THE USE OF AR-VR-BASED LEARNING IN CLASSROOM

Arunachalam B
School of Electronics Engineering
Vellore Institute of Technology, Vellore-632014, Tamil Nadu, India

Prof. G. Anburaj
Assistant Professor of English
Vellore Institute of Technology, Vellore-632014, Tamil nadu India

Abstract

This is going to bring change in the paradigms of education, and bringing the AR and VR technologies into the classroom environment is very promising. This paper explores learning about AR and VR in the classroom contexts from perspectives of levels of student engagement, comprehension, and retention. AR and VR provide an immersive and interactive engagement environment, thus allowing students to better imagine complex ideas and participate in simulations of scenarios that would be impractical or impossible to conduct in a traditional classroom. These technologies are designed to honor different styles of learning, thus making abstract and difficult subjects easier to understand and fun. Moreover, AR and VR allow collaboration in learning processes and the exercise of practical skills with virtual laboratories and actual problems. Such barriers include cost, technological infrastructure of the institution of learning, and availability of training of the teachers. Results: The result shows that, despite barriers to wide application, advantages of the application of AR and VR for improving learning outcomes override obstacles, which make innovative and effective learning experiences.

Keywords

Augmented Reality (AR), Virtual Reality (VR), Immersive Learning, Interactive Simulations, 3D Visualization, Educational Technology, Educational Resources, Mixed-Methods Analysis, Innovative Learning Environments.

Introduction

Learning through augmented and virtual reality has revolutionized the sector because of the immersive and interactive nature of the experience that definitely stands far above those traditional teaching methods. In such a way, students can experience complex phenomena through simulation as well as 3D visualization and virtual tours with real-world comfort. AR and VR can also individualize learning. They can construct contents suited to the needs of each learner; thus, curiosity and interest are instilled. Innovative ways to explore things begin with virtual science experiments and historical reconstructions that make the learning experience more interactive as well as hands-on. More deployments of AR and VR in classroom settings make them proper contenders for access to quality educational materials, hence being useful for the eradication of issues affecting cost, accessibility, and curriculum relevance. Additionally, these technologies are well-suited to enable collaborative learning in common virtual spaces - a robust quality attribute in terms of cultivating students. In addition, AR and VR can fill gaps through opportunities at learning in an immersive and equitable manner by the people at large, irrespective of geographical or socio-economic background. It is therefore equipping the minds of students to effectively take their space within this more digitally immersed future simultaneously in and outside classrooms by realizing advancements in the fields of AR and VR technologies. It allows the students to develop utmost evidently required critical thinking skills -- adaptability and power of critical thinking -- in this contemporary, technologically dependent world. Lastly, AR and VR are transforming education by offering more immersive, inclusive, and flexible learning spaces to learners.

Problem Statement

Despite the great promise that AR and VR hold for education, most schools are still confronted with great challenges in their attempts to use them effectively. It is too expensive for schools with really limited resources to afford AR-VR equipment and needed infrastructure. In addition, there is a shortage of quality content designed from scratch using AR-VB tools-a main barrier to even more extensive use. Other challenges include how much these technologies integrate with the existing curricula and whether the teachers are adequately prepared to incorporate AR-VR in their teaching. Access to equal means for these technologies is also another challenge since not all students have the equal resources or support to fully participate in learning the curriculum through the use of AR-VR. Meanwhile, overdependence on this technology could spur the eventual decline of value attributed to face-to-face contact and traditional teaching methods because that is still as highly needed for full development. Over these challenges would unlock the full potential for AR-VR to improve education and prepare students for a world where digital literacy is paramount. Along with the constant adaptation of AR-VR in schools, long-term approaches must be devised to overcome these hurdles so that all learners may benefit from this advanced means of learning.

Research Gap

Good recognition among most people is present for the benefits that AR and VR hold for education. Nevertheless, some gaps in research remain to be filled in order to understand how they could eventually achieve long-term changes. Most studies that exist today mostly deal with the short-term increase in engagement and motivation without considering other mechanisms through which AR-VR may impact deep learning, long-term retention of knowledge, and critical thinking. There has been very little research that has been conducted in exploring the impacts of these technologies on age groups and learning abilities, more so that of a student with learning disabilities or special needs. The extent of the integration's applicability in various educational settings, especially within schools with less privileged or rural settings, remains to be extended. Furthermore, there has been little study on how AR-VR can aid in facilitating collaborative learning or its adaptability across different cultures. Teacher preparedness and the effectiveness of professional development programs designed to prepare them to apply skills toward involving AR-VR in the educational process. They should be satisfied to better inform strategies that will ensure widespread and equitable use of AR-VR technologies in education.

Literature review

- VR/AR technologies are quite compelling to the learners because they offer something different and much more highly immersive than regular learning that enhances the understanding of real-world concepts. They can actually be very helpful in improving learning outcomes as they afford students something supplementary, interactive, and engaging above and beyond regular teaching methods. One of the methods through which the teachers can input these technologies into their teaching processes better would be in the design of AR applications and with the help of tools such as Aurasma Studio. Therefore, the paper is characterized by main experiences and lessons learnt that represent an extremely relevant insight for teachers in planning, designing and developing AR-based educational material without wasting much time. With VR and AR, the concept is to obtain learning outcomes that are better compared with those achieved through the traditional approach. These technologies create opportunities for greater interaction among students as experiences received through simulation and virtual environments reinforcing theoretical knowledge with practical applications. For example, an ability to identify images or objects in an application based on AR is enhanced when tonal variations of any image display enough contrast. The print quality and size make all the difference; images printed on matte paper instead of gloss are easy to read for a camera as the latter is bound to throw light and hampers detection. While creating content, the names given by the educators should have meaning with overlays in Aurasma Studio so that management becomes easier, besides navigating AR content. Beyond this, quality checking of the AR contents becomes necessary. It is to avoid cognitive overload or confusion on the part of the students. Since good AR experience ensures better learning and avoids student overload as a result of too much information, results reported here outline the importance of thoughtful design of AR contents in benefiting from immersion technologies within situations of learning.

