessity (Van Arnhem et al., 2018). All sensors work together to gather critical environmental data, maximising user immersion in VRAR projects used for education and training.

Software

This subsection introduces the software and tools needed for XR projects.

The main software required for development is a software development kit (SDK) to create the virtual environment for education and training. Furthermore, system software or operating system (OS) is needed to run VRAR applications and already embedded within the primary hardware. Since programming is involved, tools such as compilers, interpreters and integrated development environment (IDE) must be present. With that being said, the choice of SDK depends on the development method chosen, which will be discussed in the following paragraphs.

Native development can be opted for maximum performance with the drawback of limited compatibility (Ralston, 2024). This method requires developers to target a specific operating system like Meta Horizon OS (derivative of Android), VisionOS (Apple), etc. for development. Native development is suitable for non-gaming industries like education and training because it is suits the development of XR applications that are productivity-oriented (Ralston, 2024). Moreover, SDK provided by each operating system is optimised for different programming languages. For instance, Meta Horizon OS encourages the use of Java for the access to critical libraries, while VisionOS is optimised for Objective-C or Swift (Ralston, 2024; Van Arnhem et al., 2018).

In contrast, VRAR applications developed with game engine software are compatible with various platforms (multisystem). Example of game engines with their distinct SDKs include Unity, Godot, and Unreal Engine (Ralston, 2024). Aside from being multisystem, another benefit of developing with game engines is the option to use visual scripting (drag-and-drop functionality) for programming (Van Arnhem, 2018). This makes VRAR development easier to learn, especially for beginner developers who might be unfamiliar with languages like C# or C++.

Taking a step further in multisystem development for VRAR is WebXR development. Through WebXR, web browsers allow XR contents to be viewed and interacted with regardless of the platform or device used (Miller, 2022). Web game engines like Wonderland Engine and frameworks like Babylon.js are used to conduct WebXR development. This development method has advantages of overcoming hardware limitations, and create XR content easily and quickly. Therefore, this lowers the barrier of entry for aspiring developers because VRAR dedicated hardware is not needed for development. Nevertheless, the capabilities of WebXR are more limited than native development and use of game engines, thus WebXR applications are less robust (Ralston, 2024).

In summary, VRAR developers must understand the capabilities and limitations of hardware and software used in VRAR development, allowing them to choose wisely to fulfil project scope.

VRAR Industrial Application and Content

Firstly, VR technology is implemented in the development of VR online classrooms which allows for a more immersive and interactive online learning environment for students. For example, the Second Life application facilitates virtual online classes that enable teachers to conduct lessons with students seamlessly even from the comfort of their homes (Linden Research, Inc., n.d.). VR online classrooms solve the challenges faced by traditional online classes as it offers virtual face-to-face interactions that closely mimic real-life experiences (Barnard, 2024). This allows for students to have a better understanding of a topic as it allows direct communication with others and enable them to interpret teachers' body language. Furthermore, these classes also help to minimize surrounding distractions and lead to the enhancement of students' focus on the lesson. Additionally, VR online classes encourage a relaxed and enjoyable learning atmosphere for students by providing various interactive multimedia features such as allow them to change their virtual attire or post emojis. For example, ClassVR was introduced to enhance students' learning experiences and support them in achieving their educational goals (Avantis Education, n.d.). The simulated nature of VR technology also enables online classes to provide students greater freedom and boost their creativity and innovation during the class. From the teachers' perspective, VR technology allows them to conduct their classes in a more engaging and interesting way as any topics can be simulated in the virtual world (Barnard, 2024). For instance, teachers can immerse students in scenarios from textbooks and allow them to experience the content firsthand. One such example is the VR simulator, River City that will travels students to a late 19th-century American city to experience the culture of that time (Galas & Ketelhut, 2006). Moreover, virtual face-to-face interaction also allows teachers to manage their students' performance in online classes more effectively. In short, the implementation of VR technology in online classes allows students to have an enhanced learning experience from home and make education become more diverse and creative.

