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The challenges of using head mounted virtual reality in K-12 schools from a teacher perspective

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Abstract

The use of head mounted displays (HMDs) to experience virtual realities (VR) has become increasingly common. As this technology becomes more affordable, immersive and easier to use, it also becomes more serviceable in educational and training contexts. Even though the technology, content and feasibility for K-12 school purposes are still being developed, it is reasonable to expect that the call or 'push' to use HMD VR in K-12 schools will increase, especially as there is now a greater economic interest in the use of digital technologies in educational contexts. This article aims to inform the process of implementing HMD VR in K-12 contexts by researching the preconditions and challenges of use from a teacher perspective. It does this by analysing the organisational, institutional, contextual and practical challenges and opportunities in the implementation of HMD VR in K-12 school contexts. The data draws on (a) interviews, informal conversations and observations of teachers testing HMD VR and different VR applications in a Digital Learning Lab (DLL) and (b) data from a project involving upper secondary school history teachers discussing the planned implementation of HMD VR in their teaching and being in the DLL. The main findings are related to: (a) economy and technology, (b) initial learning barriers, (c) organisation and practical enactment for teaching and learning, (d) curricula, syllabuses and expected learning outcomes and (e) teachers' competences, professional development and trust. The consequences for educational contexts and possible ways forward are also discussed.

Keywords Head mounted displays · Implementation · K-12 · Technology · Teacher · Virtual reality

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1 Introduction

Virtual reality worlds have been used in educational settings for some time for simulating scenarios, visualising phenomena, encouraging creativity and facilitating learning. Virtual worlds, such as Second Life, have been used (Pellas and Kazanidis 2015) and different virtual worlds and training situations have been shown on computer screens to react to (Merchant et al. 2014).

However, in recent years the experience of virtual realities (VR) has become more powerful due to better graphics and the introduction of Head Mounted Displays (HMDs). Gaming-industry investments have contributed to the development of high resolution, high cost and "stationary" VR HMDs (e.g. Oculus Rift® and HTC Vive ®) with wired connections to powerful gaming computers. With the introduction of VR solutions in which smartphones are used as displays (e.g. Google Cardboard and Samsung Gear VR), the technology has also become more affordable. These mobile VR solutions are sometimes referred to as MVR, or smartphone-driven VR (Cochrane 2016), and have been recognised as the most suitable technology for schools at present (Cochrane 2016; Stojšić et al. 2019). The VR experience can become more immersive through the use of HMDs and it has been suggested that instead of virtual realities, we ought to talking about *immersive* virtual realities, IVR (Lorenzo et al. 2019; Šašinka et al. 2019), or *authentic* virtual reality (AVR) (Kwon 2019). For these reasons, it is important to distinguish between 2D VR experiences on computer screens like Second Life and 3D VR experiences through computer driven and wired HMDs or mobile HMDs, as they may influence and engage the user differently. However, these distinctions are not always acknowledged in research.

Wired and mobile HMDs are used with different VR applications (apps), for example in private use for gaming and exploring, in industry, in medicine and the health care sector, by the military, for pilot training and in robotics. They are also used in educational settings, such as preparing university students for earthquakes (Shu et al. 2019), in engineering training (Lucas 2018), or medical training (Alfalah 2018; Moro et al. 2017; Zhou et al. 2019). With experimental research designs focusing on the usability of the HMD VR and users' experiences, it is often generally concluded that technology can add value to teaching and learning, with no or little regard for organisational, institutional and cultural preconditions in real educational and training contexts (Hussein and Nätterdal 2015; Minocha 2015; Yildirim et al. 2018).

Moreover, most research on HMD VR appears to focus on contexts other than the K-12 school system for education and training (Kavanagh et al. 2017). Existing research on the use of HMD VR in K-12 schools is scant and explorative in nature (Kwon 2019; Minocha et al. 2017; Stojšić et al. 2019).

However, it is reasonable to expect that HMD VR will become more commonly used in K-12 schools, even though the specific technology, content, feasibility and potential added value are still to be explored (Kwon 2019; Minocha et al. 2017). Strong interest groups, such as technology vendors, think-tanks, policy entrepreneurs, government agencies and private educational companies are already advocating the implementation of new technologies in educational settings (Player-Koro et al. 2018). It has been estimated that the market for Virtual Reality (VR) and Augmented Reality (AR) in a base case scenario will reach 80bn US dollars by 2025, including both hardware and software, and that in higher education and the K-12 context there will be 15 million users and annual investments of 700 million US dollars (Goldman Sachs Group 2016).

In this context, Ralph et al. (2017) claim that the role of VR in educational settings has yet to be defined and that there is therefore a need to evaluate the presumed impact, benefits and risks of the educational experiences offered to schools. Even though some research has been conducted in a K-12 context, more research is needed in order to understand the suitability, challenges and options of HMD VR in K-12 schools. Thus, this study aims to expand the present knowledge about the challenges of implementing HMD VR in K-12 school contexts.

2 Research overview

Christou (2010) suggests that the use of VR apps in educational settings can be categorised as: (a) apps in schools and colleges to enhance core curriculum subjects, (b) apps for museums, edutainment and demonstrations and (c) apps for training (children or adults). In this study, the focus is on the use of apps in K-12 schools to promote learning.

2.1 Impact and challenges of using VR for teaching and training

The impact of using different technological solutions for VR has been researched and many benefits have been shown and proposed. For instance, VR can be used to expose users to new or challenging situations and to offer risk-free training and realistic and immersive experiences (Jensen and Konradsen 2018; Minocha 2015). Häfner et al. (2018) have categorised the advantages of using VR in teaching and learning. Their seven categories focus on: (a) enhanced motivation(b) communication and evaluation becoming more effective (c) a better understanding of as complex phenomenon that can be visualised or repeatedly trained, (d) adaptability and flexibility to individual needs, for instance visualised processes can be slowed down or additional information easily added, (e) an increase in safety and health aspects when dangerous tasks are simulated instead of experienced in reality, (f) the environmentally-friendliness of simulation and a reduction of material consumption and (g) a focus on the time and cost effectiveness for certain kinds of training and a shorter preparation and debriefing time (Häfner et al. 2018, p. 4).

