A Review of Opportunities, Applications, and Challenges of XR in Education

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Abstract **- This paper talks about the use of Extended Reality (XR) in education and the ethical issues surrounding it. XR is seen as a pathbreaking technology in the field of education and has been extensively researched by various technologists and educators over the last few decades. Multiple studies in the past have shown that using XR in education has a significant positive impact on students' knowledge development. From visualizing atomic-level chemical reactions to going on a space expedition, the possibilities are endless. But this also brings up issues regarding data privacy, misuse of the platform, and other ethical concerns. To better understand this, this paper reviews research conducted on the applications of XR in education, its advantages, disadvantages, ethical considerations, and overcoming the challenges regarding its use.**

Index Terms **- Augmented, Education, Ethics, Extended, Mixed, Virtual.**

I.INTRODUCTION

Virtual Reality is a replica of an environment that simulates a physical presence in the real or virtual world, allowing users to interact in that virtual world. Digital screens such as a television (TV) or a deeply immersive head-mounted display (HMD) device can render VR experiences. The first HMD was created in 1968 by Ivan Sutherland. HMDs enable a stereoscopic, 360-degree visual of the environment. Currently, the most popular HMDs are Oculus Rift and the much more economical option, the Google Cardboard.

Augmented Reality (AR) is a form of virtual reality where the real-world is enhanced through virtual elements by adding them to the view of the real world using a display device. AR devices consist of a display, sensor, processor, and input device. The display device could again be a TV, HMD, computer screen, or even devices as sophisticated and compact as eyeglasses or contact lenses. Mixed reality is merging the real and virtual worlds in a process to produce a new environment with virtual and real-world objects that can co-exist and interact with each other in real-time.

Mixed Reality (MR) can be visualized as a continuum or a spectrum where, depending on the amount of virtuality or reality in the environment, we can classify it as being partly in the real world or entirely in the virtual world. Extended Reality (XR) is a broader term which encapsulates everything from AR to VR. The most relevant applications of XR in today's date are in the Engineering, Entertainment, and Healthcare industries, and as covered in more detail in this paper, the Education industry [1].

II. APPLICATIONS OF EXTENDED REALITY IN EDUCATION

One of the earliest applications of VR was in educating and training pilots before and during the Second World War. Although VR is used more widely in the entertainment and video game industry, it has also created quite an impact in the education industry in more recent years. The most commonly used method for enhancing the learning experience is the gamification of concepts. Applications of XR in education are mainly classified into learning and training, which can further be classified into learning a theoretical language, learning practical skills according to prior knowledge, and problem-solving. This section discusses fields that make extensive use of XR.

STEM:

XR has a considerable number of applications in STEM (Science, Technology, Engineering, and Mathematics) education. The earliest educational research on VR was done in the field of science. For example, software like astronomy with desktop VR earth motion systems, "Dr Friction" which is a multiplayer educational game that talks about concepts such as 'motion' and 'forces', and "Protein Game" in the field of biology and biomolecules. XR facilitates engineers with immersive training experiences and helps introduce young students to engineering. It also optimises the cost and time of experimenting and maximises productivity out of failures. Making mistakes is a part of the learning process for students, but sometimes, these mistakes might cost them in various ways, like having to purchase new components. XR helps address such problems by giving students room for errors while learning [8]. In fields like chemical engineering, XR is used to carry out dangerous experiments remotely. XR opens gates to accessibility and facilitates distance learning as the simulations can be customised depending on the user's convenience. XR in STEM also allows visualisation of abstract processes like propagation of waves and atomic-level visualisation of chemical reactions. In mathematics, XR can be used to visualise and simulate an interactive environment to understand trigonometry [2].

Medicine:

Many physicians and medical researchers see XR, especially VR, as a gateway to several new opportunities for learning medical science. An essential part of a medical student's course is performing and practising surgery on a human body. VR helps eliminate the need to work on a real human every time. For VR-based surgery simulation to be meaningful, the critical ingredient is realism in the virtual environment. Users need not only visual but also haptic feedback to their actions. Varying degrees of haptic feedback allows students to perform invasive, non-invasive, and intrusive types of medical operations. Students are enabled to practice with various equipment and gain procedural knowledge by performing complicated and time-consuming procedures such as an organ transplant [6]. Doctors and nurses can use XR to develop emergency room skills and team-based medical tasks. Apart from procedural skills, VR also helps develop non-procedural skills such as presenting a case to patients and improving their communication skills. AR can help simulate genomic experiments and laboratory tests. AR also allows students to practice the use of radioactive medicine. XR enables medical students to follow a case-based learning model and can be used by medics to conduct physiotherapy sessions for patients and track their progress with the help of position and gesture sensors on the VR equipment [6].

