Benefits and challenges of adopting virtual reality in primary education

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Abstract

This bachelor's thesis discusses the suitability of virtual reality in primary education. Therefore, the research question is: "How can virtual reality benefit primary school education and what are the challenges of adopting it". First this paper focuses on what is virtual reality and how it can be used in education. Then this research considers the benefits and challenges of adopting virtual reality technology in primary education.

The reason for this research is that currently virtual reality has not yet been adopted properly in educational fields, except for some early adopters or some specific higher education. Virtual reality has had too many technological challenges for it to have been properly adopted in primary education. Therefore, problems like money and lack of technology have limited the adoption of it, but more recent innovations may have changed the situation. As such, a review was needed to evaluate the current feasibility and state of virtual reality in primary education.

The method for this research was literature review. Fair amount of studies have been conducted regarding virtual reality, with some focusing directly on different aspects of education. This paper discussed and compiled the existing literature and drew conclusions based on them.

Keywords
virtual reality, VR, education, teaching

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Contents

1. Introduction

Virtual reality is a relatively new field of technology. While term “virtual reality” has existed for a few decades, its definition has been shaping up along the way. At first it was just concepts and something from science fiction, but nowadays its more than just fantasy. Technically some aspects of VR (virtual reality) can be traced back to even before 1900s, however back then it was mostly just optical illusions and not true virtual experience. Modern virtual reality begins at late 1900s with the advent of first proper VR headsets using computer generated graphics (LaValle, 2019). In 1990s the VR industry gained major interest from many parties with the technological success of the early prototypes of virtual reality like first modern like head-mounted displays (HMD) and VR gloves (Jerald, 2015). However the interest soon declined simply because the current technology at that time could not support the demands of what VR required for succeeding (Jerald, 2015).

In recent years virtual reality has once more gained popularity with development of cheap head-mounted displays and utilizing even everyday smartphones, making VR more accessible to everyone. The technological advances and lowering of prices have made virtual reality much more available and interesting to public (LaValle, 2019). The most common source of experiencing virtual reality are head mounted displays. HMDs are the most popular and accessible source of VR technology today. Thus, this type of technology is the focus of this paper as well. There are and have been other systems for VR as well like different simulators or full roomlike VR environments (Cave Automatic Virtual Environment, CAVE). One of the problems with VR is, that even though it has been steadily rising in popularity, even today it is mostly seen as a source of fun and not adopted properly in professional fields.

Virtual reality is still concept that may confuse a lot of people. As said before, its definition has shaped up along the development of technology and understanding of VR. In his book Jerald (2015) defines VR as: “computer-generated digital environment that can be experienced and interacted with as if that environment were real.” VR also has related terms like augmented reality (AR) and mixed reality (MR), but in this case all various realities will considered under the term virtual reality. In this paper the term “virtual reality” will focus on computer generated virtual environments, which aim to simulate real world environments.

Virtual reality has major potential in different fields and can provide new views and ways of working. For example design, healthcare and education are some of the most promising fields for utilizing virtual reality (LaValle, 2019). The field of education especially is a prominent field for adopting VR technology. The goal of this paper is to find in what way virtual reality can benefit the education and the challenges related to it.

In summary, research question for this paper is: how can virtual reality benefit primary school education and what are the challenges of adopting it? The reason for this research is the lack of VR used in education. The method for this thesis will be literature review where most common scientific databases for articles are used. There exists a lot of prior research on virtual reality, some even focusing specifically on the matter of utilizing virtual reality in education. Most of them are quite recent as well due to the developments in the area during recent years.

As the education itself is a very broad term, this research will only focus on primary education, as it is educational level almost everyone gains. This means that some useful applications of VR in higher educations will not be discussed. The focus will be in the teaching side, on how teachers can adopt and utilize VR in their teaching methods. Also, this paper will target only the specific apps and ways VR is designed to help in teaching. The virtual reality in this context will also cover some aspects of augmented reality and mixed reality since it is not always clear to make distinct differences between them. As such while this paper will use the familiar term “virtual reality” or VR for the sake of clarity, it might be more specific to call it or XR (X reality) which is a term made to cover all domains of virtuality.

The topic of VR in education is now more relevant than ever. Aside from typical text based educational materials, a lot of teaching can be done through videos. One can already find a lot of self-study materials from YouTube, utilizing standard environments, but also some using virtual teaching environments. With the Covid-19 outbreak in 2020 forcing everyone to stay at home, schools have had to compromise with some less familiar remote teaching options, for example creating educational videos. The teaching environment in situations like these is limited, as most people do not have all kinds of equipment at home. VR could potentially resolve this with seemingly limitless virtual environments, since only some kind of VR system is required. Many of the benefits and topics discussed in this thesis could potentially allow better remote teaching options with VR, along with traditional teaching.

