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Implementing Virtual Reality in K-12 Classrooms

Lessons Learned from Early Adopters

Espen Stranger-Johannessen[1][0000-0003-1029-6784] and Siw Olsen Fjørtoft[2][0000-0002-0781-4010]

[1] Inland Norway University of Applied Sciences, Postboks 400, 2418 Elverum, Norway
[2] SINTEF Digital, S.P. Andersens veg 3, 7031 Trondheim, Norway
espen.strangerjohannessen@inn.no

Abstract. There is very little research on K-12 education outside designated research studies on how teachers use VR for learning. This study addresses gap in research by asking: How did teachers start with VR and how do they use it? We interviewed nine teachers from different primary, lower secondary, and upper secondary schools – who had one to five years of experience with VR – among the first to include VR in their teaching, making them early adopters. All schools used HDMs, but the number, brand, and model varied. VR was used to teach various subjects and topics, but mostly for a limited part of the lesson. Due to the limited number of HMDs, the teaching was often organized as stations, where the students took turns using the HMDs and working on other tasks related to the theme. This requires good planning from the teacher and a certain degree of self-regulation among the students, as the teacher's eyes and ears are on the student(s) wearing the HMDs. The early adoption of VR sometimes encountered challenges related to technical (e.g., firewalls) or ethical issues (e.g., privacy), but some argued that for innovation to happen, it was necessary to "act first and ask later".

Keywords: Virtual reality · K-12 education · Technology-enhanced learning · Early adopters

1 Introduction

Virtual reality (VR) is frequently heralded as a new technology with great potential in education – much like TV, desktop computers, and cell phones have been before (Spector 2013). Like other technological innovations with a potential for student learning, VR is both praised and questioned, and is receiving much attention both in the media and among researchers. Although most research and application (e.g., industry and medical training) appears to focus on post-secondary education and adults (Wu et al. 2020), there is a growing body of research on the use of VR in K-12 education, and a burgeoning interest among educators to introduce VR in schools (Merchant et al. 2014; Patterson & Han 2019; Southgate 2020). There are also indications of better learning effects in K-12 than post-secondary education (Wu et al. 2020). However, there is very little research on K-12 education outside designated research studies on topics such as students' experiences or learning outcomes or how teachers use VR for learning at their

own initiative. This paper addresses the latter, specifically by posing the research question: How did teachers start with VR and how do they use it? This study provides valuable insight for anyone interested in the background of ongoing practices among early adopters – some of the first to adopt a new technology, innovation, or product, and tend to serve as opinion leaders (Rogers 2003).

2 Research on VR in schools

Commercially available head-mounted displays (HMDs) are only a few years old. Google Cardboard was launched in 2014 and has been used in several research studies (e.g., Sternig et al. 2017). More than two million school children were estimated to have tried Google Expeditions, which points both to the interest and accessibility of this kind of VR (Charara 2017). In 2016 HMDs with more advanced graphics, such as Oculus Rift and HTC Vive were introduced, but they rely on cable connection to a powerful computer. Two years later, stand-alone HMDs became available, and by 2019 some of these also offer six degrees of freedom, allowing for three-dimensional movement of both the body and the head (Southgate 2020). Most current research rely on more advanced forms of VR, including all schools in this study.

There is no single agreed-upon definition of VR (Han 2020), but a key distinction is between immersive (such as HMDs) and non-immersive technology (such as desktop virtual reality). Non-immersive VR in K-12 education has been investigated for a long time (Merchant et al. 2014), but these findings cannot readily be generalized to also apply for immersive VR, and Wu et al. (2020) found a higher learning effect for immersive VR. Kwon (2019) concluded that authentic VR –such as using handheld controllers rather than joysticks, gave students a better sense of experientiality and higher score on analysing, evaluating, and creating questions. Taken together, these studies point to the benefits of authenticity for learning.

Immersion is widely seen as a central affordance of VR that contributes to a sense of presence, engagement, motivation, and improved learning perceptions (Buttussi & Chittaro 2018; Han 2020). The effect on learning is less clear, as the research reports different findings. Makransky et al. (2019) claimed that HMDs had psychological effects, such motivation, but not on learning performance. In a review of research on HMDs, Jensen and Konradsen (2018) found a higher effect on skills training than on knowledge learning. Wu et al.'s (2020) review of quasi-experimental and RTCs concluded that only one third of the studies had a positive effect on learning.