- This application brings forward the interior design field by proposing a new utilization of AR technology in such a way that users can interact with virtual furniture in terms of real space. In this method here, one will be shown how to manipulate 3D virtual furniture in a real environment by applying such a dynamic and flexible user interface. Among other factors, the use of an occlusion-based interaction technique in a Tangible Augmented Reality system would allow the user to replace all properties of virtual furniture, that is, size, position, and orientation. This interactive interface would involve much more intuitive interaction with those design tools, creating a larger gap between virtual objects and real-world spaces. Another supplementary feature of the study is an AR-based application using markers applicable only on Android devices. For example, people can apply this application to put virtual furniture in their real environment. They can now see, fix, and order furniture in place as if the furniture exists at that given space through a real-time view created in an environment. This makes it a good means of visualizing designs before adjustments are made. An AR application combines virtual elements with the spaces, stretching out the design process toward far more knowledge-based decisions and better levels of personalization. This is actually quite a step forward with regard to design by technology using an internal design concept with AR, an instrument that can produce total immersion in a hands-on scenario for the manipulation and visualization of virtual objects in real environments. This nascent proposed application has made design easier and more flexible while utilizing a more personalized experience of a highly interactive design. Innovations like this unlock doors to a completely different realm of AR within interior designing, unlocking new opportunities that exist through creativity and precision in the way of seeing and preparing spaces.

- This review offers current advances of self-adaptive technology in VR training, incrementally adopted in five major domains: medical training, industrial and commercial training, serious games, rehabilitation, and remote education, commonly referred to as Massive Open Online Courses (MOOCs). There are five basic technologies of VR where adaptation can be incorporated, namely: haptic devices, stereo graphics, adaptive content, assessment tools, and autonomous agents. Automatic VR training systems may really differ for practical procedures, such as distant and robot-assisted surgical interventions. In fact, the automation systems can really change the concept of training, since they may reduce the potential injury and enhance the efficiency of medical intervention. Moreover, automatic haptic interactions support telepresence that may be used to let users perceive interaction with virtual artifacts which are either remote or simulated. An important ingredient towards personalization in training for individual learners is through machine learning and data-driven approaches. The assessment gathered data can be fed into the autonomous systems to deliver bespoke content and adjust levels of sophistication undertaken to meet different training needs. Much development has been done in the components of self-adaptive technologies for VR training, and much work remains in developing an integrated framework. Major outcomes from this work include improvement of a more transportable framework for the automation of core VR technologies, designed to extend an increased set of reusability and adaptability capabilities in the direction of smoothing up the method used in developing self-adaptive VR training environments. Such a synthesis of these technologies would hence trigger the effectiveness of training while providing a platform that can be adopted for further evolution on the VR training front, which would thereby result in better learning outcomes across various domains.

Result Analysis

1. Best AR/VR Feature for Engagement and Impact

Augmented and Virtual Reality have become transformative tools for the education sector. It's an exciting opportunity for students to take part in highly interactive learning environments that cater more to their individual needs. Among the numerous features, some of the standout ones that really capture the attention of students include those features that make educational experiences meaningful and long-lasting. Interactive simulations: Perhaps the most potent feature of AR/VR is interactive simulations. Here, a student is allowed to input virtual worlds, toying with variables, exploring complex systems, and then observing real-time consequences of all that. Contrary to the other learning methods, interactive simulations require the process of an active user. It favors the use of skills of critical thinking and multi-problem solving and creativity attributes. For example, in a biology class, virtual labs would enable students to conduct experiments with cell structures or chemical reactions that would be conducted under safety guarantees in a controlled environment. In this way, from virtual labs, the process of biological phenomena can be understood as details can be seen better as ideas get easier to be comprehended since abstract and hard ideas become easy if the concept is just verbal. Another feature, which also contributes towards engagement with AR/VR, is 3D visualization. These renderings permit one to navigate and interact in ways impossible to observe or interact with in the physical world. A medical student, for instance, may be able to rotate and zoom into a 3D model of the human body in such a way that she or he could peer inside in fine detail at any organ system individually. Such models can be operated in real time, and that in itself is a great experience of being in touch with the subject, which transforms an abstract concept into an understandable experience. Therefore, it is very helpful in physics, engineering, or molecular biology, while dealing with spatial understanding to understand the pieces and puzzles that form various structures and mechanisms. Therefore, a student can interact with dynamic models at an individual pace to customize a contextual learning experience. Virtual field trips also provide another entertaining and interactive means of involving students. Live what they might never otherwise see: take them to places that would otherwise be quite inaccessible to them. Think of a history lesson in which they can walk through the ancient Roman ruins, or stand in the middle of a bustling medieval marketplace. For instance, the student science learners could be taken to the far ends of the solar system, to distant planets where they could make an actual landing and observe celestial phenomena. Such experiences make for memorable learning material since they can make the learning material vivid and relevant to the students' everyday life. Virtual field trips have the wide world open before students and give them much-needed practical context to the otherwise mere theoretical knowledge, which should be understood as applied. The Future of Education Stands the Combination of Interactive Simulations, 3D Visualizations, and Virtual Field Trips There's no learning left in the textbooks or in the classrooms anymore. More engagement and better retention happen when students get hands-on experiences within immersive environments, true for AR/VR. These features, aside from keeping students interested in the material, help in making them understand it with relevance, enjoyment, and impact for the students.