2. Method

The purpose of this thesis is to discover if virtual reality is possible to adopt in primary education and what benefits and challenges it will bring. This research will discuss both positive and negative aspects of VR and conclude on if the existing situation of virtual reality is suitable for primary education. The chosen research method for this research is literature review. The reason for this method is that it is suitable for summarizing evidence, for example benefits and limitations of technology in some aspect (Kitchenham & Charters, 2007). As such, this research will present new findings by summarizing previous research. Literature review can also provide a framework for further related studies (Kitchenham & Charters, 2007).

To find suitable sources for research, various scientific databases were used, mainly Scopus and ACM Digital Library. Some articles were also found using Google Scholar. The reason for these libraries is that ACM Digital Library and Google Scholar are relevant sources for software engineering subjects (Kitchenham & Charters, 2007). Also, Scopus was used since it has large database for journals and conference proceedings.

For constructing the search string for digital libraries, several keywords related to both virtual reality and education were considered. Suitable operators like “OR” and “AND” were used to refine results. The final search string used was “VR” OR “virtual reality” AND “education” OR “teaching”. This was to suitably limit results but also find relevant data for the purpose of this research. This search string found sources that were mostly relevant with their usage of virtual reality side and focused primarily on field of education relevant for this thesis. Some articles more focused on the educational side were found using query consisting of keywords “learning theory” AND “virtual reality” from Google Scholar.

The most matching results based on their setting and subject were selected to be reviewed. Of course, all journals and articles used were peer-reviewed. After the initial selection, the references of the initial sources were evaluated for more potential articles to be used in this research. Some of those articles were selected due to their matching subject and setting.

The selected sources also had to be somewhat recent, due both conceptual and technological evolution of virtual reality. Since the developments in VR have impacted its suitability for primary education, more recent studies carry more weight. Some older studies are still relevant since some of their benefits and challenges apply to this day as well. To accurately present different viewpoints and aspects of the research question, multiple sources had to be selected for this research.

3. Virtual reality in education

Virtual reality is mainly used for entertainment purposes. While amusement has always been one of the main points of VR, education has also interested people even early on. The limitations of technology have long restricted the educative use of VR other than in high-end military and surgical training (Jensen & Konradsen, 2018). The developments of technology have however affected the suitability of VR for primary education. Still, many aspects of virtual reality related to both benefits and challenges must be understood before adopting VR in education.

3.1 What is virtual reality

The term "virtual reality" does not have very strict definition. Same principles remain between different people, but exact definition of VR tends to change depending on the context. Its definition and context have also changed during past decades. The term "virtual" has commonly been used in context of computers to define something imaginary produced by the computer software. Virtual reality has been used describe hardware like: different simulators, CAVE or HMDs (Jensen & Konradsen, 2018). Also, VR has sometimes used to describe software such as computer generated online virtual worlds or massive multiplayer online role-playing games (Jensen & Konradsen, 2018). Fransson et al. (2020) also emphasizes the importance of differentiating the 2D computer screen virtual experiences, and true 3D VR experiences using for example HMDs.

Jerald (2015) defines virtual reality as computer generated environment which can be experienced like it was real. This is very similar to what many others describe VR nowadays. Steven LaValle (2019) however defines VR in more depth as: "Inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference." This definition includes all the most important aspects of VR and does not limit the definition to any specific hardware or software. From this we can gather that virtual reality is not just a computer-based experience, rather it can be understood as an illusion maintained upon target.

As "virtual reality" as a term can confusing, some terms related to VR try to narrow down its definition. There have also been some other words for virtual reality along its history before it was properly shaped to be what it is now known as. For example "virtual environments" predates the term "virtual reality" but they are mostly considered synonymous nowadays (LaValle, 2019). The terms "virtual" and "reality" are also rather contradictive to each other if going in-depth to their definition (Jerald, 2015). As such alternative terms like "virtuality" exist, but they are less used. As such, this paper will settle with the term "virtual reality".

There exists terms like "augmented reality", which usually means that the real world is perceived through glass or camera, with virtual objects or graphics altering the perceived environment (LaValle, 2019). In this context the term "virtual reality" usually means specifically the fully synthetic environments, though in reality it is not limited to computer generated imagery. "Mixed reality" is something that can combine virtual reality, augmented reality and even the ordinary reality (LaValle, 2019). These distinctions are not nowadays so clear anymore with developments in unifying

technologies, and a new term called “X reality” was created to include all forms of virtual realities (LaValle, 2019).