Besides, AR technology also can be applied in physical classrooms as an assistive tool to make teaching materials more interesting and visually appealing. This is because AR technology can put simulated objects that containing additional information onto the existing real-world environment (Hayes, 2024). Thus, any topics from textbooks can be vividly brought to real life to allow students to visualize them instead of relying solely on text and images. For example, Elements 4D is an application that implement with AR technology to visually display the chemical elements, their properties and the reactions between them in the classrooms (Trentadue, 2019). Students can observe these elements vividly and interact with them freely to enhance their memory and understanding. The rapid acquisition of information and skills driven by this teaching method also can improve the efficiency and effectiveness of learning and enhance students' educational performance (ViewSonic, 2019). Furthermore, AR technology also can be used to display the complete 3D models of relevant topics in the classroom. Teachers can present virtual examples of concepts in three dimensions or even incorporate gaming elements to make the class more engaging and interesting (Sinha, 2023). This enables students to gain more comprehensive information on topics in a clearer and more vivid manner as the interactive 3D models contain a wealth of detailed information. For instance, the Dinosaurs 4D+ application integrate with AR technology to display the extinct dinosaurs in interactive 3D models to allow students to observe and deepen their understanding of these creatures (Octagon Studio, 2024). As a result, students can maintain better focus and absorb more knowledge from the class. They can also enhance their abilities such as problem-solving and creativity seamlessly which will contribute to their better future (ViewSonic, 2019).

Not only that, VR and AR technologies also can be integrated into education and training to develop simulated environment that designed specifically for training purposes. With the implementation of VR and AR technologies, users can fully experience and immerse themselves in the simulated environment which are closely mimic real-life experiences (Steuer, 1992). This significantly enhances the user experience in the stimulated environments and provide a training venue which have authentic experience that can encourages both training efficiency and outcomes. For example, the VR Baseball Game is a baseball simulator that creates a realistic scenario for users to carry out baseball training and allow them to enhance their skills in the sport (SmartTek Solutions, 2024). Furthermore, with the help of VR and AR technologies, any scenario or situation can be recreated within the simulated environment even if it does not exist in real life. For example, Sansar provides freedom for the users to design and create their own virtual environments which they can then experience immersively (Sansar, Inc., 2024). This allows users to engage in various types of training or scenarios and learn through firsthand experience. Therefore, they can gain greater expertise and skills through practical training facilitated by the virtual environments (Barnard, 2024). Moreover, utilizing virtual environments for training provides a more practical, safe and cost-effective solution for the users (PIXO VR, n.d.). Due to the simulated nature of the environment, users have the opportunity to practice and experiment unlimited times in a safe setting without any significant cost or consequences. For instance, Mr. Vetro™ is used for the students to practice while facing various medical scenarios to enhance their skills (Merchant et al., 2014). Similarly, the Minimally Invasive Surgical Trainer-Virtual Reality (MIST-VR) software enables doctors to conduct virtual endoscopic training (Wilson et al., 1997). This allows the users to practice and familiarize themselves with situations before encountering with real scenarios. As a result, they can have better prepared and reduce the risk of failure in real situations that could cause serious and irreversible consequences.

VRAR Concerns and Challenges

In terms of concerns or challenges of implementing VRAR in education, it mainly comes down to 2 factors which are the high cost and health concerns.

One of the major challenges of implementing VRAR in education is the cost of setting up such a system. This is due to the high initial cost of hardware and software development when setting up. The process of developing educational VRAR contents is also a significant cost as it requires intensive labor to produce it, the person developing said content will also need to be proficient in both the technical and academic field (i3-Technologies, 2023). This does not even mention the possibility of certain locations such as poorer states not supporting the required infrastructure to run such a system whether it be dependable internet connection, unobtainable hardware etc. (i3-Technologies, 2023).

