IMMERSIVE VIRTUAL REALITY (VR) CLASSROOM TO ENHANCE LEARNING AND INCREASE INTEREST AND ENJOYMENT IN THE SECONDARY SCHOOL SCIENCE CURRICULUM

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ABSTRACT

This paper describes how an Immersive Virtual Reality (VR) Classroom in a secondary school in Singapore is used to enhance learning through visualization and deepen understanding of science and increase interest and enjoyment in science. The VR Classroom is a futuristic classroom that taps the affordances of VR and AR to enhance HCI (Human-Computer Interactions) through visualization and interactivity, as well as increase engagement and enjoyment in the school curriculum. About the size of a regular classroom, this VR Classroom has three units of Oculus Rifts coupled adorned with life-size wall Augmented Reality posters of the Coronavirus and cells. Drawing from the author's experience in implementing VR lessons as a part of everyday classroom practice, this paper aims to provide practical ideas for educators to leverage on the affordances of virtual reality technologies to plan and design VR lessons. The author will also share sample lesson ideas on how educators can use VR 360 degrees videos to reach out to their students during this COVID-19 pandemic to complement the inquiry learning experience. The immersive and interactive nature of VR makes it an ideal tool for differentiated instruction to cater to diverse learners and learning needs especially during this pandemic. Data from findings using grounded theory and quantitative studies on affective outcomes show that there is significant increase in students' enjoyment in learning science when immersive VR is used and that the use of immersive VR increases students' self-efficacy. These findings have implications on the pedagogical design of lessons that use immersive VR.

KEYWORDS

Immersive Virtual Reality, VR, Augmented Reality, AR, Visualisation, Science, Interest, Enjoyment, Oculus, VR Classroom, COVID-19, 360 Degrees Video

1. INTRODUCTION

The learning of science in secondary schools in Singapore is still largely teacher and textbook-centric. Most materials used in classrooms are two-dimensional (2D), such as textbooks and images or videos projected on the large screen. Models such as DNA, working of heart chambers and action of enzymes tend to have 2D 'imagination-caused spatial misunderstanding' that results in misconceptions in science. Interactions between teacher and student still largely didactic with dominance of teacher instruction. Such two-dimensional traditional media also does not offer any form of feedback to students in learning if wrong variables are inputted or if certain conditions are given to the system. Realistic 3D visualisation with feedback programmed through computer simulations can assist students to learn by inquiry scientific concepts and processes.

Immersive Virtual Reality (VR) offers the capabilities of dynamic representation of microscopic worlds such as cells and molecules that can give rise to a more accurate reasoning to explain scientific phenomena. They have the potential to revolutionise and improve the learning of science by enhancing visualisation, interactivity and realism, or presence. This is especially true for dynamic scientific processes that are either too dangerous, minute, or costly to observe, such as the fractional distillation columns in petroleum refinery, working of heart chambers and other body organs, and the minute environment of cells and unicellular organisms.

In Singapore, the current fourth ICT Masterplan for Education focuses on promoting active learning with technology, using technology to provide feedback to learners and enhance the ability of learners to collaborate and learn together. Singapore's Ministry of Education (MOE) has also rolled out the SLS (Student Learning

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Space), an online platform for students' learning about three years ago. This is accompanied by the lesson design tool called the SLS Pedagogical Scaffold that is embedded within the SLS platform for educators to plan active learning using technology with the help of active learning processes for each step of the lesson. Immersive VR can also support differentiated instruction as some learners require more hands-on experiential or visual learning approaches to understand scientific concepts. Authentic learning contexts and immersive virtual experiences can help students see relevance in their learning. This increases the likelihood of students choosing science-related careers which is vital for Singapore's competitiveness.

2. LITERATURE REVIEW

2.1 Benefits of VR/AR Technologies

Immersive VR technologies allow multi-sensory interaction and learners can construct meaning from experience. It makes the teaching of complex or abstract ideas useful as it provides a means of visualization and allows natural hypothesis making (Christou, 2010). Research from the River City project in the US and Canada showed that immersive, authentic, and supportive virtual environments can produce substantial gains in knowledge and skills in scientific inquiry and problem-solving (Dede, 2009). Immersive virtual environments also support diverse profiles of students such as academically weak students or students who are comfortable with learning from digital technologies and builds their self-efficacy and confidence in performance tasks.