3.2 History of virtual reality

It is hard to say when virtual reality was first invented because that depends on the definition of the term. For example, stereoscopes were invented in the 1800s and were used to make a pair of images look like a three-dimensional image (Jerald, 2015). The handheld version of this technology was later refined with View-Master and even shares similarities with today’s Google Cardboard. This however was not true VR experience, rather it was just the beginning of 3D imagery.

1800s also introduced the Haunted Swing, which was a technical illusion that could be considered a kind of VR experience. In the Haunted Swing a group of people would be placed on a slowly moving swing, but the environment around them would be completely flipped, making it seem like the swing itself is moving rapidly for the participants (Jerald, 2015). This caused very similar motional effects to what modern VR systems might cause today and the setup is technically 360-degree VR experience.

As the time progressed and 1900s brought the technical developments, more inventions akin to modern VR equipment begun to rise. Not only that, during this time science fiction stories first began introducing the idea of alternate reality and questioning the concept of reality (Jerald, 2015). Pygmalion’s Spectacles was perhaps the first sci-fi story where the person could see another world through eyeglasses (Jerald, 2015). This sounds very similar to what modern virtual reality headsets aim for and are capable of. During this time first flight simulators were also created, with the intended client obviously being the military. Of course, these simulators were rare at first but soon adopted by the military during the World War 2 (Jerald, 2015). This dawned the use of educative VR.

Sensorama was a device created in the mid-1900s by Morton Heilig and it was an immersive film experience. It was a stationary device with multiple immersive features such as wide field of view in colour display, stereo-sounds, motional seat, fans and even odours (Jerald, 2015). Sometime afterwards Ivan Sutherland created the Sword of Damocles, which was the first proper head-mounted display with head tracking and computer generated graphics (Jerald, 2015).

In the late 1900s virtual reality finally became an industry of its own with the first somewhat affordable and viable HMDs. This is also when the term “virtual reality” was properly introduced by Jaron Lanier. New virtual devices and software aimed for entertainment and research introduced, with well-known companies investing in virtual reality (Jerald, 2015). VR promised many things, and expectations were high, but by the end of 1990s it was clear that the technology was not yet capable of upholding the promises. (Jerald, 2015).

Moving onto the more modern times, VR stayed very silent for the first decade of the 2000s. Of course, it was still developed in some fields, but no new major ground breaks were made. In 2010s however VR began to shake things up once more. So far VR had been only affordable in dedicated environments such as military simulations or medical training (Jensen & Konradsen, 2018). In 2013 Oculus released its first consumer friendly VR HMDs and competitors soon followed with their own versions (Jensen & Konradsen, 2018). This was great news for VR as its affordable price made it more interesting to public and its potential for gaming industry helped to gain investments in VR from many large companies. Along with the price, other important feature of the

new HMDs was much wider FOV (Field of View), which affects the user experience and immersion greatly (Jensen & Konradsen, 2018).

Along with the new generation of standalone HMDs, a VR devices using smartphones as displays were also invented (Fransson et al., 2020). These mobile virtual reality (MVR) solutions were especially affordable and have major potential in educative VR (Cochrane, 2016). Nowadays even the consumer targeted standalone HMDs are very cheap, and due to some limitations of mobile VR, the appeal of MVR has somewhat dropped in consumer use. Nevertheless, the cheap standalone HMDs and MVR are both excellent candidates in educative use of virtual reality and the main solutions most researches on educative VR settle on.

With this brief history of virtual reality, it is easier to understand the state of the VR now. Technology has finally developed enough so that virtual reality could be adopted in general education and not just in specific high-end training. Though it was established earlier that VR is more than just the HMDs and alike, in this paper the definition of VR will be computer generated environments that simulate real world. Since the context of this study is educative use of VR, the focus will be on newer consumer friendly, easy to adopt and use VR solutions, mainly various HMDs.

3.3 Teaching and learning with virtual reality

Now that a bit of virtual reality is explained, it is time to focus on the aspect of education. This paper focused on the primary education, but many characteristics of teaching are shared among all fields of education. It is important to specify the perspectives of teaching and learning to understand how virtual reality relates to the context. While there are multiple learning theories, this research will only scratch the surface, since one could write a whole thesis about the usage of virtual reality based on each theory.

There exists various learning theories from the perspective of education sciences. There are however three fundamental theoretical frameworks under which learning can theoretically happen: behaviourism, cognitivism and constructivism (Johnson, 2014). All learning theories can technically fall under these three. In behaviourism, target is affected by stimulus, causing a shift in targets behaviour towards something, usually reinforcing positive aspects (Schunk, 2012). In practise, the learning happens through repeated actions with certain conditions, causing target to act in sought way with enough repetition (Schunk, 2012). The VR can help in this sort of teaching as it provides environment where repetition is easily possible. Of course, the learning could also happen in real world, but VR will provide environment even in some cases where physical or other limitations might restrict the teaching (Alfaro et al., 2019). This means that with VR teachers could be used well for example in distance teaching with VR simulated classroom.