It has also been found that strong VR experiences can add value to learning experiences (Shu et al. 2019). For instance, Chen et al. (2019) found that using HMDs or immersive cave automatic virtual environments (CAVE) accelerated the learning of Tai Chi, compared to showing the movements on a computer screen. Another example comes from an experimental study in a South Korean school with year four pupils (11 years of age) (Kwon 2019. Here, wired HMDs were used with two wireless hand controls that allowed the user to move around and 'touch' and manipulate objects in VR. The authors refer to this as an *authentic* virtual reality (AVR) experience, i.e. using sight, hearing and touch. This experience was contrasted with what the authors refer to as a traditional VR experience, where the users had HMDs with sound, but sat on a chair and used a PlayStation 4 hand control. Thus, the aim of the study was to contrast VR experiences with different levels of interaction and feelings of immersion to determine which experiences were most realistic and enhanced. One experience revolved around 'earth and moon' gravity and the environment that was simulated. Twenty students participated in the AVR experience and 22 in the VR experience. A questionnaire about their experiences and a learning test of academic achievement were carried out after the event. The experiment showed that in aspects like presence, tactile interactivity and simulator sickness, and in academic achievements such as analysing, evaluating and applying questions, the AVR experience generated significantly better results than the 'traditional' VR experience. One of the conclusions was that using HMD VR with hand controls facilitated an 'authentic' VR (i.e. with sight + hearing + *touch*) and had a better potential for learning than traditional VR experiences (i.e. stationary with sight + hearing) (Kwon 2019).

However, the benefits of VR for learning have been disputed. For instance, Makransky et al. (2019) found that used VR for simulation in the science lab increased the feeling of presence for 52 university students, but also led to cognitive overload and less learning. In this study, the immersive HMD VR was used to add narratives and experiences and was compared with learning through simulations and texts on a computer screen. An electroencephalogram (EEG) was used to measure the cognitive processing during the learning and then knowledge tests to measure the learning outcomes. Thus, cognitive overload when using certain immersive VR apps can be a challenge for effective learning.

Another common challenge that is identified in the use of HMD VR is a physical reaction like dizziness (Oak 2018; Kwon 2019), or 'cyber sickness', which can be experienced as nausea and headaches due to sensory mismatch (Rebenitsch and Owen 2016; Kawai and Häkkinen 2019). Most of the research on such challenges focuses on adults, although it is reasonable to suppose that similar effects could be experienced by pupils in K-12 schools, as some studies indicate (Kwon 2019).

Other identified challenges are related to costs, hardware and content. For instance, in their research overview, Jensen and Konradsen (2018) identify the challenges of using HMD in education and training that are mainly related to *hardware* and *lack of content.* Their main argument is that VR hardware and content are primarily designed for entertainment purposes and require technical skills that many teachers or instructors do not have. Managing hardware, software and content issues like purchases and updates, profile logins, game saves and so on is tricky when VR equipment has to be shared in the classroom. Moreover, the existing educational VR content is often designed for stand-alone learning experiences, with few possibilities to adapt to levels of difficulty etc., which can make it difficult to logically incorporate this in a teacher's pedagogical planning. However, as VR content is expensive to produce, teachers nevertheless often have to make do with the content that is available on the market. Jensen and Konradsen claim that if HMDs are to be truly pedagogically useful tools for teachers and instructors, they need to include the possibility to produce and edit own VR content.

Knowledge about *how* to integrate VR technology in courses and the lack of time for learning and planning how to do this has also been identified as a challenge for pedagogical HMD VR use at university level (Alfalah 2018). In K-12 contexts, Minocha et al. (2017) highlight that opportunities to enact VR technologies is limited, due to shortcomings in teachers continuing professional development opportunities.

Language, culture and interpretation of the VR content (Blyth 2018) are other potential challenges. VR apps are expensive to produce, which means that they are often only accessible in English as a lingua franca, possibly also with sub-titles, which could limit their usefulness for younger children and create misconceptions or ambiguity for older students due to translation problems and cultural differences (Blyth 2018). However, learning a language with the use of VR could be helpful if it contributes to creating an interest in and incentives to overcome the language barrier in order to further explore the VR app.

Language barriers and interpretation challenges can also occur when users interact together in the VR milieu. Research has identified the importance of having a collaborator when using HMDs (Šašinka et al. 2019). For instance, in Šašinka et al.'s (2019) study of geography education in higher education, two participants who were physically located in different rooms shared the same virtual room showing the same digital terrain model landscapes. Both people were represented as an avatar in the digital world. However, although the participants were positive about having a collaborator, they found it difficult to communicate their thoughts and feelings to each other. One reason for this was because the avatars did not have faces or only had limited gestures. Another challenge was related to the fact that the users needed to think and act in two 'realities' simultaneously – the virtual reality and their own physical reality.

This overview of the identified challenges of using VR in education and training leads to four major conclusions. *First,* most research is not about K-12 school contexts, and *second,* a number of the challenges that are identified must be acknowledged. *Third*, many of the identified studies are either exploratory or experimental in nature. Here, Southgate and Smith (2017) highlight that laboratory results are unlikely to be replicable in natural contexts. They characterise schools as complex social systems with multifaceted social and relational dimensions, as having specific organisational and cultural preconditions and routines (cf. Fransson and Grannäs 2013) and that the pupils have different kinds of knowledge and are at different stages of maturity and will therefore react differently to the use of immersive VR apps. Thus, they acknowledge that real life teaching and learning do not offer strictly controlled research protocols and therefore stress the need to 'document the "state-of-the-actual"' (p. 1) when delivering 'doable and relevant research' (p. 1). They also acknowledge that in the research 'there is far less explicit scholarship on how technologies relate to pedagogical frameworks, curricula and syllabi, and formative and summative assessment practices in schools' (p. 2).

