Designing a Curriculum With Custom and Present Virtual Reality

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Abstract
The pandemic has created many challenges for education. Despite many schools now having already returned to instruction in-person as opposed to the challenge of doing so virtually, many have adapted to the new normal of having hybrid modes of instruction. One of these methods is through VR/AR technology. This paper will discuss how custom VR/AR applications can be used for education; particularly on how to design a curriculum which incorporates pre-selected research areas that can be made by teachers through educational software to be visualised in VR/AR for students to directly experience the areas and how students can also be directed to model these areas as part of their learning. How this and leveraging available resources for learning for common subjects such as Chemistry from seeing 3D visualisations of molecules can create an interactive classroom, whether it be in-person or virtual, would be engaging to students will be discussed and how these experiences can be best adapted to fit such experiences will then be discussed. As part of this, a case study based on the authors' experience will also be included to discuss how a custom VR application based on a research area that students in a course are currently researching the area needed and how it became a core part of the course's curriculum. Finally, the authors will discuss the future of virtual reality for education and how it serves as a solid foundation to build on for creating further interactive curriculums of the future.

Keywords: Adaptive Instruction, Education Models, Hybrid Delivery, Innovation, Multidisciplinary Education

Introduction

In 1992, sci-fi writer Neal Stephenson coined the term ‘metaverse’ in describing 3D virtual spaces, which would then go about being adopted as the vision for virtual reality, such as with Mark Zuckerberg’s announcement of Meta on 28 October 2021, the new branding of Facebook towards being oriented with the metaverse. With the Covid-19 pandemic present and with trends such as remote learning and online education prevalent due to it, this concept became a more accepted, plausible future to also move towards within our communities. According to Noesgaard et al., the effectiveness of e-learning would be evaluated by the quality of the interaction that is provided and that it should provide a purposeful place to reflect on the practice and have the content customised based on the subject matter. Online education or E-learning has seen many new ways of learning being developed, with many studies focusing on new forms of learning which can bring about the best student engagement.

In the present curriculum, we have seen many institutions start to introduce virtual reality to immerse students in their learning. From its usage in chemistry such as with being able to visualise atoms to getting a walkthrough a particular designated area without having to be there using a virtual reality headset, the use cases range within a multitude of use cases. However, the problem with current implementations is that the experiences that are provided are only generalised; in which instructors have to find resources either on the internet or through what has been used by the school. Oftentimes, the need for a curriculum to be tailored towards the needs of the student requires more custom solutions to be developed. This paper will discuss and explore how instructors can implement custom virtual reality solutions into the curriculum, how students can be engaged to develop such solutions as well to increase their comprehension within their learning experience, and how existing resources can be leveraged to complement these custom solutions as part of enhancing the students’ experience.

Literature Review

The considerations of e-learning have been much affected by the emergence of Covid-19. Factors that have been found to affect the engagement of students with the curriculum and hence boosting the effectiveness of the curriculum have been the e-learning efficacy, resilience and the instructional innovation from teachers, as discussed by Ahmed et al. This was also further built on by the findings by Bączek et al. on how e-learning has been less effective than face-to-face learning in increasing skills, especially on courses that normally require IT resources which normally would not be available in the average student’s home. From this, customization to the curriculum is needed; with the hybrid learning of today, we need to be ready to build for both in-person and distance learning.

Frameworks for building VR applications for education have been covered in multiple works, such as with Nguyen et al. 's (2017) work in creating learning environments for VR applications within the curriculum. The development of such work for creating a framework for the curriculum was further examined by Paszkiewicz et al. (2021) where the authors detail designing a curriculum for a study of digital circuits. Related work that currently exists showcases the use of VR for the sake of learning VR itself and its prevalence for select use cases but does not discuss a generalised approach of teaching tailored approaches within classrooms that both involve the student and the instructor taking part in the design. This is a crucial area which the paper looks to address and build on what has already worked from the authors’ work in proposing the generalised approach.

There have been numerous studies concerning how virtual reality has been used within courses, both for in-person and distance learning. Broman et al. described how VR can be combined with Zoom in teaching chemistry, showcasing how students can develop their spatial ability even from a distance. They detail how visualising structures have helped students grasp a better understanding of them compared to just teaching them through traditional means, with instructors sometimes using terminology that may sound vague if not visualised, such as with usage of the term 'plane' in the context of a subject, which consequently also increases their engagement with the topic. Lu et Al. further expands on this by showcasing how they create a software that can be used for the purposes of remote education in experimental chemistry. Despite the papers' coverage of systems to accommodate for both in-person and distance learning as well as in its contributions in suggesting what to create for it, there is no current coverage of implementing customised learning for specific subject matter within the curriculum, both for teachers and students to design and interact with. This is hence what the paper aims to focus on and aims to propose as a means of tailoring education through the VR experience as part of the overall curriculum.