Other applications:

Not many students can afford field trips, especially those from public schools. VR allows them to visit places that they are less likely to see in their lifetimes such as the surface of the Moon and Mars. Google Expeditions is a popular application used for visiting and learning about history where students are shown monuments through a 360-degree video. XR can also be used for training pilots and airline crew using flight simulators, mainly during distress calls, through VR and MR. Geoscientists can use XR to visualise complex 3D simulations of natural disasters [2].

III. ADVANTAGES, DISADVANTAGES AND LIMITATIONS

XR unifies teaching across geographical boundaries by removing the language barriers that exist in the traditional learning system. This helps students connect globally and make the process of sharing knowledge easier and maximize the knowledge gained. The famous ‘Cone of Learning’ by Edgar Dale [7] describes that more information is retained when activities or simulation of activities are performed by an individual compared to just reading texts or seeing their visuals. VR can be used to simulate real-world tasks in an environment similar to the real world to ensure a completely immersive experience and retain maximum knowledge. Gamification of concepts in education is a unique blend of entertainment and learning with a motive of cultivating interest in the students’ mind. It also grasps their attention by providing fun in the classroom. This can be achieved by implementing XR, especially AR, in classrooms where students can learn and perform group tasks in a more interesting way compared to conventional methods. XR can be used for enhancing problem-solving skills. Students can visualize the problem

statement and replicate a real-world scenario, which can help optimize their skills and yield better results. One of the most important educational advantages of XR is its ability to dramatically expand the range of activities with which a learner can gain hands-on experience. XR can provide this experience for things that are too small to work on with hands, such as atoms; too large, such as entire physical environments; or not physical at all, such as electromagnetism. In other words, XR dramatically expands the range of topics that can be learned as skills rather than as abstract knowledge [9]. This technology makes it possible to overcome limitations like not being able to thoroughly examine something as microscopic as a cell by exploring the cell as if it were a physical space and immersing people fully in 360-degree safe and controlled virtual environments, thereby creating new learning opportunities. XR is seen as a boon for the differently abled. VR helps break physical barriers and provides more freedom to travel in the virtual world. It enhances their learning experience in ways previously unachievable, for example, a wheelchair user could experience swimming in the sea and children with autism can learn social skills in individualized settings, which is difficult to accomplish without VR.

With all the advantages mentioned, XR does have some limitations. VR devices are less accessible since the cost of purchasing them for end-users is high. They might be challenging to implement in a classroom-like scenario. VR environments for engineering and advanced medical applications require computationally powerful hardware for rendering and accurate haptic feedback which further increase the price. Mobile solutions have minimal interaction capabilities when compared with that achievable with high-end solutions. VR and MR are expensive not only for the end-users but also for the entrepreneurs since the hardware development cost might be too high for a startup to bear. Excessive use of XR might trigger addiction. It might also lead to people prioritizing the virtual world to the real one if used very frequently. On the other hand, even when used in moderation, it is uncomfortable to wear VR equipment for long durations as they cause physical discomfort and result in a lack of continuity of learning. XR can only help develop specific competencies in education. It might also reduce social interactions which are essential in a learning environment [5].

IV. ETHICAL CONCERNS

VR systems collect user data such as haptic, camera, and audio inputs which can be used to enhance simulations and drive profits. But such information can also be collected when the user believes the system is off, enabling developers to gain data without the knowledge of the user. This data can also be traits like eye movement patterns, reflexes, and motor actions (a user's "kinematic fingerprint") and information about their habits and interests. Non-XR products or experiences cannot collect this type of data; therefore, new thinking and policies will be required to address data collection in XR [4].

Some privacy policies of XR equipment manufacturers state that they collect personal information like billing address, phone number, etc. whereas some state that they collect the user's movements and dimensions of their room or space for being able to accurately build the virtual environment in the given space. If this data is sold to third parties or leaked through vulnerabilities, it would give the headset manufacturers or the data collectors access to the user's surrounding and objects in the real environment, therefore violating data collection rules and the user’s privacy. This data can also be misused if the behavioural pattern of the user is analysed, i.e., their fears, whether the user is seeking some treatment through VR, or their response pattern to fight/flight situations and can be used to hack the user's identity, blackmail them, or harm them in various ways [3], [4].

Some XR manufacturers collect personal information and record the user's behaviour and movements in the name of building a virtual environment. This data can be leaked and misused to blackmail and otherwise harm the user. Therefore, data collection policies will have to be transparent, and the implementation of permission requests (always on, only when the program is open, etc.) will be required. With this, the legislation will have to be changed to accommodate the type of individual data stored due to XR use.