Fourth, most of the studies of the pros and cons of using VR in education and training seem to discuss them in a general sense in terms of aspects like 'fun factors', motivation, learning and understanding, cost effectiveness etc., and seldom contextualise these discussions by relating to specific issues or circumstances, e.g. in relation to interpretations of the syllabus (cf. Häfner et al. 2018; Minocha 2015; Hussein and Nätterdal 2015). However, studies with a general focus can contribute general knowledge and lists of aspects to reflect on that will inform more contextualised analyses of what is relevant and applicable to a specific educational context. The next section looks at some research-based initiatives and analyses the feasibility of VR technology. These kinds of initiatives may provide information about what to watch out for and which methods are suitable for analysing the feasibility of VR technology in educational contexts.

2.2 Initiatives to evaluate the feasibility of VR in educational contexts

As VR technologies are becoming more common in education and training, the need to provide frameworks for analysing and assessing whether, when and how to use them has become more apparent (Häfner et al. 2018; Minocha 2015). For instance, Minocha (2015) suggests using a traditional SWOT analysis of strengths, weaknesses, opportunities and threats. Pantelidis (2009), on the other hand, proposes a 10-step model for analysing and evaluating the feasibility of VR in educational settings. These steps are: (1) define the course objectives, (2) identify the objectives that are suitable for visualisation and considered advantageous, (3) refine the selected objectives and focus on those that help to fulfil the course objectives, (4) review the course objectives and determine (i) the level of realism required, (ii) the type of immersion and presence that is needed and (iii) the type of interaction with sensory input and output to the virtual world that is needed, (5) according to the review in step 4 choose accurate VR software and hardware, (6) design and build the VR application, (7) evaluation of the VR application by a pilot group, (8) use the results to modify the VR application, evaluate with the pilot group and modify until it is found suitable, (9) evaluation of the VR application by a target group and (10) use the results from the target group to refine the VR application and repeat as necessary.

Häfner et al. (2018) elaborate on a more extensive Decision Support Method for evaluating the feasibility of VR in education and training courses, and do that by taking inspiration from a number of studies and fields, including training in the medical and health care sector and industry. They validate the method using examples from safety training for milling machines and for sewing leather. Their framework is based on a nine-step evaluation process of the feasibility of VR in education and training, which includes an analysis of current situations, SWOT analyses, key figures for the new teaching concept, analysis of benefits and cost-efficiency, decision-making and start of the implementation and monitoring.

These kinds of frameworks offer valuable insights into the issues and aspects to consider when enacting VR technologies, although they mainly seem to focus on educational and training settings in a general sense, including experiences from the health-care sector, industry etc. However, these frameworks offer some kind of guidance depending on the contextual circumstances in the specific educational context analysed. In this study these frameworks have inspired and informed the design of the present study and the analysis. The frameworks can be used to analyse a specific VR application or technology for immediate use in a specific context, although in this study no specific relevant technology for immediate use in teaching was applicable. Further, the study's main focus is on the organisational, institutional, contextual and practical challenges and opportunities for implementing HMD VR, rather than evaluating a specific VR application. However, this study could inform the development of such a framework, for example when evaluating and implementing a specially designed VR applications for K-12 educational settings and when implementing HMD VR. It is important to become better informed about the specific circumstances of different educational contexts when aiming to implement VR technologies like HMD VR. There are different organisational, institutional, contextual and practical challenges and opportunities and contextual circumstances between, for instance, compulsory K-12 schools, universities, technical or medical faculties, and training in the military or industry. Our conclusion is that research on HMD VR for education and training seems to focus more on its use, users' experiences or learning than on the contextual circumstances and challenges for implementing VR technologies in specific educational contexts. In this study, the focus is on the educational contexts of K-12 schools and the challenges involved in implementing HMD VR there, which is motivated by the limited existing research on this topic and the fact that in most countries K-12 is the compulsory school in which 'every student' is expected to study.

3 Aim

The aim of this article is to analyse the organisational, institutional, contextual and practical challenges and opportunities in the implementation of HMD VR in K-12 schools.

4 Method

The main empirical data for this study consists of interviews and informal conversations with (a) teachers visiting a university centre (Digital Learning Lab) for a workshop on testing wired HMD VR and (b) upper secondary school teachers of history who were involved in a project to explore and implement mobile HMD VR and VR apps in their teaching. This group also initially visited the DLL at the university to test wired HMD VR under the same conditions as in study (a).

Previous research indicates that teachers' explorations and problematisations of the pedagogical potential and implementation of VR in educational contexts are best performed in groups (cf. Šašinka et al. 2019). In this research, the participants were able to explore the potential of VR apps in groups, either through the use of wired HMD VR with a secondary display, or by using a number of mobile HMD VR sets simultaneously. This kind of mobile-based VR (MVR or smartphone-driven VR) HMD is now recognised as the most affordable and suitable technology for schools (Cochrane 2016; Stojšić et al. 2019).

4.1 The series of workshops at the university Centre (DLL)

The series of workshops (a) was delivered at a university centre (DLL) in autumn 2018. In the workshops, which lasted for two to three hours, teachers explored different VR using wired HMDs (HTC Vive) with external screens or mobile HMDs, iPads with AR apps and discussed digitalisation in education. Examples of the VR content explored were apps (e.g. 'Into the Blue', 'Human body', 'Meeting Rembrandt') and YouTube 360 videos. Although these apps were all freely available and focused on the different generic topics that could be taught in different subjects, years and courses, they were not specifically designed for teaching, as these kinds of specially designed apps are rare. Other VR technologies (e.g. Google Cardboard/Daydream View®, HTC Vive®) and apps (e.g. Google Expeditions VR tours) were shown and/or discussed. Around 120 teachers participated in 9 workshops in the Digital Learning Lab and the number of teachers in each session varied between 9 and 27.