The difference between the cognitivism and the behaviourism is basically that in the cognitivism the target processes the stimulus rather than just acting to it. As such the learning happens by observing models, listening to instructions and performing actions (Schunk, 2012). Finally, through actions and observations the target believes certain actions or solutions to be correct, occurring learning (Schunk, 2012). This may sound similar, as most of the primary education and many other educations as well are implemented in same fashion; first listen to instructions and then do them in practise. This paper will go later in more detail about the benefits of VR in relation to cognitive development. As cognitivism relies heavily on presentation of information to target, virtual reality can help immensely in teaching by providing immersive platform to

visualize and present information. This is reinforced by Mikropoulos and Natsis (2011), according to whom VR is especially beneficial in teaching of complex content.

Lastly, in constructivism the learning occurs by constructing the knowledge from information, rather than just memorizing it like in cognitivism (Alfaro et al., 2019). Some theories include social factors in construction of the knowledge (Alfaro et al., 2019). In practise this means that every learner is different and may construct their ideas differently based on their past personal knowledge and experiences. With constructivism, individual knowledge is constructed as their own and is thus not correct or incorrect (Johnson, 2014). In this sort of teaching, the role of the teacher is not to give straight answers, but to provide support and framework for learning to happen (Schunk, 2012). As construction of knowledge is individual practise, it requires a first-person experience (Alfaro et al., 2019). The HMDs provide immersive first-person experiences, eliminating interfering interface factors, making VR an unique tool for constructivist based teaching (Alfaro et al., 2019). In primary education however, constructivism may usually be avoided due to potentially inconsistent learning outcomes.

No matter the used teaching method or learning theory, various benefits are included in usage of VR. Furthermore, the presented benefits and teaching methods can apply to other learning frameworks as well. In practise there are many methods teachers can utilize virtual reality in primary education. Later the benefits of VR will be discussed in detail and can also provide more light into the context of teaching.

3.4 Educational virtual reality

Virtual reality has most commonly been associated with games and other entertainment purposes. However even early on its potentials were realised in training simulations. In this study the idea of educational virtual reality is specific VR environments and simulations in which the purpose is education. These could be for example VR apps that that were specifically designed to be used in any context of education. This also means that any benefits of playing virtual reality games or such is not considered educational VR in this study.

Technology has always limited the adoption of VR in any area. For this reason, virtual reality simulations used in training have mostly been reserved for military and high-end medical training (Jensen & Konradsen, 2018). With the advances in technology, the VR has become more possible to be realistically adopted in primary educations as well. Of course it has long been theorized how the VR could revolutionize education (Jensen & Konradsen, 2018). Even in the year 2000 when the VR was still quite different from today, a HMD was used in research of utilizing virtual reality in middle school education (D. Allison & Hodges, 2000). However in the ten-year review of educational virtual environments by Mikropoulus & Natsis (2011), they found that the use of VR was not yet suitable in mainstream education.

There are two major hardware options for adopting VR in primary education. First one is stationary HMDs and the second one is mobile VR solutions. Hardware options like CAVE or some specific simulators are not very suitable for primary education, mostly because of the financial constraints. It is also important to note that the VR device itself does not cause the learning to occur, but acts as a medium for simulation in which learning can happen (Jensen & Konradsen, 2018).

One of the key concepts in VR is immersion (Jensen & Konradsen, 2018). This is also closely related to educational VR as immersion is one of the main things that separate

VR from normal teaching methods and affects the learning experiences. Stationary HMDs provide good immersion as they provide high resolution and quality display (Fransson et al., 2020). They are also usually equipped with some sort of controller or haptic device for even better immersion. Downside of stationary HMDs is that they are more expensive and usually powered by powerful computer, adding to the cost (Fransson et al., 2020). The HMD prices have however dropped in recent years and the trend indicates that they will drop more in the future as well (Fransson et al., 2020).

Mobile VR solutions were seen as the most suitable answer for primary education (Cochrane, 2016). Technologically limited schools have easier time implementing mobile or Google Cardboard type solutions, even if that means less immersion (Rasheed et al., 2015). The price is the main selling point of MVR for educative virtual reality as it is otherwise inferior to standalone HMDs. However, smartphones are nowadays usually found from the pockets of practically anyone, so mobile VR is compelling option to adopt in general education. The handheld virtual reality systems are also easier to manage from the perspective of teachers, though they too have their own problems (Alalwan et al., 2020).