2. Benefits of AR/VR in Education and Addressing Learning Disparities

From these, much of the process of change is reflected in terms of how learners learn through Augmented and Virtual Reality. Among its most vital benefits is the potential for personalizing a learner's experience, offering learners an opportunity to relate to and engage with material in ways that best appeal to their individual learning styles. Unlike the traditional classroom, AR/VR instruction is learner-driven in pace and style. The student can go through the content of his or her choice at whatever pace or preference feels best; therefore, higher levels of engagement, understanding, and retention of information are upheld.

The classroom that's kitted with AR/VR shall then provide learners the choice of paths that really would resonate more with a unique strength. For example, visual learners learn more of the immersive 3D environments wherein they could manipulate visually objects or scenarios; the auditory learner learns better through verbal explanation that goes along with such immersive environments. An interactive learning environment also will appeal to kinesthetic learners who typically do best with interactive simulations that are lifelike: a great example of this is to dissect a virtual frog within a virtual biology lab or to run virtual physics experiments. With AR/VR, students are able to review problematic material or delve deeper into areas of interest at their own pace. This enhances the motivation of students because this level of personalization results in shifting the approach from passive reception to active involvement, where the student manages the learning and educating effort. The other advantage that AR/VR brings is the chance to overcome the inequalities of learning, particularly in a deprivatized school or community. Historically, access to high-quality learning content has been geographically unequal; students in other underserved or more rural areas will not necessarily have the materials and experiences that are meant to enrich learning. Field trips to museums, science labs, or cultural landmarks-activities that can improve education immeasurably-are oft impossible for these students due to logistical or financial constraints. But AR/VR can democratize education through virtual access to those world-class experiences. For example, a rural student can embark on an e-food adventure of the Louvre in Paris and the Smithsonian Museum in Washington, D.C. Conversely, the pupils who experience the same magnitude of art, culture, and history as they learn together find themselves in the same neck of the woods than their counterparts in high-income cities areas; this will most certainly bridge the achievement gap among the pupils from different socio-economic backgrounds. In this way, AR/VR will once again level the playing field so that even the students in less privileged communities get a chance to engage with similar material and thus can bridge the gap with their counterparts in better-resourced environments. More importantly, there is now a potential for experience-based learning that cannot be envisaged through the local curriculum-for example, virtual internships, simulations of historical events, or even exposure to cutting-edge scientific research-in the world of AR/VR. These experiences enhance the awareness of students toward the world, broaden horizons regarding education, and incorporate other kinds of learning. The greatest advantage that AR/VR holds for education is its power to transform the whole process of learning for students by providing personalized learning opportunities equalized by making one not differ from another. Apart from interesting and motivating learning activity, this would also sort out long-standing issues of educational inequity. Personalized learning experiences tailor-made to the needs of individual learners will reduce barriers to access high-quality resources. From the current scenario where successful access to knowledge determines success for the future, technology promises to make education spaces more inclusive and fairer for all students.

3. Future of Learning with AR/VR and the Most Impactful Content

An ever-powering Augmented Reality (AR) and Virtual Reality (VR) may change the very face of education. Perhaps the most interesting point here is when such education changes the receiver into an interactive, immersive environment. Education, up to now, has been and is largely based on receivers of knowledge: being lectured to or reading off papers and books. AR/VR would shift students from being passive recipients waiting for information to be fed into them to becoming active participants. That change would ensure not only better engagement but also deeper and longer retention of knowledge. Students in classrooms deployed with AR/VR would be able to participate in fully immersive experiences extending even beyond the physical space. For example, instead of passively reading about historical events, the student will experience a virtual step into some great moments in history in order to get a firsthand experience of them. They might stroll through old cities; they might be witness to important political decisions being taken or see themselves sharing conversation with historical figures. Such engagement will help create vivid, emotive connections to the subject matter, making it not just interesting but memorable as well. Additionally, virtual experiments in the simulated lab environment through AR/VR will transform this world of science education. Scientific models will influence the students the most and for the longest time since, for the very first time it allows the learners to handle complex principles practically, hence many investigations across disciplines including chemistry and astronomy. The kid can experiment on different variables in the virtual chemistry lab to see how certain chemicals behave under different conditions. They can also simulate real-time lunar eclipses. This means students can engage with these relatively abstract concepts in ways simply impossible for them to do via texts or lectures. The STEM fields are especially well-suited to AR/VR. They encompass some pretty complex technological and scientific concepts that students really find much too difficult to digest through more traditional pedagogical approaches. AR/VR may make even learning and mastery of these ideas as rich as experimentation in real time with immediate feedback on actions undertaken. For instance, engineering students can build and test virtual models of the structures using AR/VR, minus the connotations of real costs or risks involved in the creation process. By allowing the students to progress safely and make mistakes, AR/VR can facilitate creativity, innovation, and a deep understanding of a myriad of themes in STEM. Besides STEM, language and cultural studies will also be transformed with immersion programs in language as well as cultural experiences. For instance, learning a new language is drastically modified as it offers students an unparalleled chance to practice conversational skills, pick up cultural nuances and understand the context in which the language is used once students can virtually visit any country where such language is spoken and can themselves interact with locals in real-life conditions. For the student studying history, geography, or art, a virtual tour through museums, historical landmarks, and cultural sites around the world is available. Global access increases the depth in coverage of the issues but has the wonderful side effect of ensuring that the student develops cultural awareness and empathy while experiencing perspectives other than his/her own. This is the best mode in the delivery of cultural and language immersion programs because experiential learning is quite a hard package to occur in the classroom. It basically takes the student to other countries or even time periods in a virtual setting, thereby creating an experiential context that has an elevating power greater with regards to language acquisition and cultural literacy-which, besides bringing in deep appreciation for diversity, prepares one for global connectedness.