Immersive VR is a powerful tool for students can apply their scientific knowledge in realistic settings and increase transfer of learning to the real world. This is due to better generalisation of learning, which occurs when there is increased similarity between training and real-world tasks (Schultheis and Rizzo, 2001). An immersive VR software called VISE developed by Keio-NUS (National University of Singapore) CUTE Centre enables medical students to practice the skills of responding and handling patients injured in an emergency scenario (NUS, 2019). VR controllers are used to assess the conditions of casualties be it excessive bleeding, wound or even death. The simulation allows medical students to familiarise with the triage methodology process by going through the actual motions of assessing casualties (Figure 1).

Figure 1. Vise immersive VR software used to train medical students

2.2 Immersive VR Classrooms

The VR School Research Project (Southgate et al., 2019) is a major project conducted in two government junior high schools in New South Wales (NSW), Australia that studied the affective, cognitive and safety aspects of using VR for children and teenagers. Findings include the need to translate the motivation to collaborate into pedagogy for on-task behaviour and respectful ethics in the use of VR Head Mounted Devices (HMD) including how to respond for example if the VR interactions got too intense or uncomfortable. The students had access to three Oculus VR headsets as they worked together to build virtual 3D objects in Minecraft VR. On the other hand, schools such as Cecil Hills High embarked on low-cost self-made immersive VR Cardboards to access VR 360 degrees videos to broaden their students' experiences as they go on virtual tours (NSW, 2020). A student reported that his marks improved because he became more engaged. Others felt that VR created a more empathetic feeling through videos presenting social issues. See Figure 2.

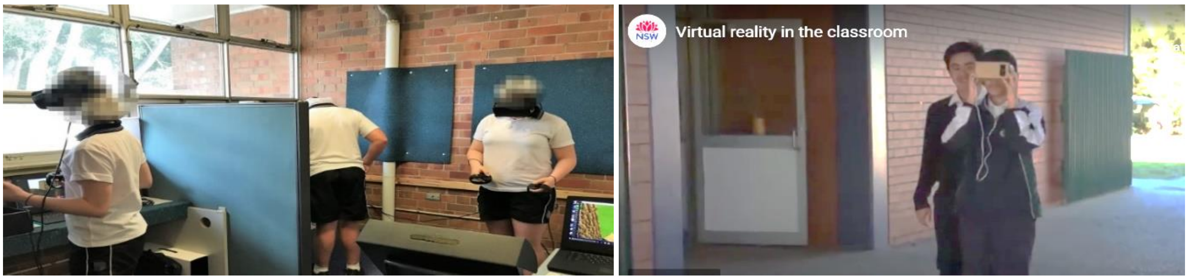

Figure 2. Immersive VR Classrooms in NSW, Australia

Liu (2020) researched on an Immersive VR Classroom (IVRC) in a middle school in China, whereby each student desk comes with a complete VR headset with tablet and screen. The immersive VR classroom students showed better science achievement compared to traditional teaching methods of using slides and video. The VR group showed better engagement in cognitive, behavioural, emotional, social domains. The research noted the importance of complementing IVRC with collaborative learning activities. See Figure 3.

Figure 3. Immersive VR Classroom (IVRC) in a middle school in China

2.3 Effects of VR and AR on learning

With regards to the use of VR on the teaching of science at the secondary school level, Tan and Waugh (2014) found that immersive VR helped students to overcome frustration and lack of understanding in molecular biology, which caused some students to rely heavily on memorization in traditional 2D diagrams and models in textbooks and slides. These traditional media are insufficient to represent the DNA, proteins, and dynamic processes that take place in three-dimensional space in the cell. The study found significant increases in Molecular Biology achievement in male students. Data from interviews also found out and the visualization through immersive VR increased understanding leading to achievement.