Some kind of frameworks and common practises could also be useful for adopting VR in education. Different kinds of frameworks like SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis or more extensive decision support methods have been proposed to assess when adopting VR in education is feasible (Fransson et al., 2020). These frameworks are however more designed for general or higher education than primary education (Fransson et al., 2020). Common practise for adopting VR for primary education does not seems to exist yet is likely to appear if usage of virtual reality becomes more mainstream in school teaching. Previous or other existing frameworks could still be beneficial for assessing specific VR technology for targeted context (Fransson et al., 2020).

3.5 Benefits of virtual reality in education

Virtual reality offers some unique benefits, which has always interested people. Even early on the virtual reality was seen to be useful in education, with simulators being some of the first applications of VR (Jerald, 2015). HMDs and other VR hardware can be used as mediums for traditional teaching, but they can also provide some additional benefits and can even be better in some situations than typical teaching mediums.

There are many benefits of using VR in education. VR has been found useful for a longer time in military and surgery training, but in this paper it was important to focus on the benefits that will gained when adopting VR in primary education. Jensen & Konradsen (2018) reviewed several researches of using HMDs in education. They categorized the benefits of VR broadly in three categories: cognitive-, psychomotor- and affective skills acquisition (Jensen & Konradsen, 2018). These are very general-purpose benefits, but important anyways for all students.

Cognitive skills are very important in primary education as lot of the learning done in elementary- and high schools is done cognitively. For cognitive skills acquisition, using HMDs helps in understanding and remembering the related visual and spatial aspects (Jensen & Konradsen, 2018). It is crucial to focus the studying to those aspects, so the immersive VR environment itself does not distract from the learning experience (Jensen & Konradsen, 2018). Rasheed et al. (2015) also found that using virtual reality in schools helped in the improving the spatial awareness of students, but was actually less effective in learning strict facts.

Psychomotor skills are usually improved by doing things repeatedly. Using HMD can improve one's psychomotor skills and the learning in virtual environment is possible to be transferred to the real world (Jensen & Konradsen, 2018). Acquiring psychomotor skills via VR is possibly more fit for higher education and requires usually better haptic devices for immersion and is such not so suitable for this context of primary education.

Affective skills or mainly interpersonal skills are also important for students of all age. Learning affective skills is very suitable for cheap VR solutions since the learning is more dependent on quality of the simulation and less on the peripherals of the device (Jensen & Konradsen, 2018). Allison and Hodges (2000) used VR system to teach children the behaviour of gorillas by having them act as a one in virtual reality simulation. Same principle could be applied in teaching interpersonal skills in different situations but instead of gorillas using simulations of other people.

Freina & Ott (2015) found that VR was most beneficial in situations which would be difficult or impossible to experience physically. These included travelling in time to historical periods or travelling to impossible places like the space and planets (Freina & Ott, 2015). History as a subject usually first comes to mind when thinking about time travelling for educational purposes. Virtual simulations could easily present different timelines of history and travel between them (J. Allison, 2008). It is also much easier to teach history from different perspectives using VR than using several books for different viewpoints (J. Allison, 2008).

Aside from near impossible places to visit, VR can also be used to just travel into other places like different countries. For example history can be taught by making a virtual filed trip to historical site using VR (Rasheed et al., 2015). Since virtual reality was found to increase spatial awareness of students (Rasheed et al., 2015), VR could fit very well in teaching of physics, geography and astronomy.

Virtual reality environments could also simulate simple classroom or laboratory. Teachers could present their teaching in a virtual environment more suitable for the context (J. Allison, 2008). VR environment can theoretically have unlimited number of devices and equipment of any type. Student can practise their skills in VR environments to develop new skills, though it is important to emphasis the process since real and virtual world are not quite the same (Jiang et al., 2019). Practising in virtual reality is also safe and can experiments can be easily repeated (Jiang et al., 2019). Some dangerous or ethically problematic situations and trainings can also be performed without risk in VR (Freina & Ott, 2015). Dangerous situations are of course more fit for higher training as primary education is relatively safe under normal conditions.

3.6 Challenges of virtual reality in education

As there are benefits to adopting virtual reality in education, there are of course also challenges. The existence of VR technology itself might not be the main problem anymore, but its price and relative rarity is still one of the most limiting aspects virtual reality. It is not however the only challenge VR has to face to be adopted in education.

One of the main problems now is related to economic and technological limitations. All VR required hardware and software combined adds up to a hefty cost. Even the smaller acquirements like apps for VR might be challenging, since the funds are usually quite limited in schools and already reserved for some traditional teaching equipment (Fransson et al., 2020). Also it is very important for technology to work without problems and start quickly so that time can be used for learning (Fransson et al., 2020). This is of course familiar problem with normal computers as well in education, but

more and new technology is likely to result in problems, especially early on. Other than hardware, software also proposes its own challenges. There is a lack of educational content for VR and the available content is mainly meant for self-learning rather than school environments (Jensen & Konradsen, 2018).