VR in education raises a number of ethical issues, including age. As children develop, so do they cognitive and psychological abilities as well as their physiology, all of which are central to how VR is perceived. For instance, primary school children are more susceptible to audio and visual stimuli (Baumgartner et al. 2018), and children are not always able to separate VR experiences from real life (Segovia & Bailenson 2009). Cybersickness can be a challenge in VR. Reports vary on the extent of cybersickness (Jensen & Konradsen 2018), but some approaches to reduce cybersickness have been identified (Weech et al. 2019).

Privacy is also a concern, since some VR systems require login and collect biometric data, such as hand movements. This is particularly relevant in the context of the rapid development of AI, which might combine biometric and other data for personalized learning (Southgate 2020). Southgate et al. (2019) raised the question of the learning outcomes of students who did not use VR, including students who functioned as "spotters" to guide students who moved around wearing HMD, and noted that some girls were reluctant to try VR, and urged researchers and practitioners to consider possible effects of gender.

Most of the recent studies on the use of VR in K-12 education are intervention studies where researchers introduce VR to schools to measure learning or other effects. Fransson et al. (2020) interviewed teachers about their thoughts on using VR after a workshop, and identified organisational, institutional, contextual and practical challenges and opportunities. Few studies are based on researcher–teacher collaboration over time to provide an account of both pedagogical and technical/practical challenges and solutions (e.g., Patterson & Han 2019; Southgate, 2020). While these studies as well as those with research-driven experimental approaches point to the potential for the use of VR in schools, they also clearly demonstrate a range of challenges that need to be overcome, and beg the question of how teachers will make use of VR without the technical and theory-based pedagogical support from researchers. This is the case of almost all the teachers in this study – the early adopters of a new technology on the frontier of research.

3 Methods

For the purpose of data collection, we attempted to identify all schools in Norway where VR was used by searching online, as early adopters tend to influence others by sharing experiences and reviews in blogs and social media. We also used professional networks, as well as snowball sampling (asking interviewees about other schools that used VR). This search yielded 18 different schools, all of whom were contacted. Some replied that they did not have enough experience to meaningfully contribute to the research, but nine agreed to be interviewed. All nine interviewees had personal experience of using VR as a teacher (including one as a substitute teacher), but some had since changed jobs and worked with leadership or support at the time of the interview.

The interviews were done via video conferencing due to the Covid-19 pandemic, and lasted between 17 and 53 minutes, with an average of 37 minutes (the shortest interview experienced technical difficulties). The audio recordings were transcribed verbatim and the teachers' responses were analysed using thematic analysis to develop categories of salient issues (Miles et al. 2019).

4 Findings

4.1 The schools, the teachers and the equipment

The schools where VR was used, were geographically spread and represent the whole school system: two primary schools, four lower secondary schools, three upper secondary schools (see Table 1). In three cases the equipment was shared between the schools, which means that the interviewees represent 20 schools in total. In the primary schools, VR was used in the upper grades, which roughly correspond with the lowest recommended age for using VR (usually 12 or 13 years).

All schools used HMDs, but the number, brand and model varied, from five at one school up to a full set for the whole class (approx. 30) at one school and a municipality (where the HMDs circulated between schools), with the majority somewhere in between. In most cases, the HMDs were used in groups, so some students used VR while the others did other activities. Five of the schools had more than one brand/make, such as both Oculus Quest and HTC Vive, which gave them an opportunity to use different (and usually more advanced) software, but also required more effort to learn and maintain the equipment. Because the technology improves so quickly and prices go down, some schools purchased new, more advanced hardware over time.

Table 1. Overview of teachers and schools.

ID	Gender	School	VR equipment
1	Male	Lower secondary school	10 Oculus Quest, 10 Oculus Quest 2
2	Female	Upper secondary school	5 HTC Vive, 5 Oculus Quest, 2 360-degree cameras
3	Male	Upper secondary school	17 Oculus Go, 1 Oculus Rift, 1 360-degree camera
4	Male	5 primary, 2 lower secondary schools	Approx. 30 Samsung Gear VR
5	Female	Primary school	10 Oculus Quest
6	Male	Lower secondary school	Approx. 30 Oculus Quest, 5 HTC Vive (can upgrade to Oculus Rift through 5 computers)
7	Male	Lower secondary school	5 Oculus Quest,7 HTC Vive, 1 HMD for PlayStation®
8	Male	Upper secondary school	5 Oculus Quest connected to gaming computers
9	Male	4 Lower secondary schools	10 HMDs for the four secondary schools in the municipality

Table 2 (continued). Overview of teachers and schools.