4. Concerns and Challenges with AR/VR in Education

Although AR and VR do promise much with regard to education and its real possibilities, the integration does bring along with it many apprehensions and challenges that need answers for successful and equitable implementation. The most salient of these among all is the financial barrier that is said to limit access to these technologies-the underserved schools being one likely affected. This type of hardware, be it VR headsets, AR glasses, or even supercomputers, is costly. Economically impossible to match in schools with a shoestring budget, schools would begin lagging behind, and many would take a beating because of this. Advanced technologies are being used differently with the gap between schools continuing to widen since only the well-funded schools would really be able to implement an AR/VR program. Policymakers would partner with educational institutions and technology companies to address such inequity. In that regard, solutions could include funding AR/VR programs by the government, partnering with tech companies to make equipment available free or at a low cost, or developing low-cost AR/VR tools for easy uptake by resource-deprived schools. Equal access is a must not to make AR/VR a learning tool only for the students coming from affluent areas while others are deprived of its potential. Another very essential issue brought about by the integration of AR/VR into education is privacy and data security. Ordinarily, it will produce mountains of information from the time students interact with such virtual environments as the systems record movements, behaviors, preferences, and sometimes physiological responses like eye movement or heart rate in extreme cases among others. Without proper regulation on matters of privacy and adequate security measures, there is a strong likelihood that some of such collected data will be misused through breaches or worse, unethical data collection. Basically, this information must be protected, and schools, developers, as well as policymakers need to collaborate in making the privacy safeguards. This would mean policies that encompass how the student's data would be used, how it would be protected, and the time duration it would be stored. Control of personal information should also be granted to the students and their parents. They should be assured of the ethical concerns about use in classrooms. Since data is becoming commoditized all the time, such a concern will arise with how student data collected via the AR/VR system is assured not to be taken out and used for something other than education. There should be proper understanding that the data is owned by the students and that third-party vendors should not exploit or monetize it without explicit approval. Now come both the cost and privacy questions but there also come technical challenges when AR/VR is used in education. The third requirement involves strong infrastructure to work appropriately. High speed internet access is quite essential to experience VR applications with high performance, coupled with a powerful computing system capable of handling the heavy processing demands of an immersive experience. However, no school possesses the infrastructure required for supporting AR/VR entirely. Even the schools that are provided with proper equipment need maintenance of that equipment. Technical failures ranging from software problems to hardware failure or even connectivity issues can leave a disruption in the classrooms and will frustrate students and teachers in general. Schools will rely on responsive IT support and educators who are able to identify simple glitches and use technology at their discretion. Teacher professional development and education programs should then focus on how AR/VR can be used effectively for learning and not disrupt the learning process because of technical issues. Unless such proper training and support is given to teachers for the integration of AR/VR, this technology may flop because teachers are not going to be interested in applying it or will leave if it does not work each time. Another is that AR/VR should supplement not supplant traditional forms of learning. Now, use of AR/VR offers so many unique opportunities for adaptation and interactive learning environments, but so not completely supplant the very bedrock of teaching and learning. There are essential activities reading, writing, critical thinking, face-to-face discussion-in place of which face-to-face discussion-it doesn't take anything away from the base. AR/VR could be harmoniously accommodated into mainstream traditional education rather than replacing some tested and tried teaching methods. Their over-reliance on value could be reduced upon other forms of learning like a project of group work, creative writing assignment, or actual experiments. The balance that should be found by educators is one that imports AR/VR with most of the traditional education systems so that students could be provided with balanced education.