Language related matters can also be problem, especially if VR is designed to be used in education for younger people. This is related to the lack of content as most apps use English as their language. This can be a bigger problem in case of small children and still some challenge with older students (Fransson et al., 2020). Mistranslations are also issue that can affect the learning. Even spelling mistakes can affect the learning process (Rasheed et al., 2015).

Related to the new technology is always the initial learning barriers. It will take time for both students and teachers to understand the virtual reality itself and the different VR apps that will be used (Fransson et al., 2020). Different VR devices and applications can vary greatly and make switching between challenging (Fransson et al., 2020). The mainstream VR devices are mainly meant for amusement and usually require high skill level to use (Jensen & Konradsen, 2018). Therefore, using VR devices will require technical competence from teacher to even use the device, let alone utilize it in teaching. As such it will require professional help and time for teachers to learn virtual reality apps and equipment before using them in teaching (Fransson et al., 2020).

There are also organizational problems related the usage of virtual reality in primary education. These problems relate to practical side on how to use limited number of VR devices in various class sizes. Since its unlikely that in the near future it is possible to equip whole classroom with HMDs, some other solutions are needed (Fransson et al., 2020). This brings up the possibility of using smartphone driven VR systems but that also has its own problems. It is not guaranteed that every student has a smartphone that is usable for VR and can the experience then be equal (Fransson et al., 2020). Other solutions could be sharing the HMDs or some external VR centres where learning could happen (Fransson et al., 2020).

Using VR devices, especially immersive HMDs tend to cause physical discomfort to some people. The magnitude and frequency of this so called “cybersickness” varies from person to person, but causes negative attitude towards VR and lower learning outcomes (Jensen & Konradsen, 2018). Cybersickness is usually caused by sensory mismatch, which typically happens when virtual world avatar is moving while in real world one’s body stays still. Using HMDs for extended periods also causes strain to the eyes, at least in the case of younger students (Rasheed et al., 2015). There is also limited research on using VR in education specifically for small children and immersive VR can affect the cognitive and physical development of small children (Freina & Ott, 2015). Immersive virtual environments also present a lot of information at once. Cognitive overload is typically a situation where too much information is presented at once, leaving target unable to process all of it. Especially in some cases, VR can cause cognitive overload, which has negative effect on the learning (Fransson et al., 2020).

It is also important for VR to be integrated in the learning properly so that it is not just separate activity, but closely tied to the courses and learning outcomes (Fransson et al., 2020). This will need careful planning so that usage of VR will not remain just for amusement. It will also be more difficult measure the added value of VR and whether it will correspond to the learning outcomes (Fransson et al., 2020).

4. Findings and discussion

Important aspect of VR is immersion, which was highlighted by many studies. Immersion in case of virtual reality means, that the VR device uses stimuli to make virtual environment feel authentic and captivating to the user (Freina & Ott, 2015). Another key concept of VR is presence. Presence happens when user is fully immersed in VR and starts to act in virtual environment like in real word, forgetting the technology providing the stimulus (Jerald, 2015). Together immersion and presence make the experience of VR what it is and set it apart from typical 2D experiences from displays. This is important for education as better immersion correlates to better learning outcomes (Mikropoulos & Natsis, 2011). It is however worth noting that too immersive systems can be confusing and distract from the learning task (Jensen & Konradsen, 2018).

As was previously established, virtual reality is and has been usable for decades in many higher fields of education. Military and medical have mostly been the only fields to use VR simulations in training due to the technological limitations (Jensen & Konradsen, 2018). Even in the beginning when more modern virtual reality first started to show up in 80s and 90s, education has been one of the main areas VR was though to revolutionize (D. Allison & Hodges, 2000). Lot of research has gone into finding whether VR was suitable for school education, and for long the attitudes have been positive, but practical applications were clumsy. In more recent studies after the breakthroughs with mobile and affordable VR technology, the positive notes have started to increase. Benefits of VR in education are understood, but many practical problems and challenges still remain, with some downsides of using VR are found as well.

VR is usually hoped to help specifically in acquisition of cognition skills. These skills are of course very important for primary education and all other education alike. While the immersive virtual reality helps in cognitive skill acquisition, it is important that the experience does not overshadow the learning (Jensen & Konradsen, 2018). Rasheed et al. (2015) found that factual learning was slightly more effective using typical teaching methods than using virtual reality. However the best learning happened when group was taught using both traditional learning methods and using VR (Rasheed et al., 2015). Not just in cognitive skills, but in other areas as well, virtual reality is best used along with standard teaching, rather than replacing it.