ID	Subjects/topics with VR	Initiative	VR use
1	English, mathematics, religion and ethics, social studies	A teacher	About 1 year
2	Anatomy, Norwegian, nursing	A teacher	4–5 years
3	Anatomy, architecture, chemistry, electrical installation, English, history, Norwegian, religion and ethics	A teacher	2 years
4	Mathematics	A VR company	2–3 years
5	Interdisciplinary, religion	A teacher	2–3 years
6	English, Norwegian, physical education, religion and ethics, social studies	Two teachers	3–4 years
7	Mathematics, music, physical education, religion and ethics, science, Social science	A teacher	3-4 years
8	Anatomy, history	The principal	2–3 years
9	Physical education, Science	A regional research project	About 1 year

VR was used in various subjects and topics (as well as interdisciplinary), including foreign language (English), language arts (Norwegian), humanities, social studies, pure and applied science, nursing, first aid, music, and physical education. In other words, most subjects were covered, except art and crafts, but one school had plans for that subject. All "core subjects" were taught using VR by at least three schools, while the subjects/topics mentioned by just one teacher, are electives in upper secondary schools which not all students study (architecture, chemistry, electrical installation, and nursing) or not usually taught in upper secondary school (music).

Out of the nine teachers, seven were men and only two women. While this difference may not be significantly different statistically speaking, it seems to reflect assumptions that men are more likely to be early adopters of new technology.

4.2 Initiative and implementation

In six of the nine schools, the initiative to start using VR in the school came from the teacher. Three of these teachers had been to an annual fair – two technology fairs in London and one local VR fair, which the principal had asked this teacher to attend. At the other three schools, the initiative came from the principal, a VR company that entered an agreement with the municipality, and lastly, a teacher started experimenting with VR because the school was involved in a research project on VR. Personal initiative, mostly from teachers, but also from school leadership, is clearly the main entry point for starting with VR. The majority of these teachers expressed interest in and often experience with technology, and a few have or have had responsibility for IT as part of their work alongside teaching.

Seven out of nine schools did not have one HMD for each student in a class, which meant that not all students in a class could use VR simultaneously. Therefore it was most common to organize the learning sessions as stations, where one group of students used VR while the others worked with something else related to the same topic. Several schools had also organized technology/VR labs, which meant that they had to move to a specific room to use the equipment. This required planning in advance.

The following are examples from use of VR in different subjects/topics and with different approaches.

Anatomy. Two of the teachers used VR in teaching anatomy. This application is available in the game portal, for example in HTC Vive. Due to limited access to equipment, the class is divided into two or three, depending on the size. One teacher said that a typical anatomy session starts with a theoretical review before groups of 5–7 students enter the VR lab, while the rest work in the classroom with different tasks. Those who are in the VR lab get about 15–20 minutes, depending on the specific topic. Finally, there is a whole class summary, sometimes with assignments. The advantage of VR in anatomy is that students get to see internal organs, the heart pumping blood, size and body functions in a completely different way than what is possible by watching a movie or using a dummy.

Social studies or interdisciplinary. Several teachers have used the game Ghost Giant, where you are a friendly giant who helps a village. For example, students can write their own stories of the people they meet in the game, such as their background and more. The students can also analyse the literary tools in the game, including the use of music. One of the teachers who used this application said that the students could play the game for several hours straight.

Religion and ethics. Two teachers related how they let the students try a VR application that was not about content, but they linked the experience itself to a theme in the subject religion and ethics. The plan was to let one student at a time try a virtual roller coaster while the other students watched (for example, in 2D on a large screen in the classroom). For those who had not yet tried the application, it was fun to see how the students with the HDMs reacted with movements and sounds and how they tried to tell the other students how incredible this experience was – but without being able to imagine it. When all the students had tried a minute or two of the roller coaster, the teachers used this experience as a starting point in discussing the inside/outside perspective of a religion. It is difficult for those who are not part of a denomination or religion to understand the genuine enthusiasm of the believers who view it from the inside.

Other use. Other VR games that they mentioned were geometry app in mathematics, Beat Saber for rhythm and movement in physical education and music, and various

social awareness games in social studies and religion and ethics. In addition, one used a 360-degree first aid application on tablets.

4.3 Challenges

Much of VR is novel technology and relies on an Internet connection. One teacher described HTC Vive as technically complicated, and several pointed out that teachers need to spend time learning both hardware and software before introducing it to the students. The schools' firewalls and networks caused technical challenges, and in one case the use of VR had violated the municipality's security regulations. In spite of this, the novelty of the technology makes it hard to navigate technical, practical and regulatory bottlenecks. Some teachers argued that for innovation to happen, it is sometimes necessary to "act first and ask later", i.e., to buy the VR equipment first and manage issues with Internet connection, firewalls and security measures later. Cybersickness, however, was not raised as a concern by any of the teachers.