5. Choosing AR/VR Content and Optimal Learning Environments

This is actually a delicate and critical decision since it determines how learners will interact with and retain material. The first consideration therefore should be the level of correspondence between the content selected and the learning objectives of the curriculum. In simple terms, integrating AR/VR into learning is bringing a curriculum to the learner in a way that the concepts are understood and experiences otherwise inaccessible within a traditional classroom are offered. For that reason, it should be a question of prioritizing selection on the basis of content that generates meaningful knowledge in their minds rather than choosing content that is visual but lacks conceptual meaning. Another critical factor in the choice of AR/VR content is its ability to increase student engagement. Although good graphics and designs are appealing, alone, they should not be used to decide. The most important truth about AR/VR content is that it renders learning active rather than passive by allowing students to be active and engage within the virtual environment. Good AR/VR content should be interactive, exploratory, and experimental in the virtual environment. For instance, AR/VR activities should elicit creation of new applications for learning by them, real-time solution-finding during experiments with different outcomes-for instance, virtual modification of factors in a science experiment or cause and effect interactions inside a historical simulation all the while thinking critically and actively engaging with the material. Such content through AR or VR must be more than just the ordinary visual spectacle. The content has to be relevant and challenging enough for students so that they think critically and solve meaningful problems. Such experiences may range from virtual experiments where the student can test hypotheses in real time to collaborative problem-solving exercises where groups of students are working together to share a common objective. This enables them to interact with the environment, handle the variables, and then observe what their efforts produce. It is one of the greatest motivators, in keeping students interested in the process of learning. Individual workstations are helpful where students are required to perform tasks at their own pace in the learner path. Now, in the case of AR/VR, each student can immerse himself or herself in the virtual experience at his or her own pace and spend more time on areas they need to practice or are interested in. Such a setting is ideal for topics for which learners require different time cycles to capture the concept, especially those in complex STEM fields where some learners take their time to get the concept while others can put it down immediately. However, individual learning is only but one constituent of a holistic experience in an AR/VR classroom. Group work within small groups also offers tremendous educational benefits. AR/VR can promote teamwork and collaborative problem-solving because students would involve mutual communication among peers toward the achievement of a common task. In the collaborative VR environment, probably every student in the group might be assigned different roles so that each member contributes toward solving a problem or completing any given task. For example, a whole class may be working in a virtual environment to research and explore a historical period where each student has a different segment of responsibility for the research or exploration. This will develop academic skills and some of the key soft skills like communication, teamwork, and leadership. Whole-class demonstrations are another rich environment in which learners might engage with AR/VR applications. This familiar setting allows the instructor to take the class on exploratory forays into complex concepts. The structure of having a whole-class web allows students to track along because the instructor controls the speed of the virtual exploration and the class moves as a unit. This method is very effective for the introduction of new material or general overview followed by breaking the students into smaller groups or individual activities to continue to investigate. For instance, she can allow the entire class to explore the solar system through a virtual tour, but focus on some major concepts. After that, students will be able to research specific planets or phenomena for more depth. The best approach to integrate AR/VR in the classroom is always leaving space for individual learning, group work, and demonstrations suitable for the whole class. The flexibility between the environments will give a student the advantages of personalized learning experiences and benefits from cooperative problem-solving. Ensuring also that the technology satisfies its optimum potential, servicing different learning types and creating a dynamic and interesting classroom environment, this creates the foundation for an optimal AR/VR content selection for the classroom. Indeed, while finding the right curriculum-aligned content is essential, the opportunities of active engagement by students should not be overlooked. The crucial aspect is that AR/VR experiences should help students to learn better-not only impressive visualization but through exploration, experimentation, and collaboration. Second, the learning environment should be designed to support all the modes of teaching: both individual exploration as well as interactive participation by groups of children. An appropriate content material, with 'tailoring learning environment', would make AR/VR just a powerful tool in transforming education and engaging the students.

Discussion on Results

It offers intense insight into impact on learning, engagement, and accessibility through education. Key findings: Interactive Simulations and 3D Visualization Give a New Kind of Student Engagement-the dynamic, hands-on experience calls for real-time execution of virtual experiments or dissections of complex structures to drive deeper understanding through direct and experiential learning. Virtual field trips open the frontiers of education - previously inaccessible environments and experiences are now effectively bridged between theoretical knowledge and real-world applications. The learning path is person-centered with high-quality resources; it equips students from undervalued communities to engage with content on a level field. Given its potential in evolution with technology, there is wide promise for education and much more for STEM applicants wanting to make abstract concepts reality with AR/VR, be it through science or cultural immersion programs. While many challenges abound regarding fair access to AR/VR hardware, preserving privacy, and overreliance on technology, considerations made toward relevant AR/VR content and actual alignment with curriculum goals maximize the potential of benefits to education. AR/VR has tremendous transformational potential but needs to be thought of in very careful handling of these challenges.

Unexpected Finding

More studies into introducing AR/VR-based learning into a classroom revealed findings that question the rhetoric and ideology surrounding immersive technologies and learning. The most surprising perhaps is that engagement among students varies with content type. Several assumed that AR/VR would please every student everywhere, but research found out that not everything can benefit equally from the use of these technologies. For example, in STEM courses like science or engineering, the engagement of students occurred during simulation or actual performance of virtual experiments, which was highly interactive and hands-on. For subjects like history or literature, where AR/VR hardly imposed much impact, then one can well argue that it is not useful for any course. The other is the increased presence of the teacher that occurs during the sessions about AR/VR. Traditionally, it was thought that AR/VR would steer the activity, needing little teacher input. Yet, through this study, it was established that in practice, teacher facilitation is required because students require constant attention for focus, awareness of education goals, and proper usage of the virtual environment. This means that rather than replacing their traditional teaching roles, AR/VR works best when used together with active participation by the teachers. Another logistical need was space for the safe use of VR headsets and physical settings. Most schools cannot afford this requirement. In addition, AR/VR can lessen disparity in learning in that each student will have an equal opportunity to learn with the same content of equal access to resources. Technical issues, as well as inequities in device accessibility, also became a problem within under-funded schools. Their inability to take full advantage of this new technology places the emphasis on improved school infrastructure and better access. That leads to some important findings about AR/VR, that this is really a highly promising technology tool for the classroom, but the actual implementation depends on good curricula design, appropriate training for teachers, and access to the technology itself.

Scope for further research

Even more would be in store with regard to AR/VR in classes as the technology would advance and the potential across education becomes even more defined. Long term effects on performance, and trends across age and across educational levels show great potential to be a future research area. Although there has been increased engagement and understanding of some topics during short-term studies, longitudinal studies are quite essential to find out how long-term use of AR/VR would affect knowledge retention, critical thinking, and problem-solving abilities. The use of AR/VR also impacts collaborative learning. While this research has focused the spotlight on what these technologies are used for by individuals, future research may unpack how AR/VR might be used in a setting that fosters teamwork, communication, and collaborative problem solving among students. Much also will be learned about the social dynamics of virtual environments and how such dynamics impact learning outcomes. Further, research would be required to develop AR/VR, such that it can be customized to accommodate individual student needs. Diversities and learning disabilities or special needs of the students should be able to find a way so that these can be inculcated into AR/VR content easily, thus enabling the students to learn better. And later on, scalability and accessibility will come under focus. It may thus be the most practical to be attentive to cost-effective ways of introducing AR/VR technology in a more balanced scale given that many schools, especially those in disadvantaged areas, really have limited resources and infrastructure. Some research areas, for example, could include partnerships with technology companies, developing affordable solutions in AR/VR, and alternative funding models. With more research into these trends, AR/VR could be even more impactful, universal, and scalable in the near future.