Methodology

This paper will use a qualitative study employing narrative analysis as an approach to analyse students' responses towards the customised learning proposed by the paper through a case study that puts in place such a system accompanied by gathering quantitative data for the analysis done through surveying students within a classroom. According to Figgou, narrative analysis refers to a cluster of analytic methods for interpreting texts or visual data that have a storied form. This would be appropriate for our study given that VR-based learning should be focusing on the students' experiences, particularly given that much information about this cannot be gained from just statistical data that would have been needed from a quantitative analysis but can still be supported and interpreted based on it while also getting quantitative data to support it.

This data was based on research between 2020 and 2022, the peak years of the pandemic, with the case study being done over a span of January to June of 2022, in which the development of the custom VR application for a curriculum was developed and implemented as part of it. The survey as part of the quantitative element of the research was done in April 2022. We will focus on addressing three themes in this analysis: challenges students currently face as part of distance education with VR, how customised VR applications can address these challenges and the future of such education alongside students' hopes and aspirations of how it will help them in their learning.

The customised application created as part of this research was a representation of a research area in Victoria, Australia, where students could explore the modelled area based on actual terrain data that was obtained. The approaches were later then documented, and the application implemented as part of the curriculum in introducing students who were also doing research within the area to first explore the area without having to be there in-person, which was especially effective given the efficiency of the activity and the restrictions in place limiting research activity due to Covid-19 during that time.

Engagement & Curriculum Embedment

With the use of virtual reality, remote learning provides a sense of community for the students, whereas in person use of VR tools in the classroom allows students to construct a

comprehensive view of the subject. In 2020, Yoshimura and Borst conducted a study that allows students to use VR headsets during their 7 weeks of online sessions. Students who did not experience motion sickness have found the VR learning experience to be useful and engaging since most students were able to perceive the presence of their instructor and peers (Yoshimura and Borst, 2020, p. 3). When comparing different modes of instruction, although students prefer in-person learning slightly better, they prefer VR learning when compared to traditional remote teaching due to engagement (Yoshimura and Borst, 2020). Similarly, some institutes in the United States have already begun to explore the possibilities of conducting classes using virtual reality. A student from University of Pennsylvania who was able to participate in seminars using VR reported that she was able to recall what happened in class better compared to seminars on zoom, and that the virtual reality world makes online learning less detached from real life (Metz, 2022).

Without neglecting students' need for social interaction, customised virtual reality courses can be embedded into the curriculum that transforms rote learning into proactive learning for the mind. To achieve efficiency, the modern way of teaching usually provides core ideas to the students without having them fully absorb the mechanism; this can usually be seen in teaching methods that are standardised test-oriented. But for many subjects that are required for students to earn their degrees, the concepts are abstruse and likely to form in their short-term memory which provides them no sustained benefits. To illustrate, in an article written by Costandi — a neuroscience writer — he talks about how important mental imaging is in the classroom, explaining that it is crucial for students to comprehend what they have learned (2016). Examples of what can be learned better include new vocabularies, computer science, and mathematics, given that the students can visualise in their minds what is happening (Costandi, 2016). Furthermore, in a study conducted by Evagorou et al., after reading the notebooks of several scientists, they have concluded that impactful scientists such as Watson and Crick or Faraday relied heavily on visualisation as scientific evidence for their discoveries (2016). They urge that the aspect of visual data should not be ignored in the teaching of science (Evagorou et al., 2016).

Aside from the benefits in terms of mental stimulation, virtual reality in education also poses the possibility of conducting training sessions in a safer approach. For example, having a practice-customised VR chemical lab session before in-person labs will reduce the rate of students being injured during lab training, helping the students increase their familiarity with the experimental procedure and lessen the use of resources. VR customization in this scenario can be efficient as students can see (as an example of a Winkler titration reaction) the consequences of having an unbalanced stoichiometric ratio for reacted thiosulfate and iodate when compared to literature. Similar practices have been used in medical training during the COVID-19 pandemic by the School of Medicine of the University of Insubria, Italy. 122 medical students were assigned to perform online training sessions that simulate clinical scenarios such as cardiovascular or nephrological cases mentored by an experienced tutor (De Ponti et al., 2020). Although the training sessions were conducted using virtual reality, students still reported 94% positive reviews obtained as feedback for the realistic diagnostic activity (De Ponti et al., 2020). With customised virtual reality and manual practice, most students will be able to bolster what they have learned by practising mentally and physically. The integration of technology can also be exerted on high school students to incite their interest in different disciplines as part of choosing a path for their careers.