Parong and Meyer (2018) carried out a study of undergraduates who learnt the biology of human body using immersive VR versus learning through didactic teaching with slides. The immersive VR group reported higher motivation, interest, and engagement than those being taught by slides. However, there was no differences in performance between VR and the slideshow group for conceptual items, and the VR group performed worse for factual items. The reason may be due to distraction by excitement and novelty of VR experience.

Pang (2021) carried out a between-subject study of two classes learning biology of enzymes. He obtained the effect size of 0.50 for the experimental class which indicates the VR has a positive effect on learning of the molecular representations of enzymes and their interactions. This suggests the possible impact of immersive technologies such as VR to enhance interest and achievement in science for topics such as enzymes in the high-school curriculum. Studies example by Tangaard (2019) also suggests that adding generative learning strategies such as enactment after the VR experience greatly increases the efficacy of VR on student learning and knowledge retention.

3. METHOD

3.1 Quantitative and Qualitative Studies

This is an ongoing study on lower secondary science classes (13-14 years old students) using pre-test post-test quasi-experimental design. There will be one experimental group (VR in learning science) and a control group (non-VR). In the first part of this study, the independent variable is the mode of learning science, either using VR or the traditional classroom approach. The dependent variable is students' performance based on whether there is significant increase in the pre- and post-tests' results. The second part of this study deals with one independent variable, the use of VR or traditional classroom approach, and the dependent variable, which is the enjoyment in learning science. To facilitate ease of implementation, intact classes. Each experimental and control group comprises of 80 students from the Express stream, total n=160.

All students will be given a pre-test (before intervention) and post-test immediately after the experiment. The pre- and post-tests each comprises two parts – an academic test and a self-rated questionnaire. The planned order between the pre-test and the treatment reduces learners' awareness of experimental observation and reduce test sensitization and hence improve test validity. In the next lesson immediately following the intervention, students are required to complete the post-test. The short time frame from intervention to post-test reduces interference from maturation factors such as consulting other reference materials. For the self-rated questionnaire, a second post-test to determine if the improvement is being sustained.

For the first part of the study, the analysis of variance (ANOVA) with between-subject factors would be used to examine their respective effects. The ANOVA will be done using the difference between the means of dependent variable, which is the increase in scores between the pre-test and post-test (academic test). If the p value obtained is less than 0.05 ($p < 0.05$), it confirms that there is a significant difference between the use of learning mode (with VR or without VR) on the performance of students. For the second part of the study, I will likewise use analysis of variance (ANOVA) to examine the effect of learning mode (with or without VR) on enjoyment of learning science based on the pre- and post-tests (attitudinal questionnaires). If the p value obtained is less than 0.05 ($p<0.05$), I can conclude that using VR leads to greater enjoyment in learning science.

Due to the impact of the COVID-19 pandemic which resulted in government measure that students do not need to attend school physically for close to three months in the year of 2020, the author was not able to carry the first part of the study. The author carried out a within-subject study on the impact of VR on students' science attitudes. The self-rated questionnaire is derived from ATSI or 'Attitudes towards Science Inventory'. Only the items specific to the variable of enjoyment of science is relevant and extracted for use, the 16 questions utilize the 5-level Likert response scale and probes students' enjoyment of science (Schruba, 2006).

3.2 Using Immersive VR as Part of Everyday Classroom Practice

My experience as a VR practitioner I have been integrating VR into science lessons In Riverside Secondary School for the past 4 years since March 2017. I have been using VR during science lessons to teach students in Secondary 1 on the topic of cells as well as in Secondary 3 in teaching topics such as enzymes. The VR/AR lessons take place in a specially designed and equipped VR Classroom in the school called 'VR Hub' to provide an immersive experience. The school obtained VR software from NTU through a collaborative partnership with Assoc. Prof. Cai Yiyu of NTU's VARTEL (Virtual and Augmented Reality Technology Enabled Learning) Lab. The rationale for using VR in our school is to harness the immersive and interactive nature of technology to enable students to improve learning of science. For example, in the topic of cells, students can visualize the microcosmic cellular environment, manipulate its organelles and even navigate the intra- and intercellular spaces through online VR games. As for the topic on enzymes, students are able to hold the enzyme molecule and see how it interacts with the substrate molecule. Such actions facilitate conceptual understanding as they transform abstract scientific concepts such as lock-and-key hypothesis into concrete experiences. See Figure 4.