In these workshops, author three hosted and facilitated every session, while author two participated in six sessions by observing, interviewing and participating in informal conversations and occasionally helping out as a co-facilitator. Some 90 teachers were involved in these six sessions and of these approximately 25% were interviewed in each session, making a total of 22 teachers (see Table 1). Nine interviews were conducted in groups of two or three teachers and one teacher was interviewed alone. Teachers from the same school and years were included in some of the groups, which made it possible to gain different perspectives on the same educational context and in some sense to validate the data. Teachers from different schools and years (K-12) were included in the other groups, which led to a dynamic conversation about differences in educational contexts and in the views expressed.

The formal and recorded interviews lasted between 11 to 33 min, with an average length of 19 min. The interviews had a contexualised approach, which drew attention to the teachers' present teaching practices (Goodson 2001). The interviews were semi-structured and the interview themes focused on spontaneous reflections, challenges and opportunities and any eventual needs when enacting HMD VR in educational contexts, and had a special focus on the teachers' own schools and on the contextual, organisational, institutional and practical prerequisites. When the formal recorded interviews were over the topics were often continued in informal conversations rendering further data.

During the session in which the teachers tested digital technologies they were also observed using the HMD and VR apps. Their informal conversations and interactions when using the apps or when commenting on each other's experiences were overheard by authors one and three and on some occasions by author two. The author(s) often became involved in these conversations and the facilitation of the teachers' use of the VR apps. The observations were informal and unstructured (Hammersley and Atkinson 1983) and together with the informal conversations contributed to the addition of data and the construction of a frame of reference for the researchers (author one and author two) in order to understand the teachers' experiences, educational contexts and reasoning and validate the interview data. An example of added data in relation to the practical use of VR was the teachers' actions and discussions when trying to connect and use the wireless controller, which illustrated how a seemingly minor problem such as lack of batteries could pose a challenge and deter teachers from using VR. Brief field notes from these observations and conversations were made by author one.

Table 1 Overview of interviewed teachers

	Grade K-3 (7–10 years of age)	Grade 4–6 (10–13 years of age)	Grade 7–9 (13–16 years of age)	Grade 10–12 (16–19 years of age)
Dataset (a) (No.1–22)	6	6	9 (teaching maths and science))	1
Dataset (b) (No. 23–28)				8 (2 group-discussions) 2 (in one interview)

4.2 The research and development project with history teachers in upper secondary schools

The project (b) with the upper secondary school teachers of history to explore VR apps and how they could be used in their subject teaching generated the data for this study. The project also looked at the contextual, organisational, institutional and practical prerequisites for the enactment of HMD VR in history education in upper secondary schools and the challenges and opportunities involved. This project was initiated in autumn 2018 by the team of teachers and involved six teachers of history at one upper secondary school. Initially, they visited the Digital Learning Lab to explore wired and mobile HMD VR and discuss the advantages and disadvantages of digital technologies and VR apps in the teaching and learning of history. Thus, they participated as a group in a similar workshop as that in study (a), but in this case it resulted in a continued cooperation. In this, the three authors of this article became speaking partners and facilitators for the teachers' explorations of the VR apps. The visit to the Lab took 2 h and during this time 55 min of group discussions were recorded. Two of the teachers were also interviewed together for 27 min (nos. 23 and 24). Meetings later took place at the teachers' school, where 72 min of the group discussions were recorded. The teachers also borrowed six mobile HMD VR devices from the university to use at their school for their own experimentation and learning purposes. Thus, the data from the project was collected over a period of 10 weeks, during which two meetings were organised. The exploration of HMD VR and VR apps and the ongoing reflections in the meetings produced data relating to the contextual, organisational, institutional and practical prerequisites, challenges, opportunities and needs regarding the enactment of HMD VR in the educational contexts of the upper secondary school, and especially in the subject of history.

Thus, both datasets (a and b) focused on contextual, organisational, institutional and practical prerequisites and the challenges and opportunities for the enactment of HMD VR in educational settings in a K-12 context. Here, grades K-3 and 4–6 essentially involve class teachers, while grades K7–9 and K10–12 involve subject teachers, thus making an additional whole.

4.3 Analysis

The interviews with the 28 teachers, 22 from group (a) and 6 from group (b), were transcribed verbatim and analysed with the view to gaining an understanding of the teachers' views of the challenges and opportunities of enacting HMD VR in educational contexts and how contextual organisational, institutional and practical aspects might affect this enactment. In a first step, the material was read inductively to get an overview of possible themes and issues. In a second step, the individual teachers' comments were analysed to identify the contexts and contextual factors and how different themes and issues emerged in the individual comments and stories. In a third step, a thematic categorisation (Miles et al. 2014) was made from the perspective of the material as a whole, with examples of individual comments. The analysis was initially attempted inductively, but later became more deductive in nature due to our pre-understanding of the educational contexts (ibid.).

Authors one and two were operatively involved in these analyses, while author three critically scrutinised and validated the themes and the trustworthiness of the findings in a later stage in the analysis (Guba and Lincoln 1981), based on his experience as a facilitator of the workshops in the Digital Learning Lab.

All three authors have been teachers themselves and are involved in teacher education and in professional development courses for teachers. Authors one and two also research the use of digital technologies in educational settings. Thus, the authors can be said to be informed about circumstances and reforms in the educational sector and have up-to-date knowledge about teachers' work and working conditions. For this study, these experiences have been beneficial when interpreting and trying to understand the teachers' points of views and descriptions of institutional, organisational, cultural and contextual circumstances. However, these experiences also mean some challenges in calling for a researcher reflexivity approach (Creswell and Miller 2000). For instance, the importance of being aware of the risk of over-interpreting the teachers' comments or narratives, or extrapolating the described contextual circumstances into something other than the reality has been acknowledged. Thus, the conclusion is that the authors' experiences have been beneficial to the study.