In developing a curriculum that integrates VR into it, schools will have to start off their planning by first finding the areas which could potentially use visualisation to help increase

student interaction with the material, as not all material in all subjects would benefit from such visualisation. They must consider three factors in deciding whether to implement VR within a certain topic of a subject: development, interactivity and creativity. With development, students need to be able to develop their understanding and fulfil the learning outcomes based on the material with VR. With interactivity, students need to be able to fully interact with the material in such a way that would have not been possible with just teaching it through traditional means. With creativity, students need to be able to remember the material and understand why things are as such better compared to traditional teaching means more creatively.

After considering which topic to embed the use of VR in, they need to consider where they will find the resources as part of that. This will need them to look for resources currently available for their own subject use case context. This may include online sources, currently available VR headsets (if any), potential partnerships with VR providers, or through working with their local counties based on the venture put out by the country's board of education. They may also have to tap into their own school funds when necessary, in investing into this venture, which requires them to set aside extra budget for this. Therefore, it is crucial for there to be more discussions with boards of education and subsidies to be given by relevant stakeholders for this venture.

With the available material, they need to develop relevant experiences as part of what they aim to teach. With available VR applications, they can do this simply by directly taking applications off the internet or the resources from the school and use them for learning purposes, but if they are for specialised, custom purposes, they need to spend time creating those. As part of this, they need to undertake training on creating VR applications with specific software such as Unity or Unreal Engine and on how to utilise the headsets. Conversely, these training experiences can also be given to students as well, should the needs of the education fit the need for them to learn VR application development skills and that they can remember the material with more ease that way. This would create interactivity and tailored solutions for both the instructor and the student.

As most schools would most likely not have had VR experiences embedded into their curriculum yet, a pilot program would be necessary to see how the experiences have performed. This would involve the teachers putting forward the VR experience within a certain topic and getting students to then fill in a post-experience survey to see how they have enjoyed the learning experience and whether it was more effective for them. Teachers can also track this from comparing the performance of students within their class before and after the VR experiences they had created for their classroom were put in place. This would also allow for continuous improvement of the VR experience within the classroom, as changes can be made continuously and adjusted based on students' suggestions, given that they have to be the ones leading the change as well with how they find the new learning experience has impacted them overall.

Questionnaire

A questionnaire was provided to high school students in grades 10 and 11 who studied in a private international school located in Taiwan during their synchronous online honours chemistry class. In the questionnaire, high school students were asked five questions regarding the use of virtual reality in their learning experience. The questions include whether the students have used any kind of virtual reality in the past, if they have used the technology

for educational purposes, and if personalised virtual reality content would be helpful towards their learning goals. We have utilised a Likert scale for the students to indicate the extent of interest in VR learning, but also include short answers to questions that require elaboration. The use of a questionnaire allows students to participate rapidly and reflectively. It is important to note that before the questions were given to the students, the instructor had given them a demonstrative video of stimulation to hydrogen burning reaction to give them some context of scientific modelling.

Results

In the questionnaire, we have found that while more than half of the individuals have used virtual reality before, none of them have used it for educational purposes (figure 1). In a short answer question on the thoughts of using virtual reality in education, although a few individuals are not entirely sure if the technology will benefit their studies, most of the students are willing to integrate the technology into the classroom in hopes of making the class more interactive. It can be seen from some of their short answer responses:

"Maybe the class will be more interesting [with VR being used in lessons]."
"It's fun and it helps me focus more on [the studying material]."

There are also some students that worry the use of virtual reality may be abused by other students in the classroom:

"Students would probably just mess around."
"I'm sure it might have its usages, although I'm not exactly sure if [virtual reality is] an entirely necessary classroom feature."

Regarding the use of demonstrative videos that reflect what virtual reality can provide, half of the students have found the stimulation to be very helpful for visualising chemical reactions while the other half find it partially helpful (figure 2). When being asked which type of teaching method employed by the teachers would be most helpful to them, most students comply with the use of technology in the classroom but only a few state that immersive teaching methods can be helpful (figure 3). This can be because none of the students have tried virtual reality before, therefore whether this method will aid them in their studies is purely a prediction for them.