Conclusion

It is one of the really innovative possibilities that, in education, AR/VR can make learning dynamic, interactive, and immersive into subjects traditional teaching cannot. And its value proposition of adoption has thus far been pretty promising: higher engagement with subjects like STEM, where otherwise complex concepts can be assessed through simulations and hands-on activities. These technologies, therefore, bridge gaps between theoretical knowledge and practice, thus allowing students to experience environments they could not otherwise access, such as virtual field trips to historical sites, laboratories, or even far off cultures. Not all subjects apply equally well to AR/VR in education. While it is highly impactful in science and engineering, its effects on subjects like history or literature are less palpable and would therefore reflect that maybe, indeed, some fields might be more suited for distinct pedagogy in order for the technology to be used at its finest. On the other hand, teacher involvement is still important, as even the use of AR/VR does not replace guided instruction. Teachers play an important role in maximizing learning in the AR/VR experiences, meaning attention can remain focused on target objects and navigate vast virtual environments. While AR/VR may contribute to reducing educational inequity, its diffusion is still constrained in many under-resourced schools. Technical problems and unequal access to devices circumscribe the spread of this technology, thus prompting better infrastructure and the wide offering of more affordable options. Future research will focus on personalization as the technology would be used to match the needs for learning and better collaboration in virtual environments. Therefore, AR/VR can revolutionize education if proper planning, teacher involvement, and unequal access are well managed. Only above will make AR/VR a very effective medium for improvement in learning and success in various education settings.

References

1. Al-Azawi, R. Embedding augmented and virtual reality in educational learning methods: Present and future. In the 9th *International Conference on Information and Communication Systems (ICICS)*, 218-222. IEEE, 2018.
2. Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Alzahrani, A. I., & Sarsam, S. M. Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Studies in Educational Evaluation*, 66, Article 100876, 2020.
3. Antonioli, M., Blake, C., & Sparks, K. Augmented reality applications in education. *Journal of Educational Technology Development and Exchange (JETDE)*, 7(1), 63-77, 2014.
4. Ayoub, A., & Pulijala, Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. *BMC Oral Health*, 19(1), 1-8, 2019.
5. Beck, D. Augmented and virtual reality in education: Immersive learning research. *Journal of Educational Computing Research*, 57(7), 1619-1625, 2019.
6. Bernacki, M. L., Greene, J. A., & Crompton, H. Mobile technology, learning, and achievement: Advances in understanding and measuring the role of mobile technology in education. *Contemporary Educational Psychology*, 60, Article 101827, 2020.
7. Biswas, P., Orero, P., Swaminathan, M., Krishnaswamy, K., & Robinson, P. Adaptive accessible AR/VR systems. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*, 1-7, 2021.
8. Boyles, B. Virtual reality and augmented reality in education. *Center for Teaching Excellence, United States Military Academy, West Point*, 2017.
9. Cheng, K. H., & Tsai, C. C. A case study of immersive virtual field trips in an elementary classroom: Students' learning experience and teacher-student interaction behaviors. *Computers & Education*, 140, Article 103600, 2019.
10. Chen, P., Liu, X., Cheng, W., & Huang, R. A review of using augmented reality in education from 2011 to 2016. In *Innovations in Smart Learning*, 13-18. Springer, 2017.
11. Childs, E., Mohammad, F., Stevens, L., Burbelo, H., Awoke, A., Rewkowski, N., & Manocha, D. An overview of enhancing distance learning through augmented and virtual reality technologies. *arXiv preprint arXiv:2101.11000*, 2021.
12. Cieri, R. L., Turner, M. L., Carney, R. M., Falkingham, P. L., Kirk, A. M., Wang, T., & Farmer, C. G. Virtual and augmented reality: New tools for visualizing, analyzing, and communicating complex morphology. *Journal of Morphology*, 282(12), 1785-1800, 2021.
13. Criollo-C, S., Altamirano-Suarez, E., Jaramillo-Villacís, L., Vidal-Pacheco, K., Guerrero-Arias, A., & Luján-Mora, S. Sustainable teaching and learning through a mobile application: A case study. *Sustainability*, 14(11), 6663, 2022.
14. Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, A., & Luján-Mora, S. Mobile learning technologies for education: Benefits and pending issues. *Applied Sciences*, 11(9), 4111, 2021.