5 Findings

The main focus in this section is on the identified challenges, although initially (a) the teachers' personal experiences of exploring HMD VR are highlighted, and (b) a brief overview is given of the potential pedagogical benefits of HMD VR according to the teachers.

The challenges the teachers address are related to: (a) economy and technology, (b) initial learning barriers, (c) organisation and practical enactment for teaching and learning, (d) curricula, syllabuses and expected learning outcomes and (e) teachers' competences, professional development and trust.

5.1 The teachers' personal experiences

All the teachers found the use of HMD and the explored VR apps compelling and in general terms as having potential as a feasible technology in education. However, no teacher was 'over-enthusiastic' about VR as a 'revolution' for education, but considered VR as a technology that could add value in some pedagogical settings. Overall, most of the teachers expressed having a curious and reflective approach to VR technology and HMD. The advantages and disadvantages, as well as possibilities and challenges, were discussed by the teachers. The quote below summarises most of the teachers' relations to the VR experience.

> You are open, critical and somewhat reserved, that's how I think we should explain it. (Teacher no. 13, years 7-9, maths/science)
> I know that it is always, as with any new things, that it is difficult and to see it when you don't have … You don't have any idea at all about what there are for possibilities and such. (Teacher no. 13, years 7-9, maths/science)

As the second quote illustrates, the teachers have had too few HMD VR experiences to adequately evaluate the possibilities of the HMD technology for specific teaching and learning situations. However, during the VR sessions the teachers discussed different 'think-if-it-was-possible-to-show' scenarios and the advantages and disadvantages with the technology as far as they could ascertain. The teachers of years 7–9 or at upper secondary school had more to say about specific content, such as how to visualise chemical reactions, physical phenomena, structure of the body or historical situations like World War II, Viking villages, or discussing Rembrandt's painting 'The Night Watch', than the teachers of years 1–6.

5.2 Expected benefits

In general terms, the teachers highlighted the potential of HMD VR to add value to teaching and learning, especially when it came to making the teaching and learning more (a) interesting, (b) affective and engaging, (c) fun, (d) varied and (e) experience-based, as well as providing increased opportunities to (f) visualise complex processes and (g) bring status to teaching and teachers' work.

> Their [the students] interest increases, I noticed with Minecraft that those pupils who can't stand chemistry all of a sudden regarded VR as amazing and possible to combine with chemistry. But when you talk about it in the classroom they have too abstract image of what it [chemistry] is and that you can visualise different things with VR. (Teacher no. 13, maths/science, years 7-9)
> In history you read about things that don't exist. And by describing them through these technologies you can begin to understand what things were really like. (Teacher no. 28, history, upper secondary school)
> If you can step into a VR world then you can do something that you can't do in reality, not at all. I mean molecules are 3-dimensional, aren't they? When you have shown the esters, you should be able to step inside and *be* in the reaction. You *cannot* do that without VR, which takes you to a different level.
> (Teacher no. 15, maths/science, years 7-9)

The third quote, above, draws attention to the opportunities to experience something that would otherwise not be possible and that adds value to learning. These kinds of utterances were common amongst the teachers. For instance, when talking about the learning of history, the teachers discussed how HMD VR could give new insights into historical events and settings, living conditions, social roles and reasons for people's choices, by making historical accounts more engaging and personal. In this, the teachers referred to the tested VR app that enabled the user to assume the role of an apprentice to the seventeenth century artist Rembrandt, or an app that one of the teachers had read about that enabled students to experience life in the London underground during the blitz. The teachers argued that these kinds of insights could be used to analyse, interpret and understand historical events and perspectives in our current society and to predict future developments, which the teachers described as the central aim of history as a subject.

Some teachers also perceived the enactment of HMD VR as an opportunity to bring increased acknowledgement and 'status' to teachers' work and, in this way, promote teaching as a leading high-tech profession. For instance, the upper secondary history teachers experienced that by discussing VR they would gain the acknowledgement and support that is often reserved for other teachers, such as maths teachers. In that sense, the use of VR was described as a potential mediator for resources and acknowledgement.

5.3 Economic and technological challenges

The main challenge highlighted by all the teachers was related to a lack of economic resources to purchase the necessary hardware and software. For instance, hardware for VR, such as a HTC-Vive station including a computer, HMD and controllers and a secondary display to allow simultaneous 2D viewing by others, costs approximately 1200 Euros (1400 US dollars) (excluding taxes).

Even if the most expensive technology can be financed in ways other than from each school's regular budgets, smaller current expenses, such as downloading the relevant apps for around 4 Euros each, can be challenging. As one teacher said: 'our glue money will likely then disappear' (teacher no. 14). Moreover, some of the more digitally knowledgeable teachers had themselves bought and downloaded apps to test, because it was too complicated to do this through the school.

Based on their earlier experiences, the teachers expressed some general doubts about the functionality of technology. For the teachers it was important that the technologies worked, did not cause problems, started quickly and were easy and intuitive to use.

> It is important that things work, and work quickly. Because it's like this, when it comes to technology in school and having to log in, the students try to log in and then find that unfortunately their logins not are working…. So it takes an age to even get started on whatever you are supposed to be doing. (Teacher no. 15, maths/science, years 7-9)

The teachers stressed the importance of new technologies not causing problems and being easy to use, maintain and upgrade. In this context, the importance of rapid technical support for and intervention in the teaching practice was emphasised to deal with any problems that occurred. Some teachers even warned, due to previous attempts at implementing other digital technologies, about a backlash when implementing VR technology if it was too complicated to use, or if there were technological challenges associated with it. Moreover, the teachers discussed how part of the technological challenge was to help their students use the HMDs and apps as they were intended. This in turn could potentially mean a lot of hands-on student support and ideally two teachers in the classroom:

5.4 Initial learning barriers

The teachers drew attention to the initial learning barriers when using HMD VR for first time (and perhaps later on) for both teachers and students. For instance, learning how to deal with the functionality of the devices, understanding the 'logic' of each VR app in order to manoeuvre 'in it' can take time.