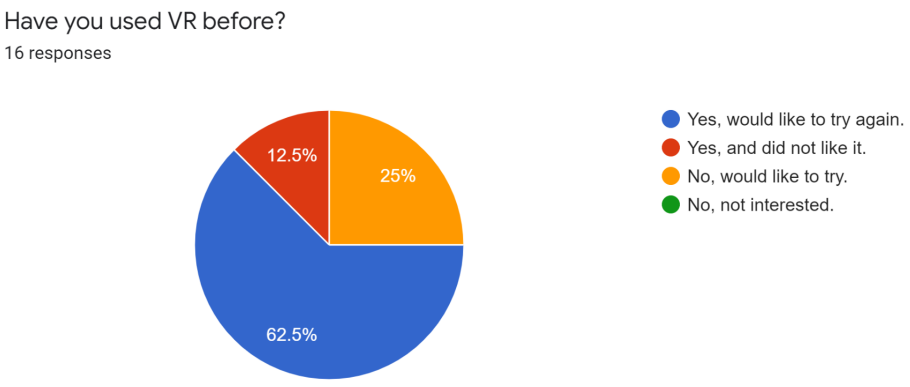

Figure 1. Virtual reality experience. Percentage of students' response to whether they have used any kind of virtual reality in the past, and the degree of interest.

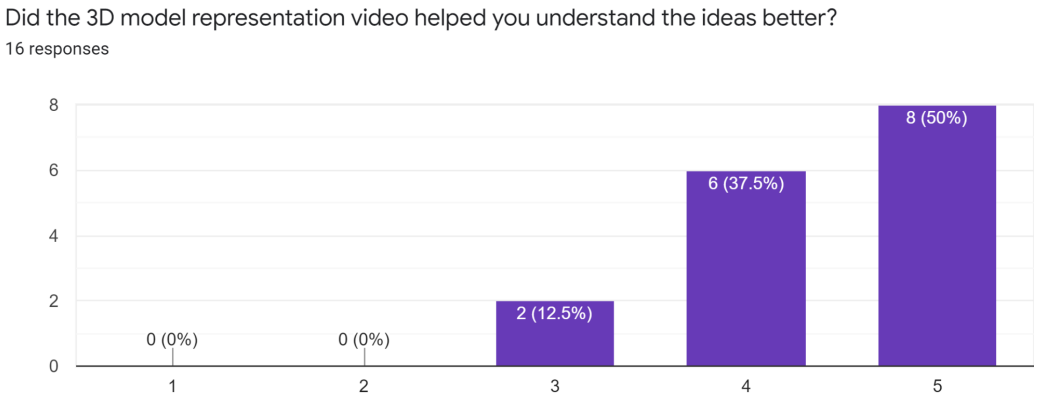

Figure 2. Using demonstrative video for modelling of chemical reactions. The students rank the degree of helpfulness to the understanding of concepts.

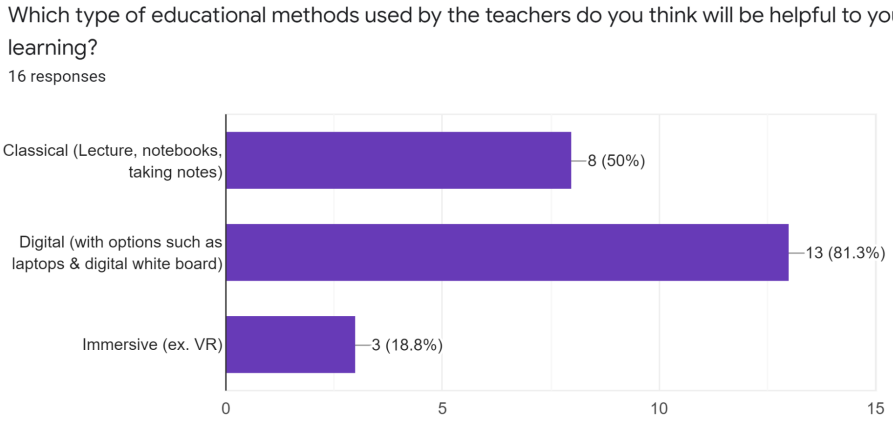

Figure 3. Educational methods. Students state which methods might aid them in learning.