Other than that, another major challenge in implementing VRAR in education is that it may lead to potential health and safety concerns towards students. This stems from the fact that as of now, VRAR is still in its early stages of release. As to what are some of the health concerns of VRAR, it is split into 2 major types which are physical and psychological health risks. When using VRAR in long sessions, it can lead to users having cybersickness or also known as motion sickness, where the user will have a loss of spatial awareness, dizziness, nausea and disorientation (Spilka, 2024). VRAR may also cause certain side effects such as eye soreness, trouble in focusing, weaker reaction time, loss of balance etc. (Spilka, 2024). With that being said, the physical health concerns of VRAR have been reduced with newer iterations of VR but it still suffers from Vergence-accommodation conflict where the human brain will receive mismatch cues between vergence and accommodation. As for the psychological health concerns of VRAR, is that the immersive experience of VRAR may affect the users' emotions by amplifying negative rumination such as self-harm related to distress (Spilka, 2024). VRAR can also cause users to get addicted to it, leading to excessive usage of such devices (Adamska, 2023). It was also found that long sessions of VRAR may blur the lines of VR and reality, causing users to have issues when reintegrating with the real world (Spilka, 2024).

Outside of these 2 major challenges, there are also minor challenges such as privacy issues, where certain programs of VRAR may require access to sensitive information from the users such as location, visual or auditory information (Adamska, 2023). To conclude this section, VRAR as a whole is still a very new concept that is being mainstream, and therefore it will still have some imperfections such as high cost, health concerns and even privacy. In the future, it is very possible that VRAR as a whole will be able to overcome most of its challenges and potentially become a mainstay in our lives.

Critical Evaluation and Discussion (Potential and Future Perspective)

With, education system has been the same as always since the beginning and now, there is no difference at all. The only thing that has change is the amount of knowledge and the level of the education/syllabus. With how the technology is progressing and how it is changing how things are being done which affects peoples' day to day lives.

Based on the article that have been written by Thompson (2024) that a survey has proven that most parents and teachers approve that VRAR can bring countless of benefits to the students. In the same article Thompson (2024) also wrote many of benefits that can bring to the education system. Like being able to conduct virtual experiments for science class. This can prevent any mess or risk that can bring to the students and also not all students can understand through words/verbal explanation. Some students need are more to pictures/images or hands-on experiments to understand what is taught by teachers. Besides that, there is a potential for VRAR technology to have a virtual world recording where students can watch back the recording on history class for example. This can also let students to visualize situations about the past.

Another article that is written by M. Al-Ansi et al. (2023), says that an immersive and interactive environment can help students in many different ways/subjects like history, science, and economics. M. Al-Ansi et al. (2023) also wrote that ARVR technologies are perfect for special needs students by providing a safe and engaging learning experiences. This prevents any inconvenience for them during any class where they need to move around like during experiments. This can lead them not being left out during such events.

Based on these two articles alone shows that VRAR education can lead to a more fun experience where students can be more creative and interactive within the subjects. It can bring a different way to learn and study where students would not get bored of. Since education system have been the same as always, it is time to change the way we learn things.

As for training, with VRAR people can receive training without risking harming people in the process. For instance, F1 training, flight training, gun training and etc. VRAR training can save a ton of resources and costs where physical training needed to perform the training. With everything being virtual, people can be trained in different kind of scenarios. This is because in physical training it is hard for people to mimic unforeseen circumstances or a specific situation that could happen.

Conclusion

Long story short, Virtual Reality (VR) and Augmented Reality (AR) have transformative impacts on education and training, providing unparalleled convenience for students and teachers alike. Due to the versatility and adaptability of VR and AR, these technologies increasingly popular and widely adopted into education and training like VR classroom and VR training. With essential devices like VR and AR headsets, controllers and sensors, users can immerse themselves in fully customizable virtual environments or interact with simulated elements seamlessly integrated into the real world. However, VR and AR technologies also come with setbacks such as user fatigue, security vulnerabilities and privacy concerns that could expose users to a danger situation. Consequently, the development and implementation of VR and AR technologies in education and training must be carefully managed to ensure that students and teachers can maximize the benefits and convenience these technologies offer.

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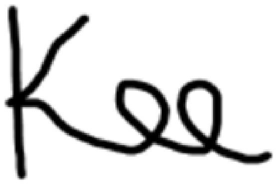
Workload Matrix

Members	Responsibilities	Signature
Khoo Guo Hao TP076267	- Introduction - VRAR Software and Hardware	
Kee Wen Yew TP076357	- VRAR Industrial Application and Content - Conclusion	
Joshua Liew Yi-Way TP076206	- VRAR Concerns and Challenges	
Colwyn Pang TP074675	- Critical Evaluation and Discussion (Potential and Future Perspective)