Virtual reality simulations are also found to improve psychomotor skills, at least in the simulation itself (Jensen & Konradsen, 2018). Surely training in simulation does somewhat translate in real skills, but there is still difference between real world and the virtual environment. According to Jensen & Konradsen (2018) the psychomotor skills acquisition is more related to haptic peripherals than simulation itself. Training can however happen freely in virtual environment. Skills honed in VR should focus more in the process of the skill, so that they better translate to the real world (Jiang et al., 2019). These problems with psychomotor skills may be related to the “solidity” of VR i.e. things interactable in VR do not have actual weight or other concrete properties. This is reinforced by J. Allison (2008), according to whom immersion is destroyed when solid objects are not working according to physical laws. Some new simulations in VR have found clever ways to “fake” gravity and accurately simulate real world physics, though this mostly exists only in technical demos and games for now. Improving physics of the

simulation could improve the acquisition of psychomotor skills in virtual reality. This would help in the case of primary education where the main VR device would likely be lower-end HMDs with less immersive haptic peripherals.

Affective skills are of course important for people of all age. For younger people VR can be used to teach communication skills through interaction with virtual environment. Affective skills acquisition with VR rely heavily on the quality of the simulation (Jensen & Konradsen, 2018). Since acquisition does not necessarily require extensive peripherals, it is well suited for primary education. For example, students could experience social situations through HMDs in different environments, helping in learning interpersonal skills. The idea of using VR to teach behaviour related situations was used by D. Allison and Hodges (2000) to make students perceive behaviour of gorillas by acting as one in virtual reality simulation. The same principle works in teaching affective skills by making the student take place in human interaction situation. The other party of this situation can either be another student or even artificial intelligence (AI). The improvements in AI will also increase the range of affective skills to be taught through VR (Jensen & Konradsen, 2018).

Some school subjects may also benefit more of virtual reality than others. VR shines when the experience is about something that is not doable under normal circumstances. This means travelling in time or to some faraway places are some of the main opportunities of VR (Freina & Ott, 2015). The subject of history often comes to mind when thinking about virtual reality and education. It is possible to experience historical events from unique perspective using VR (J. Allison, 2008). This also allows easy switching to different viewpoints and better present interconnection of history (J. Allison, 2008). It is clear that subjects related to past like history and religion could benefit from virtual reality's immersive visualization.

Natural sciences are another subject that greatly benefits from the virtual reality. In this case the VR allows visiting places from other side of the globe or even the space. In geography, travelling to distant countries could help memorizing related matters more easily by making the experience more personal. Physics and astronomy can use VR to model planets or some physical phenomena in way not possible normally. Size related or complex things are more easily understandable in immersive VR environment (Mikropoulos & Natsis, 2011).

While there are many benefits, there are also challenges which may impact the suitability of VR for specific educational context. First of all, the most prominent problem is still the technology. There are many challenges related to the adoption of VR in primary education, but most of them somehow relate to the technology. The price of the technology is the key, especially when considering the context of primary education. The cost of the initial acquisition of the hardware is one the main concerns of teachers (Fransson et al., 2020). Full price of all the hardware for multiple students likely exceeds the normal budget of many schools. The prices have come down for standalone HMDs and will very likely continue to do so. As such this problem might not even exist in the future. Currently however, even the cheapest standalone HMDs cost several hundred euros. Many proper HMDs need powerful computers to power them, raising the price to at least a thousand per device (Fransson et al., 2020).

Google Cardboard type mobile VR solutions are very cheap, however they need a smartphone to power them. MVR was recognized as a very suitable solution for schools (Cochrane, 2016). This can solve the price problem but brings its own challenges. BYOD (bring your own device) strategy where students use their own smartphones is logical implementation to minimize the costs. Quality of the virtual reality learning experience is however dependent on the supporting smartphone (Fransson et al., 2020).

Schools will likely need suitable spare smartphones, raising the costs in the case of MVR as well. Some juridical questions will also rise as who will be responsible in the case of equipment breakage during use (Fransson et al., 2020).

Hardware had its problems, but so does the VR software. There is a lack of suitable educational content for VR (Jensen & Konradsen, 2018). Scarcity of content was found to hinder the usage of VR in science teaching in primary schools (Alalwan et al., 2020). Also, while the VR apps might not be too expensive, the resources of teachers are very limited, so even small purchases might be troublesome (Fransson et al., 2020). As such the software content is a very real problem for VR adoption. The generalization of virtual reality in the future will likely increase the amount of educative software as well. Another problem of the educative VR apps is that they are usually designed for self-learners and for that reason the educative content for schools should be produced by teachers themselves. (Jensen & Konradsen, 2018). Some educational content could nowadays be relatively easily produced by teachers in the form of 360 videos (Fransson et al., 2020). 360 videos might limit the interactivity of VR and raises the question whether the content will be immersive or useful enough to be worth using.