Adding to this, it was also seen that the case study based on the custom VR application created for the purposes of research has been proven to serve as supporting material better suited towards students' interests. As part of a spatial engineering subject, an application was created which aimed to show a section of the area being researched, as there were no currently existing models that would show optimal resolution in this experience. As such, the VR experience was built based on showcasing it as an application, letting students customise their experience as such and instructors to better talk through the area, given that they can experience it in real time.

As part of this process, some informal training was undertaken in order to get a grasp of tooling within Unity, the software in which the application was developed. Terrain data was then collected over the research area to be used for modelling the area within Unity. The custom application was then developed, with a report outlining how it can be used and the intentions of the application. Afterwards, the application and the report were included in an introductory segment of the curriculum of a research subject. Students who have taken the subject have commented that they feel that they have been more prepared for undertaking the research, given that they have seen the area first-hand, albeit it being only virtually at that stage.

Discussion

From the classroom teacher's observation and communication to the researchers, students who have the best grades in class showed a diverging interest in the use of virtual reality in class. Those students are either willing to try or worried that the class discipline will be disrupted. Students who have average grades overall tend to be more enthusiastic about the possibility of using new methods for studying. What this result may reflect is that students with better grades that are less willing to try virtual reality may have already been accustomed to the current learning method and felt that they should employ the same method because they are getting results from it. Students who still have rooms for improvement are generally more receptive to trying out new ways of learning, such as the use of virtual reality. To them, VR may offer them a possibility of obtaining a better grade. Although not applicable to every individual, using virtual reality as a tool may potentially help students develop a new studying method that integrates what they were taught and have imagined. Customised programs will be able to fortify students' weaknesses, leading to a substantial foundation for higher education.

In addition, contemplating the degree of helpfulness of using modelling videos as part of demonstrating chemical reactions (figure 2), it can be hypothesised that if the videos can be introduced to the students using virtual reality, the students will find it to be more helpful because it will allow them to explore the immersive space, size of atoms, and see the chemical reaction as if it is happening concurrently. This hence would achieve the goal of using entertainment as a hook to education (Roepke, 2019).

The qualitative study also shows that students also enjoy getting a more first-hand experience that VR would be able to provide them rather than just theoretical or conceptual knowledge that they would have received from just learning without the practical element. It can also be seen that it is not difficult for instructors to be accustomed to utilising and developing these kinds of customised experiences (if they are unavailable by default), given that they can utilise many online sources as part of their learning as well. Consequently, students can also utilise these same sources and develop solutions of their own as part of their learning, which also enhances their understanding of both the tools necessary and the topics they are learning.

To better understand the specifics of what a learner would perceive as helpful in education and technology, further research and questions need to be asked. This questionnaire is a prelude of how the students perceive the use of technology and if learning with virtual reality has been introduced in the past. For future research, the engagement of customised virtual reality, participation, and whether the resulting product matches students' expectations can be further explored.

Challenges for VR education

Apart from the cost of purchasing virtual reality headsets for the students, the major disadvantage of virtual reality in education is the lack of a standardised curriculum (Fransson et al., 2020). Without a fixed curriculum for the teachers to follow, educators will need additional training and students will need to adapt to the unfamiliar learning experience. Also, in terms of equity and inclusiveness, whether the use of virtual reality should be embedded into the national curriculum or be utilised as a supplemental material should be discussed by the country's board of education, given that there may be differences in resource allocation and funding for different school districts.

Limitations and Future Research

One limitation that the research encountered was that given the lack of VR technology in the school where the quantitative research was performed, students were not able to get hands-on experience on the technology itself which could possibly affect their responses. In general, it is notable that VR technology is still a novel concept in many teaching environments and many do not yet have access to them. This is, however, substantiated with seeing the success students came across with the customised VR solution developed within the university case context.

As a continuation to the studies done in this paper, future research could focus on a longitudinal study focusing on gauging how a curriculum performs when VR is a major part of it over multiple semesters, seeing how its inclusion would affect students' performance compared to the normal curriculum. As with this study, this could be performed on a chemistry subject or any other subject, where there could be substantial benefit with including VR as part of teaching it. This would also further enhance the case for schools to invest more within VR technology to strengthen their students' understanding of the curriculum and to further promote new ways of learning.