15. Du, R., Turner, E., Dzitsiuk, M., Prasso, L., Duarte, I., Dourgarian, J., … Kim, D. DepthLab: Real-time 3D interaction with depth maps for mobile augmented reality. In *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology*, 829-843, 2020.
16. Eckert, M., Volmerg, J. S., & Friedrich, C. M. Augmented reality in medicine: Systematic and bibliographic review. *JMIR mHealth and uHealth*, 7(4), e10967, 2019.
17. Elmqaddem, N. Augmented reality and virtual reality in education: Myth or reality? *International Journal of Emerging Technologies in Learning*, 14(3), 234-243, 2019.
18. Fu, Y., Hu, Y., & Sundstedt, V. A systematic literature review of virtual, augmented, and mixed reality game applications in healthcare. *ACM Transactions on Computing for Healthcare (HEALTH)*, 3(2), 1-27, 2022.
19. Gandedkar, N. H., Wong, M. T., & Darendeliler, M. A. Role of virtual reality (VR), augmented reality (AR) and artificial intelligence (AI) in tertiary education and research of orthodontics: An insight. In *Seminars in Orthodontics*, 27(2), 69-77, 2021.
20. Garzón, J., Pavón, J., & Baldiris, S. Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality*, 23(4), 447-459, 2019.
21. Gudoniene, D., & Rutkauskiene, D. Virtual and augmented reality in education. *Baltic Journal of Modern Computing*, 7(2), 293-300, 2019.
22. Guo, X., Guo, Y., & Liu, Y. The development of extended reality in education: Inspiration from the research literature. *Sustainability*, 13(24), Article 13776, 2021.
23. Hantono, B. S., Nugroho, L. E., & Santosa, P. I. Meta-review of augmented reality in education. In *10th International Conference on Information Technology and Electrical Engineering (ICITEE)*, 312-315. IEEE, 2018.
24. Huang, S. Augmented reality and virtual reality: The power of AR and VR for business. Springer, 2019.
25. Huang, K. T., Ball, C., Francis, J., Ratan, R., Boumis, J., & Fordham, J. Augmented versus virtual reality in education: An exploratory study examining science knowledge retention when using augmented reality/virtual reality mobile applications. *Cyberpsychology, Behavior, and Social Networking*, 22(2), 105-110, 2019.
26. Javornik, A. Augmented reality: Research agenda for studying the impact of its media characteristics on consumer behavior. *Journal of Retailing and Consumer Services*, 30, 252-261, 2016.
27. Kamińska, D., Sapiński, T., Wiak, S., Tikk, T., Haamer, R. E., Avots, E., … Anbarjafari, G. Virtual reality and its applications in education: Survey. *Information*, 10(10), 318, 2019.
28. Kim, C., Yoon, H. C., Kim, D. H., & Do, Y. R. Spectroscopic influence of virtual reality and augmented reality display devices on the human nonvisual characteristics and melatonin suppression response. *IEEE Photonics Journal*, 10(4), 1-11, 2018.
29. Köse, H., & Güner-Yildiz, N. Augmented reality (AR) as a learning material in special needs education. *Education and Information Technologies*, 26(2), 1921-1936, 2021.
30. Krüger, J. M., Buchholz, A., & Bodemer, D. Augmented reality in education: Three unique characteristics from a user's perspective. In *Proceedings of the 27th International Conference on Computers in Education*, 412-422, 2019.
31. Kumar, P. P., Thallapalli, R., Akshay, R., Sai, K. S., Sai, K. S., & Srujan, G. S. State-of-the-art: Implementation of augmented reality and virtual reality with the integration of 5G in the classroom. In *AIP Conference Proceedings*, 2418(1), Article 20069, 2022.

32. Lai, N. Y. G., Wong, K. H., Yu, L. J., & Kang, H. S. Virtual reality (VR) in engineering education and training: A bibliometric analysis. In *Proceedings of the 2nd World Symposium on Software Engineering*, 161-165, 2020.
33. Lavrentieva, O., Arkhypov, I., Kuchma, O., & Uchitel, A. Use of simulators together with virtual and augmented reality in education. *AIP Conference Proceedings*, 2020.
34. C. M. Jung and T. Dieck, *Augmented Reality and Virtual Reality: Empowering Human, Place and Business*, vol. XI, no. 5, 2018.
35. I. M. Kochi, M. Harding, R. Campbell, D. A. Ranyard, and D. Hocking, "Apparatus and method for augmented reality," vol. 2, no. 12, 2017.
36. M. H. Hilliges, D. Kim, S. Izadi, and D. Weiss, "Grasping virtual objects in augmented reality," vol. 1, no. 12, 2018.
37. M. Habashima, Y. Kurosawa, A. Alaniz, and G. May, "System and method for providing an augmented reality vehicle interface," vol. 1, no. 12, 2017.
38. M. Akçayır and G. Akçayır, "Advantages and challenges associated with augmented reality for education: A systematic review of the literature," *Educational Research Review*, doi: 10.1016/j.edurev.2016.11.002, 2016.
39. P. Chen, X. Liu, W. Cheng, and R. Huang, "A review of using augmented reality in education from 2011 to 2016," pp. 13–18, doi: 10.1007/978-981-10-2419-1, 2017.
40. M. Fernandez, "Augmented-Virtual Reality: How to improve education systems," *Higher Learning Research Communications*, vol. 7, no. 1, p. 1, doi: 10.18870/hlrc.v7i1.373, 2017.
41. J. Ferrer-Torregrosa, J. Torralba, M. A. Jimenez, S. García, and J. M. Barcia, "ARBOOK: Development and assessment of a tool based on augmented reality for anatomy," *Journal of Science Education and Technology*, vol. 24, no. 1, pp. 119–124, doi: 10.1007/s10956-014-9526-4, 2015.
42. U. Ozcan, A. Arslan, M. Ilkyaz, and E. Karaarslan, "An augmented reality application for smart campus urbanization: MSKU campus prototype," *5th International Istanbul Smart Grids and Cities Congress and Fair*, pp. 100–104, doi: 10.1109/SGCF.2017.7947610, 2017.
43. P. H. Wu, G. J. Hwang, M. L. Yang, and C. H. Chen, "Impacts of integrating the repertory grid into an augmented reality-based learning design on students' learning achievements, cognitive load, and degree of satisfaction," *Interactive Learning Environments*, vol. 26, no. 2, pp. 221–234, doi: 10.1080/10494820.2017.1294608, 2018.
44. L. Johnson, S. Adams Becker, V. Estrada, and A. Freeman, *New Media Consortium Horizon Report: 2015 Museum Edition*, 2015.
45. V. Marín-Díaz, "The relationships between augmented reality and inclusive education in higher education," *Bordón. Revista de Pedagogía*, vol. 69, no. 3, p. 125, doi: 10.13042/bordon.2017.51123, 2017.
46. F. Saltan, "The use of augmented reality in formal education: A scoping review," vol. 8223, no. 2, pp. 503–520, doi: 10.12973/eurasia.2017.00628a, 2017.
47. C. J. Dede, J. Jacobson, and J. Richards, *Introduction: Virtual, Augmented, and Mixed Realities in Education*, 2017.
48. H. Tobar-Muñoz, S. Baldiris, and R. Fabregat, "Augmented reality game-based learning: Enriching students' experience during reading comprehension activities," *Journal of Educational Computing Research*, vol. 55, no. 7, pp. 901–936, doi: 10.1177/0735633116689789, 2017.