Figure 4. Immersive VR lessons in the science curriculum, Riverside Secondary School

4. FINDINGS

Out of 16 ATSI-derived items, 2 items on "Science is something that I enjoy very much" (p value= 0.012) and "I feel at ease in a Science class" (p value=0.028) showed a significant increase in pre- and post-test scores for $p<0.05$. For the remaining items such as "I have a real desire to learn Science", "I do not do very well in Science" and "I would like a job that does not use any science" there is no significant increases shown. The pre-test was conducted was conducted on the first week of June and two post-tests were conducted, one immediately after the VR lesson in end-July and the other two months later in September 2020. The second post-test is necessary to determine if the improvement in scientific attitudes were sustained. Further analysis revealed high to moderate levels of correlation between the key attitudinal variable of "Science is something that I enjoy very much" to other variables such as "I would like a job not related to science" (negative correlation) and "I have a good feeling towards science", "Science is one of my favourite subjects" and "I have a real desire to learn science". This suggests that the impact of immersive VR on students' intrinsic motivation and their orientation towards future careers.

The author also carried out participatory inquiry using grounded theory study to determine "To what extent can the successes of one's virtual identity in immersive environments induce greater self-efficacy?" and "How does using VR cater to the varied learning styles of students in a differentiated classroom?". Analysis of line-by-line coding from interviews showed that the participants in general experienced a high sense of presence and immersion from the various VR experiences. One student who used immersive VR for biology shared that "VR has endless possibilities and capabilities, in that it allows us to travel to the other side of the ocean and still physical in our country…by merging VR and 3D objects, it allows users to get the same adrenaline rush as if they are physically doing the activity, we get to try out difficult things that seems impossible in real life, it not everyday that we get to look at cells and touch them." The increased sense of self-efficacy builds learner agency and self-directed learning.

Other students preferred "to learn science using VR as it is interactive so they can change values" and wanted more gamification elements because "it would be more fun if it were a game with scores." An immersive VR environment provides learners with 'embodied cognition learning experiences" (Barsalou, 2008) as they develop 'mental perceptual simulation' (Dede et al., 2017) to draw upon when retrieving or constructing knowledge. This is particularly useful for students with preferences in learning styles towards experiential or situated learning. In a related study, the same group of students who viewed 360 degrees videos on conservation of species using Google Cardboard reported the experience as immersive and real. Students were deeply engaged, and students expressed fear when the tigers or sharks approached them in the 360 degrees videos. See Figure 5.

Figure 5. Immersive VR Classroom in Riverside Secondary School, Singapore

5. DISCUSSION

Results from this experimental study have provided empirical evidence that the use of immersive VR in teaching of science can lead to positive emotions such as enjoyment in learning science, which may translate into greater academic interest motivation and future career orientation. More research can be conducted on areas such as whether VR is more suited as a learning mode for which type of ability level or variety of learning styles. In addition, we need to find out where there are other moderator variables such as the characteristics of VR or the learning pedagogy that affects the efficacy of VR use. Immersive VR technologies can bring about greater understanding of science concepts by presenting educational content through more authentic, lifelike and visual representations of scientific models and concepts. It can also enhance user enjoyment leading to deeper engagement and greater interest in the learning of science. Using immersive VR in science not only increases the learner's scientific knowledge and skills, it also enhances their sense of self-efficacy (Dede, 2012).

From this experience of implementing VR in Riverside Secondary School, it is observed that many teachers still lack the understanding of immersive VR and AR technologies and the pedagogical content knowledge to use them proficiently to achieve curricular goals. It is therefore important to put in place a comprehensive professional development plan (Figure 6) to support teachers in their learning and use of immersive technologies and to provide ample support and opportunities for more experience VR practitioners like myself to handhold other teachers who are keen on trying immersive VR lessons but lack the pedagogical know-how or resources to begin. The ability to integrate VR into lessons to achieve learning and academic goals requires the teachers to be flexible and adaptive to harness the immersive nature of VR technologies, while ensuring that there is sufficient scaffolding of content and effective lesson enactment strategies to enable students to have a clear understanding of scientific theories and models. The ability to understand also depends on co-constructing knowledge and receiving feedback through collaborative work with peers.