> But we are all novices in all this. I would imagine that it would take each person at least 10 minutes to learn how to use an app. What am I supposed to do? How do I find out? And so on. When the last person has seen all this it might take him 5 minutes. (Teacher no. 14, maths/science, years 7-9)

From the above comments it is clear that the 'technological' learning barriers are mostly about working out the logic of the different VR hardware and software. Similar hardware and software can have different user interfaces, which makes switching between different apps and/or types of HMDs challenging. The teachers were concerned about how to reduce this layer of complexity and the group of history teachers opted out of the offered opportunity to use Google Daydream View and Samsung Gear mobile HMDs and their associated app stores when evaluating the potential of VR.

Moreover, the teachers reflected that when the use and functionality of the devices was mastered and the 'logic' of each VR app had been understood, the students' focus might nevertheless be on *experiencing* the VR app in a general sense, rather than focusing on the 'subject matter content' intended by the teachers. Some teachers saw this as a challenge, while others highlighted the teacher's responsibility and expertise in guiding the students in what to focus on, for instance when students ought to be 'studying clothes and the shape of the room' as one teacher commented when using the VR experience 'Meeting Rembrandt' and saw a room filled with artefacts and people (teacher no. 25, history, upper secondary school). Thus, 'going beyond' the experience and focusing on specific learning objects in the VR app presupposed that the teachers were familiar with the tool and its potential to add value to teaching and learning in relation to the topic studied.

5.5 Organisation and practical enactment for teaching and learning

All the teachers discussed the organisational challenges of practically enacting HMD for teaching and learning. These challenges related to issues such as class size, the available number of HMD devices, teachers and support staff, the availability of group rooms and the opportunities to be flexible with locations, group size, schedules, staff and in-house teaching. One comment that summarised these challenges was:

> I mean, it's fantastic, it really is. But then if you have x components and x students it'll be difficult to put it all together, because you need a big room to do this with 15 students, that's all there is to it. I wouldn't dare to be in a classroom with 15 students and only have five of these (HMD-VR). (Teacher no. 14, maths/science, years 7-9)

As none of the teachers believed in a foreseeable future with as many HMDs to make it possible to have whole-class VR sessions, alternative ways of organising the sessions were discussed. One scenario was an out-of-school centre with these kinds of expensive (at present) technologies facilitated by 'experts' in the technology and certain VR content

> if I had a kind of science centre, like that we talked about, somewhere local for the entire municipality. So that you could book times and go there and have a guide who could show you.
> (Teacher no 10, year 5)

However, as many teachers expressed, what is expensive, exotic and 'hype' today, will probably be tomorrow's 'common use' at an affordable price and with more functional use. Thus, a 'science centre' of this kind could be obsolete within the space of a few years, despite its temporary appeal and importance.

That students could use their own mobile phones in accordance with bring-your-own-device (BYOD) and use the phones in a head mount (e.g. Google Cardboard) was proposed as an alternative. This could facilitate the simultaneous class use of VR experiences, but would also create obstacles and dilemmas. For instance, do all students have mobile phones with sufficient resolution and storage space to allow the use of VR apps? What about equity if students do not have the 'right' type of mobile phone? Will the school be liable if the private mobile phones break during teacher warranted use? These and other issues are challenges in the enactment of VR via BYOD.

The teachers also discussed the possibilities of sharing a limited number of HMDs in a class. This kind of organisation would mean some students having to wait their turn or do other activities. Most often the teachers discussed the possibility of organising some kind of station-system, in which smaller groups of students rotated, explored or used different kinds of technologies or did different kinds of activities and tasks and where HMD VR apps were dedicated to one station. In these situations, some teachers suggested that some sort of assistance could be necessary during the carrying out phase. In addition, the ability to be flexible and use different rooms in the school was proposed as beneficial for dividing classes into smaller groups.

However, the majority of the teachers saw the beneficial issues related to being flexible about extra staff or locations as challenges in their schools. This was most evident for the teachers of years 1–6 and in some cases less evident for upper secondary school teachers. The main reason for this seemed to be the age and maturity of the students. Older and more mature students could take more responsibility themselves to explore the HMD VR apps. However, the teachers also highlighted the digitally skilled students, most often named as 'gaming students', as resources for other students and even the teachers. Here, some of the teachers of years 4–6 regarded students in their classes as valuable resources.

The importance of flexibility with staff, locations and so on also seemed to be largely dependent on the *schedule* organising the inner life of the schools. As the schedule determined which subject was taught at a specific time, in a specific place, for a specific group, and by a specific teacher, it was a key factor in helping to organise and structure the resources for teaching and learning. Most teachers discussed how the schedule influenced the opportunities to use VR for teaching and learning. In years 1–6, where most teachers were class teachers and the students met few other teachers, it seemed easier to be flexible and change the schedule than in years 7–12.

> In that I basically take all the lessons I can change and fix things in the way I want. (Teacher no 8, year 3)

It seemed more difficult to change the schedule in years 7–9 and at upper secondary school, as here the educational system, and consequently the schedules, were organised on the basis of teachers as subject specialists, which meant that the students met many different teachers during their school day. In that sense, the schedule could be a significant challenge when it came to flexibility, but could also operate as an instrument for allocating resources – such as rooms or staff – in time and space to enable the use of VR. However, for specific events like 'theme days' it was, according to the teachers, possible to override the everyday schedule.

5.6 Relation to curricula, syllabuses and expected learning outcomes

When the teachers explored the HMD VR apps during the sessions in the Digital Learning Lab, in their conversations many of them discussed the VR content and also how to relate this to the curricula, syllabuses, expected learning outcomes and grading. In the interviews the general opinion was that the use of VR should not be a 'flash-in-the-pan', but preferably integrated as course modules in a coherent learning process that focused on the content, aims and goals stated in the curricula and syllabuses. In this the teachers' professionalism as course designers with clear intentions was evident in many of the comments.