XR must not have negative advertisement. In the TV and newspaper era, everyone watching and reading them would see the same ads. These ads would be localised, but they couldn't target an individual. Now, ads are shown to an individual based on their browsing history and personalisation and are therefore more focused. It was possible to ignore these ads easily, but now, in XR, we may get bombarded with ads where

virtual entities approach the user and try to persuade them to buy their products or try their services. Users cannot go about their daily lives with such interruptions. These ads must also not contain any malicious links that drag the user out of their current application and to their website. This can lead to illegal user data collection, breach of privacy, or infect their system with viruses. Additionally, no education-based software should contain any malicious or unethical ads since kids might open these links and make purchases without their parents' permission or even discover things inappropriate for their age.

Since shared environments will be typical in fields like education and medicine for group activities and exercises, harassment and bullying must not be tolerated, and steps must be taken against this. In areas such as the military where violence is part of their training, they must have their principles and guidelines in place. There must also be other software or exercises which help alleviate stress and frustration caused due to rigorous training. Additionally, given the realism in XR worlds, if someone carries out a task that would be illegal in the real world, it might later be used in legal proceedings as evidence to bring out the character of the person. Strict policies must be formulated about the types of activities that can be held up in court.

The well-being of users must be of prime importance. Repeated re-entry into XR may cause motion sickness and lead to accidents. Physical actions carried out in XR that don't reflect their surroundings like running around during a team-building exercise must require appropriate management to avoid injury. Psychological well-being is as important as physical well-being and must be maintained. In the case of young children, studies show that they are unable to differentiate between real and virtual environments due to their under-developed cognitive thinking. In adults, different measures must be taken depending on their field of work (refer to the example of the military in the above paragraph). Emotional and behavioural changes in the user should also be displayed to them, but since this data is sensitive, it should be encrypted. Users should be able to trust the content shown to them in virtual environments.

V. OVERCOMING THE ETHICAL CHALLENGES

XR must be made accessible to all by bringing more flexibility. Not only does this include having products at different prices but also having them cater to all kinds of users, like those who are physically or intellectually differently abled.

In the case of XR in the classroom, students' activities must be monitored by their teacher or an instructor to keep bullying or any other form of misuse of XR under check. All applications must be screened, and their content must be filtered and/or restricted to make sure virtual characters within applications do not encourage or promote illegal or inappropriate activities, especially to children. Ethical guidance must be given to end-users as well as developers before using or making an XR application. If developers and hardware manufacturers take an oath to stop sharing users' collected data with third parties, it will increase the users' trust and create a more secure environment [3].

Since the short- and long-term effects of XR are unknown, guidelines will have to be modified as future research unravels new findings. For now, clear warnings and age requirements or restrictions would be advisable. Developers must also be aware of the consequences and ethical implications of how they showcase their products and construct their environments [4]. They must understand that they have a significant ability and responsibility to safeguard against the dangers of immoderate use and that they must accept the evidence-based regulation to minimize harm. More research is needed to formulate correct policies. This requires developers and legal authorities to work together. Products will only then be received positively by society, making the overall experience better for everyone [3].

There must be an option for users to simply "opt-out" or exit if the content becomes distressing or uncomfortable to the viewers to minimize content-induced risk. A person could simply close their eyes and remove the device, but it might not be so easy to disengage if the virtual environment makes users forget that they can do so. Some training would also be required. Additionally, a cleansing experience must be available if the user feels too distressed. All these scenarios, especially those preparing for children's education, should be accurately examined and evaluated by professional psychologists and educators [4].

VI. XR VERSUS REALITY

XR, especially VR and MR, might offer an immersive experience, but this still cannot entirely replace physical experience in the real world. This disconnect may lead to anxiety while doing a task in the real world. For example, performing surgery in VR might feel more comfortable and less taxing since there are no real consequences, but there is no room for error when operating on a real human. Another major limitation is that XR can only provide visual, auditory, and haptic feedback. It cannot accurately provide users with varying degrees of olfactory and sensory feedback, such as the smell of a chemical or feeling cold. For example, in the case of training firefighters, smelling smoke and feeling the extreme heat is very important. XR cannot bring in the feeling of fatigue or stress during the training of very high-intensity tasks like extended military operations. It is crucial to be able to test the user's performance under such factors.

VII. CONCLUSION

This paper supports the view that XR is the future of education. XR has a wide range of applications and positive implications. Most of the literature reviewed in this paper has demonstrated that XR in education interests and involves students more than the classic form of education and helps them retain subjects longer. However, we must address its limitations. The hardware required must be made accessible for all by making them economical and flexible for the differently abled. More research and innovation in the industry will help overcome its current limitations. Still, we cannot overlook the associated ethical concerns, especially now, as the 2020 pandemic has fast-tracked developments in the XR industry. Strict guidelines and policies about data collection and illegal activities will not just have to be implemented but also revised with advancements in the field of XR.

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