49. R. Cakir and E. Solak, "Exploring the effect of materials designed with augmented reality on language learners' vocabulary learning," *Journal of Educational Online*, vol. 13, no. 2, pp. 50–72, doi: 10.1016/0196-9781(88)90009-5, 2015.
50. S. L. Thorne and J. Hellermann, "Contextualization and situated language usage events: Proceedings of the Mobile Augmented Reality: Hyper-contextualization and Situated Language Usage Events," no. July, 2017.
51. N. Zainuddin and M. S. Sahrir, "Multimedia courseware for teaching Arabic vocabulary: Let's learn from the experts," *Universal Journal of Educational Research*, vol. 4, no. 5, pp. 1167–1172, doi: 10.13189/ujer.2016.040529, 2016.
52. N. Zainuddin, M. S. Sahrir, R. Idrus, and M. N. Jaafar, "Scaffolding a conceptual support for personalized Arabic vocabulary learning using augmented reality (AR) enhanced flashcards," *Journal of Personalized Learning*, vol. 2, no. 1, pp. 102–110, 2016.
53. B. Perry, "Gamifying French language learning: A case study examining a quest-based, augmented reality mobile learning tool," *Procedia - Social and Behavioral Sciences*, vol. 174, pp. 2308–2315, doi: 10.1016/j.sbspro.2015.01.892, 2015.
54. D. N. E. Phone, M. B. Ali, and N. D. A. Halim, "Learning with augmented reality: Effects toward students with different spatial abilities," *Advanced Science Letters*, vol. 21, no. 7, pp. 2200–2204, 2015.
55. J. Bacca, S. Baldiris, R. Fabregat, Kinshuk, and S. Graf, "Mobile augmented reality in vocational education and training," *Procedia Computer Science*, vol. 75, pp. 49–58, doi: 10.101
56. H. F. Hanafi, C. S. Said, M. H. Wahab, and K. Samsuddin, "Improving students' motivation in learning ICT courses with the use of a mobile augmented reality learning environment," *IOP Conference Series: Materials Science and Engineering*, vol. 226, no. 1, doi: 10.1088/1757-899X/226/1/012114, 2017.
57. Y. H. Wang, "Using augmented reality to support a software editing course for college students," *Journal of Computer Assisted Learning*, vol. 33, no. 5, pp. 532–546, doi: 10.1111/jcal.12199, 2017.
58. S. Cai, F. K. Chiang, Y. Sun, C. Lin, and J. J. Lee, "Applications of augmented reality-based natural interactive learning in magnetic field instruction," *Interactive Learning Environments*, vol. 25, no. 6, pp. 778–791, doi: 10.1080/10494820.2016.1181094, 2017.
59. C. Moro, Z. Štromberga, A. Raikos, and A. Stirling, "The effectiveness of virtual and augmented reality in health sciences and medical anatomy," *Anatomical Sciences Education*, vol. 10, no. 6, pp. 549–559, doi: 10.1002/ase.1696, 2017.
60. P. E. Pelargos et al., "Utilizing virtual and augmented reality for educational and clinical enhancements in neurosurgery," *Journal of Clinical Neuroscience*, vol. 35, pp. 1–4, doi: 10.1016/j.jocn.2016.09.002, 2017.
61. S. J. Lu and Y. C. Liu, "Integrating augmented reality technology to enhance children's learning in marine education," *Environmental Education Research*, vol. 21, no. 4, pp. 525–541, doi: 10.1080/13504622.2014.911247, 2015.
62. G. J. Hwang, P. H. Wu, C. C. Chen, and N. T. Tu, "Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations," *Interactive Learning Environments*, vol. 24, no. 8, pp. 1895–1906, doi: 10.1080/10494820.2015.1057747, 2016.

63. M. T. Yang and W. C. Liao, “Computer-assisted culture learning in an online augmented reality environment based on free-hand gesture interaction,” *IEEE Transactions on Learning Technologies*, vol. 7, no. 2, pp. 107–117, doi: 10.1109/TLT.2014.2307297, 2014.
64. F. Giard and M. J. Guitton, “Spiritus Ex Machina: Augmented reality, cyberghosts, and externalized consciousness,” *Computers in Human Behavior*, vol. 55, pp. 614–615, doi: 10.1016/j.chb.2015.10.024, 2016.
65. A. Tesolin and A. Tsinakos, “Opening real doors: Strategies for using mobile augmented reality to create inclusive distance education for learners with different abilities,” pp. 59–80, doi: 10.1007/978-981-10-6144-8_4, 2017.
66. C. Y. Lin et al., “Augmented reality in educational activities for children with disabilities,” *Displays*, vol. 42, pp. 51–54, doi: 10.1016/j.displa.2015.02.004, 2016.