Conclusion

From this research, there are clearly many benefits with including custom VR/AR solutions into education curriculums. This is evidenced from the quantitative research demonstrating how students' perceptions towards VR have shown their interest towards the technology and their experience believing that they will find it to work well as part of their education and the qualitative analysis showing how a customised solution has been well received within research. Though there are still many challenges and limitations, including the lack of VR technology available in many schools, there is still much potential for research within the area towards the benefits that including VR in education can bring to students. Towards the future, VR will continue to be a deeply researched area within education, and it is the authors' hopes that this paper will contribute towards getting more researchers to build on this paper towards building more of a case towards making VR technology more accessible to schools, given the clear benefits that it provides towards students' experience within education.

References

Bączek, M., Zagańczyk-Bączek, M., Monika, S., Andrzej, J., & Beata, W.-K. (2021). Students' perception of online learning during the COVID-19: Medicine. *Medicine*, *100*(7). https://doi.org/10.1097/MD.0000000000024821

Broman, K., Chorell, E., & Holmboe, M. (2021). Virtual Reality and Zoom in combination to visualise chemical structures and develop students' spatial ability during the Corona pandemic. *Book of Abstracts: 9th European Variety in University Chemistry Education Conference EUROVARIETY 2021*, p. 60. University of Ljubljana.

De Ponti, R., Marazzato, J., Maresca, A. M., Rovera, F., Carcano, G., & Ferrario, M. M. (2020). Pre-graduation medical training including virtual reality during COVID-19 pandemic: a report on students' perception. *BMC Medical Education*, *20*(1). https://doi.org/10.1186/s12909-020-02245-8

Evagorou, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to "seeing" how science works. *International Journal of STEM Education*, *2*(1), 11. https://doi.org/10.1186/s40594-015-0024-x

Ferrell, J. B., Campbell, J. P., McCarthy, D. R., McKay, K. T., Hensinger, M., Srinivasan, R., … Schneebeli, S. T. (2019). Chemical Exploration with Virtual Reality in Organic Teaching Laboratories. *Journal of Chemical Education*, *96*(9), 1961–1966. ACS Publications. https://doi.org/10.1021/acs.jchemed.9b00036

Fransson, G., Holmberg, J., & Westelius, C. (2020). The challenges of using head mounted virtual reality in K-12 schools from a teacher perspective. *Education and Information Technologies*, *25*(4), 3383–3404. SpringerLink. https://doi.org/10.1007/s10639-020-10119-1

Lin, M. T.-Y., Wang, J.-S., Kuo, H.-M., & Luo, Y. (2017). A Study on the Effect of Virtual Reality 3D Exploratory Education on Students' Creativity and Leadership. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(7). https://doi.org/10.12973/eurasia.2017.00709a

Lu, Y., Xu, Y., & Zhu, X. (2021). Designing and Implementing VR2E2C, a Virtual Reality Remote Education for Experimental Chemistry System. *Journal of Chemical Education*, *98*(8), 2720–2725. https://doi.org/10.1021/acs.jchemed.1c00439

Metz, R. (2022, January 27). Forget Zoom school. For some students, class is in session in VR. Retrieved May 4, 2022, from CNN website: https://edition.cnn.com/2022/01/27/tech/vr-classes/index.html

Mo Costandi. (2016, June 4). If you can't imagine things, how can you learn? Retrieved May 12, 2022, from the Guardian website: https://www.theguardian.com/education/2016/jun/04/aphantasia-no-visual-imagination-impact-learning

Nguyen, V. T., & Dang, T. (2017, October 1). Setting up Virtual Reality and Augmented Reality Learning Environment in Unity. https://doi.org/10.1109/ISMAR-Adjunct.2017.97

Paszkiewicz, A., Salach, M., Strzałka, D., Budzik, G., Nikodem, A., Wójcik, H., & Witek, M. (2021). VR Education Support System—A Case Study of Digital Circuits Design. *Energies*, *15*(1), 277. https://doi.org/10.3390/en15010277

Roepke, J. (2019, October 5). Solving these 5 issues will make education AR/VR go mainstream. Retrieved May 4, 2022, from VentureBeat website: https://venturebeat.com/2019/10/05/solving-these-5-issues-will-make-education-ar-vr-go-mainstream/

Yoshimura, A., & Borst, C. W. (2020). Remote Instruction in Virtual Reality: A Study of Students Attending Class Remotely from Home with VR Headsets. *In: Hansen, C., Nürnberger, A. & Preim, B. (Hrsg.), Mensch und Computer 2020 - Workshopband. Bonn: Gesellschaft für Informatik e.V.*. DOI: 10.18420/muc2020-ws122-355

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