> You really need to have thought through what you want to achieve and how you want to use it in advance. (Teacher no. 8, year 3)
> Everything should be connected to the content, aims and goals. It shouldn't just be a kind of stunt, everything should lead to something. Like, what do I need this knowledge for? (Teacher no. 9, year 4)
> There are loads of cool things, but you must have in your mind: 'What shall I use it for?' (Teacher no. 20, year 4)

Thus, in general terms the teachers stressed the importance of aligning the goals in the curricula, the intended learning outcome, the content, tasks and the ways of assessing students' performances. The teachers displayed pedagogical skills and highlighted the importance of didactically informed evaluations and decisions in their teaching. However, at this point they did not seem able to be specific about this alignment, probably because they were not familiar with the content of the VR app or knew how to align more specifically to the goals or assessments. In actual fact, for the majority of the interviewed teachers, their knowledge and experiences of specific VR apps were too limited for this kind of review and alignment.

On the other hand, the group of upper secondary history teachers also discussed how VR could potentially stimulate increased motivation and help students to develop historical awareness, as stated in the curriculum, and that the realisation and 'effect' of these potential added values would very difficult to 'measure' as clearly identifiable learning outcomes. They raised the question as to whether added pedagogical value that was not clearly identifiable as higher test scores or higher grades would be accepted as added value by other people.

> Will the school leaders nod and say: 'Yes this was an added value for us', or is it a more long-term value, or an 'invisible' value? (Teacher no. 27, history, upper secondary school)

5.7 Teachers' competence, professional development and trust

The importance of teachers' competence when enacting HMD VR for teaching and learning was both explicit and implicit in many of the teachers' comments. Examples of the latter are given above with regard to teachers' competences in making pedagogically informed evaluations and decision related to the enactment of, for instance, HMD VR apps for teaching different content and different student groups. Such pedagogical reflection on the design situation forms the core competence of the teaching profession (cf. Schön 1987) and is highlighted by the teachers when, for instance, discussing the purposes and tasks related to the use of VR apps.

In terms of the 'technical' enactment of HMD VR, the teachers stressed the challenges of developing the accurate digital competence to master the related hardware and apps. Thus, the majority of the teachers requested technical support and professional development and time to learn about and familiarise themselves with the HMD VR equipment and which VR apps to use.

> We would need several days to learn about these things. However, we have to work out how to include them (in the teaching) ourselves. But we shouldn't need to do this at home. (Teacher no. 7, year 3)
>
> Knowledge and education are very important to the staff. Several of us have to dare to get to grips with it (the new technology). It has to be easily managed for us as well. […] We have very little time to learn about anything. And here were have a programme that is not intuitive, with no chance of immersing ourselves in it because that would take at least a couple of hours or so. We don't always have the time that we need. (Teacher no. 10, year 2)

The latter quote highlights a misgiving expressed by several of the teachers, which is that if they do not have the right competence or are aided by knowledgeable staff, there is a risk of backlashes in the intention to implement HMD VR. For many of the teachers, this fear of a lost trust emanated from earlier experiences of efforts to implement technologies in an unsatisfactory way.

6 Discussion

This study identifies a number organisational, institutional, contextual and practical challenges as well as opportunities for using HMD VR technology and apps in educational settings.

First, the teachers identified a range of pedagogical possibilities for HMD VR. These included increased opportunities to visualise complex processes, and make the teaching and learning more interesting, varied and experience-based. They also expressed that the use of state of the art technology like HMD VR could enhance the status of teachers' work.. These possibilities are expressed in a general sense and rarely refer to specific teaching situations or experiences, but can be characterised as an 'envisioned potential' of HMD VR. These are signs that VR (and AR) is not simply a 'hype' and that it can be used to meet these kinds of expectations (Bom 2017; Papanastasiou et al. 2019). However, as is often the case when new technologies emerge, their potential can be overestimated and the hype around them exaggerated (van Lente et al. 2013; cf. Passig and Sharbat 2001). Although the teachers were generally positive about VR, when discussing the practical use of VR in the classroom they had a more nuanced picture of what they thought might be possible and desirable.

Second, economic weakness was highlighted as a major obstacle to enacting HMD VR in the sense of exceeding the existing financial resources. While this may be true at present, we have seen that over time technologies not only become more qualified and user-friendly, but also cheaper. We are already seeing this today with for example Oculus Quest. With low-cost HMDs, this kind of economic concern may thus become unwarranted (Wu et al. in press). Moreover, in schools where BYOD (bring your own device) is allowed (Olmos et al. 2018), implementation may be easier. For instance, Vishwanath et al. (2017) have demonstrated that mobile-driven VR (MVR) (with the Google Cardboard-type viewers) could be successfully integrated into low-resource educational settings (Stojšić et al. 2019). However, using the students' own mobile phones raises ethical issues related to equality, whether or not pupils have the necessary equipment that can offer the sought after experience (e.g. with sufficient screen resolution and processing power) and juridical issues, such as who is liable if phones break during school use. A BYOD approach also puts increased pressure on teachers to support students using different types and brands of phones with different operating systems and apps. The coming technological solutions in which the VR content is streamed to multiple users simultaneously may remove some of these obstacles and make BYOD VR use more viable. However, increased use of this kind of hardware-as-a-service (HaaS) (Stanik et al. 2012) will in turn put increased pressure on schools' wifi speeds and bandwidths.

Third, some organisational, institutional, contextual and practical challenges and opportunities have been identified in this study when introducing HMD VR. One such organisational challenge is related to the fact that VR devices are mostly designed as 'individual' experiences and tools. Accounts and purchases are also often linked to individuals, which makes administration problematic in a centralised IT environment, such as in a K-12 school. Moreover, borrowing phones or sharing HMDs means that pupils' individual progress will not be saved and allow them to continue where they left off in a subsequent lesson.