5 Discussion

5.1 Early adopters and development of practice

Getting started with VR requires commitment and investment from the school, and arguably more importantly, someone to take initiative to acquire hardware, software, negotiate technical, legal, infrastructural challenges, and develop a VR pedagogy for one's own subjects. Often the teacher who takes the lead, the early adopter, ends up assisting colleagues with several of these issues as well. No teachers mentioned resistance from the leadership. Instead, they report support ranging from a "hands-off" approach, to active, financial support, including the school principal effectively being the initiator for using VR at the school. In only two out of nine schools did the initiative come from outside (a company and a research project).

Funding is central to implementing VR. Although the schools had somewhat different ways of securing funding, it seems that funding was ultimately about priorities and willingness on behalf of the school and/or school owner (municipality or county). The VR hardware collection expanded over time in several schools, pointing to a development in the use of VR technology. Some teachers pointed to the need to explore and learn before going to scale, while others mentioned the benefits of more advanced technology, such as 360-degree cameras, that allowed for production of their own content. When asked about recommendations for other teachers or schools who are thinking about starting with VR, the most common response was the importance of sense of commitment on part of the teacher and the need to explore.

5.2 Curriculum, content, or motivation as drivers?

VR was used in a range of subjects, except in the two cases with an external collaborator. To the extent there is a limiting factor to the subjects where VR is used, it is the

number of teachers who use it. If only one teacher uses VR, the number of subjects with VR is naturally limited. Most of the use was based on specific content or topics that may be related to the curriculum, e.g., anatomy, or the solar system. VR applications are rarely developed for or adapted to a specific curriculum (Jensen & Konradsen 2018; Kwon 2019). Hence, it requires both experience and confidence as a teacher to see the benefit of implementing VR experiences as part of the subject. As one stated, "The fact that we use VR is merely a feature to spur students' engagement in the subject."

With one exception, all the teachers used VR for a limited part of the lesson. Some emphasized that they never played for entertainment. As one of them said, "VR is a tool, and the tool is only as good as the lesson plan you make." Limitations due to equipment and the number of students who can receive guidance from the teacher, require careful planning and organization of the session. The teacher's focus is on the student(s) wearing HMDs. The other students must be given tasks that keep them busy, which requires a certain degree of self-regulation and maturity.

Some teachers mentioned overcrowded curriculum as a potential inhibitor of use (cf. Southgate et al. 2019). This was possibly a reason why some of their colleagues were sceptical about using applications that cannot be directly linked to the curriculum. The use of HMDs and other technical equipment requires some time for preparation. In many cases, they had to move to another location at the school. Therefore, it is crucial to ensure that VR provides added value, which requires both will, ability, and curiosity from the teacher – typical features of an early adopter (Rogers 2003).

5.3 Technical and ethical challenges

Technical challenges can give rise to ethical challenges, such as secure networks and issues of privacy, which teachers are not always aware of (cp. Southgate et al. 2019). Depending on the equipment, some devices require a personal account to buy and download games, e.g., the second-generation Oculus Quest requires login with Facebook. It would be a violation of GDPR to use learning tools were teachers or students have to use their private profiles.

Other ethical challenges can be related to age and reactions that occur when using HMDs. In the research literature there are few studies on primary schools, and VR is not recommended for young children due to their limited ability to cognitively regulate and process the VR experiences (Southgate et al. 2019).

6 Conclusion

This study has shown how different Norwegian schools in K-12 education have implemented VR. The schools represented were well equipped with digital devices, and all had access to quality HMDs, but only one had a complete set for the whole class. We interviewed nine early adopters who provided insight into how the acquisition came about and how they use VR within various subjects. We found that VR is used as a tool to engage students in a specific theme or content, mostly as a limited part of the lesson. The students are usually divided into groups in which the ones that are not wearing the

HMDs are working on other tasks related to the theme. This requires good planning from the teacher and a certain degree of self-regulation among the students, as the teacher's eyes and ears are on the student(s) wearing the HMDs. The teacher should be conscious about whether and how VR can provide added value within a subject. The early adoption of VR sometimes encountered challenges related to technical (e.g., firewalls) or ethical issues (e.g., privacy), but some argued that for innovation to happen, it was necessary to "act first and ask later". There is need for more research on didactical approaches and the pedagogical value of using VR in K-12 classrooms.

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