Current research shows that school-based job-embedded learning and creation of learning communities are the most effective way for teachers to learn new pedagogical and technology skills to change classroom practice (Sparks and Hirsh, 1997). In view of the nature of the immersive VR technology, it would be better to focus on depth rather than scalability of implementation. This means that the PD efforts would entail a group of teachers who sign up and are enthusiastic about the use of immersive VR in science or other subjects' lessons.

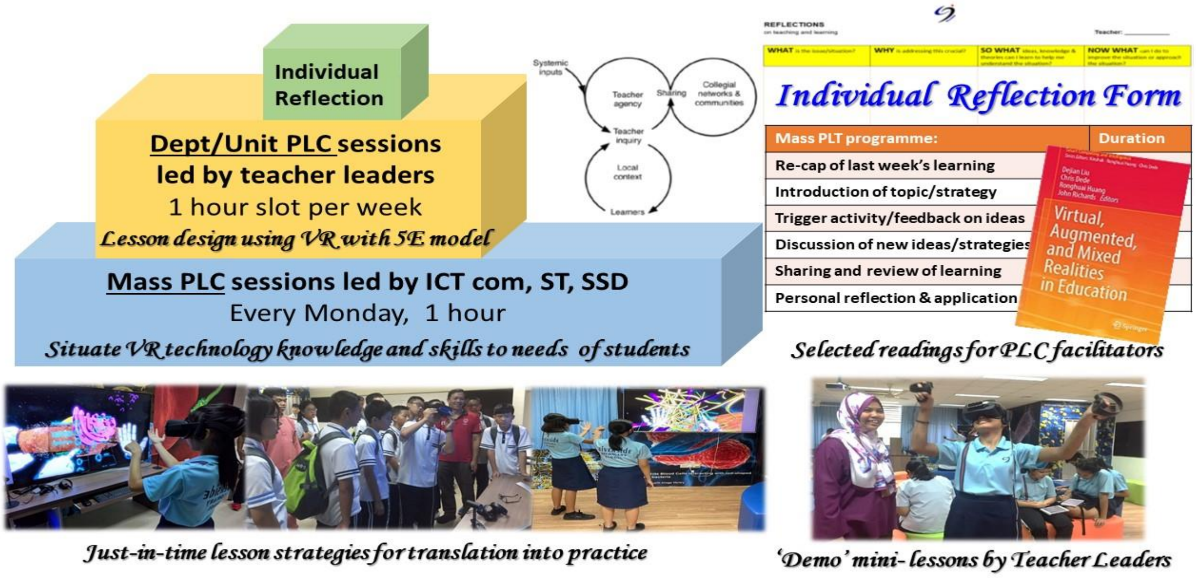

Figure 6. Suggested Professional Development plan to equip teachers with skills and pedagogical knowledge for VR

6. CONCLUSION

The use of VR and AR can provide more varied and authentic experience to enhance equity and opportunity for all students. More research will be needed to shed light on how to operationalize, using effective pedagogies and learning strategies, immersive VR in a secondary school/high school curriculum. Such strategies can also be adapted to primary/elementary schools. The use of immersive VR is *not* about the technology. What is important is a measured approach of integrating VR into lessons with specific learning intentions and learning outcomes in line with curricular goals that is aligned and suitable for Singapore's science curriculum. Riverside Secondary School, like many other schools in Australia, Europe, China, and Singapore, have been taking on the challenges of innovating e-pedagogies such as immersive VR to improving the teaching and learning in schools. Hopefully, more schools will come on board to share educational content and VR software, as well as lesson strategies and resources that will better support educators to embark on this exciting frontier of VR/AR powered by HCI and Artificial Intelligence, in the years to come.

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