Another potential challenge is that using VR for pedagogical purposes in schools today seems to necessitate the division of classes into smaller groups doing different tasks while some students use a limited number of costly HMDs. This highlights the need to be flexible when it comes to extra rooms, group size, schedules and extra staff with experience of using HMD VR. These needs require a flexibility that in some senses may challenge the ordinary ways of organising, structuring and conceptualising teaching, learning, schools etc..

Further, the knowledge base of specific subject domains may change, as may the expectations of which specific subject content should be taught. Changes like these may also bring new opportunities, challenges and prerequisites in terms of long lasting organisational, institutional and contextual ways of acting and conceptualising issues. For instance, a potential increased use of digital technologies like HMD VR may mean that subjects like social science, different languages and so on may need substantial budgets for technologies, laboratories and technicians – resources that are most often related to the natural sciences, technology etc. Thus, new technological developments may challenge organisational and institutional assumptions and funding.

Fourth, steering documents and relating the enactment of HMD VR to a discourse of grading could also be challenging. The teachers in this study wanted to avoid using HMD VR as an isolated 'happening' or 'wow-factor'. They preferred VR to be integrated into a coherent learning process and stressed the importance of aligning the use of HMD VR apps to the national curriculum and course syllabuses. These preferences can be understood in at least two ways: i) as an expression of teacher professionality to align every activity to the learning intentions, goals and the prescribed content in the curricula or syllabuses (Biggs 1996) and ii) as an expression of a 'discourse of assessment' (Medland 2019). The latter discourse could help to weed out 'unnecessary play', but may also have negative effects if teachers feel pressured to only do things in school that can be assessed and graded (Smith and Kovacs 2011). Notably, initiatives to support teachers aligning the use of HMD VR apps to national curricula and course syllabi have started to emerge (www.immersiveit.com.au, www.classvr.com).

However, the findings illustrate how skilled teachers strive to motivate their use, or non-use, of digital technologies like VR in relation to curricula, syllabuses and their professional knowledge (and if necessary motivate their use of VR for students, colleagues, head teachers, parents etc.). This is in line with, for instance, Häfner et al. (2018), who suggest not using VR in education if the use cannot be pedagogically justified. Here, we also find incentives for teacher education. It is important for student teachers (and their teachers) to master the technological aspects of different analogue and digital tools. However, to be able to make informed pedagogical decisions as reflective practitioners it is equally important to learn how to critically scrutinise, curate and adapt these tools in alignment with pedagogical intentions, tasks and assessment (Schön 1987; Holmberg 2019).

Moreover, the use of HMDs involves challenges for teachers to interpret students' reactions to the VR app and the intended learning experience. A teacher cannot see (without a secondary display) what students are experiencing or their reactions or efforts to e.g. solving a problem. This makes it difficult to assess how students are developing, what they need to be taught and/or how to scaffold them to help them proceed.

However, aligning the HMD VR content to specific learning goals may be problematic, given that customised content is scant (Jensen and Konradsen 2018; Kwon 2019). Furthermore, customising VR apps to specific learning goals in different national curricula or syllabuses may be expensive and have a limited scope. For instance, in an experiment using VR in learning in year four, Kwon (2019) found that the efforts to remain within the framework of the curricula resulted in too easy tasks and not using the full potential of the VR app. The findings of this study indicate that teachers themselves need to experience a number of VR apps in detail to be able to: (a) assess their pedagogical usefulness in the situated context, (b) know what the VR experience involves to be able to include it as part of their teaching and (c) interact with and/or scaffold students in relation to their use of a VR app. Developing the ability to test, review, curate and allow students to use VR content in ways that add pedagogical value is a complex process for which teachers require time and support. This is especially important if teachers decide to produce their own content. Today, this is increasingly possible through the use of 360 cameras and the growing number of freely accessible 360 videos and 360 editing services, which also allow the adding of elements of interactivity such as quizzes or pop-up windows (e.g. h5p.org, briovr.com, thinglink.com). Moreover, spin-offs from the gaming industry may offer more coherent and extensive VR experiences and thus offer increased opportunities for alignment to curricula and syllabuses. This is already happening today with 2D games like Minecraft©, Civilisation© and Assassin's creed©, all of which offer educationally focused versions. Jensen and Konradsen (2018) claim that for VR to become a valuable tool for instructors, they need to have the ability to produce and edit their own content.

7 Limitations and final thoughts

In this article we have focused on teachers' views concerning the challenges and opportunities of using HMD VR in educational settings. However, some possible limitations must be addressed. First, a limited number of teachers were interviewed in a context in which most of them were exploring HMD VR for the first time. Despite this, our conclusion is that the teachers' thoughts about the challenges and opportunities of enacting HMD VR in educational settings were reasonable. However, it must be acknowledged that their reasoning may have been different and more in-depth and experience-based if they had used HMD VR themselves in their teaching before being interviewed (cf. Häfner et al. 2018). Nevertheless, we have highlighted some organisational, institutional, contextual and practical challenges and opportunities of enacting HMD VR in K-12 contexts. These insights, and others, may inform teachers, head teachers, educational designers and other stakeholders wishing to introduce HMD VR in educational settings so that this process is positive, brings added value to teaching and supports learning in an appropriate way. In our view, the issue of whether to include or omit digital technologies like HMD VR for teaching and learning must be in the hands of the teachers themselves, and not primarily in the hands of Edtech business interests. Sometimes, the educational context is used as a market for experiments and the pushing of digital technologies that are not always suitable or bring immediate added value to teaching and learning (Convery 2009; Player-Koro et al. 2018). Here, it would be beneficial if the EdTech business could cooperate with teachers to develop the technology, customise the content and refine the teaching methods.

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