The challenges related to any new technology are also present in virtual reality. Initial barriers for learning hinder both student and teachers alike. Teachers must first understand the logic of VR and the functionality of the systems before using them in teaching (Fransson et al., 2020). The skill level to learn and use VR devices in education is high as they are mainly entertainment devices (Jensen & Konradsen, 2018). HMDs can sometimes be unintuitive as they are primarily still meant for technologically advanced people. Teachers with lower technical skill will have hard time using VR, as some might have trouble using even the standard computer. If new technology is poorly implemented, it may cause backlash and negative attitudes towards the usage of that technology (Fransson et al., 2020).

The learning barriers are also present not just in hardware, but in software as well. User interfaces of both apps and devices vary, and quick change between might be difficult (Fransson et al., 2020). The concern many teachers have is that even after initial learning barriers, using VR in teaching will take longer time than with normal teaching methods (Fransson et al., 2020). For these reasons, schools may need some extra personnel with required VR skills to be ready to assist in VR use. Alalwan et al. (2020) found that VR required specific virtual reality equipped environment to be used effectively.

If VR rooms or some shared computer laboratories are the only place to teach with VR, it will create problems with time constraints. Laboratories have to be shared among different teachers and subjects, limiting the use of VR (Alalwan et al., 2020). It may also be necessary to split classes into smaller groups due to limitations on number of equipment, requiring more scheduling and organizing (Fransson et al., 2020). This makes it very difficult to teach syllabus using just VR (Alalwan et al., 2020). However, as best results were achieved by using both VR and traditional teaching methods (Rasheed et al., 2015), using just VR to teach is not recommended.

The problems with VR are also related curricula. It is important for teachers that teaching with VR is integrated closely to the curriculum and courses, and not just for isolated experience (Fransson et al., 2020). While it was established that virtual reality had many benefits, they may not be easily measurable. This raises a question whether using virtual reality in education is justifiable if its added value cannot be pedagogically identified (Fransson et al., 2020). VR can however be used to motivate students and spark interest to learn more (Alalwan et al., 2020). The effects of motivation should not be underestimated, especially in primary education context. Motivation can increase the

learning in cognitive based learning theory (Schunk, 2012), which is the typical primary education based teaching scenario.

There are also some challenges concerning equity of students. Virtual reality can cause severe cybersickness to some students, though the severity and frequency vary greatly between different people (Jensen & Konradsen, 2018). This sensory mismatch can cause varying physical discomforts like nausea and headaches. Strong symptoms may cause student stop the virtual simulation and even the milder symptoms can cause negative attitudes towards the technology and lower the learning outcomes (Jensen & Konradsen, 2018). This means that the learning experience is not similar between each student. Inequity of experiences can also happen from BYOD method. Students may not have powerful enough smartphones to bring virtual experience to required level (Fransson et al., 2020). This is of course only a problem when using MVR solutions.

From previous findings, VR can be found suitable for many learning theories. Virtual reality provides repeated practice for behaviorism, motivation important for cognitivism, experiences for constructivism, just to mention some of the benefits. While some of these benefits may first seem best fitting to some specific theory, most of them are valid for any learning theory in some form. All in all, the VR seems best used in conjunction with traditional methods and not replace them. They have many challenges which must be addressed when adopting VR for primary education. Virtual reality offers unique experiences, which can benefit the learning of student, but must be carefully planned for specific teaching scenarios.

5. Conclusion

The research question for this paper was: how can virtual reality benefit primary school education and what are the challenges of adopting it? As such the question can be split into two main parts: benefits and challenges. In the reviewed literature many benefits and challenges alike were found. Aside from the main points, many articles dealt with other things related to the adoption of virtual reality in education.

Virtual reality has rapidly advanced in recent years. It has had a long history, beginning from imagination, concepts and simple optical illusions (Jerald, 2015). Nowadays virtual reality is automatically associated with HMDs and mainly thought as a source of amusement. While it might still be seen as a sort of a niche, it has begun to gain attention with technical breakthroughs that have made it more accessible and appealing to mainstream audience.

Developments in virtual reality have also made it more appealing to be adopted in primary education. Previously only specific higher educations like military and surgery training could use expensive simulations in practise (Jensen & Konradsen, 2018). Now immersive VR experience can be achieved relatively cheap and is much more mobile than earlier robust virtual reality systems. VR has also been found to be useful in different aspects of teaching, though many challenges still remain.

Skills that can benefit from VR were broadly categorized into cognitive-, psychomotor- and affective skills (Jensen & Konradsen, 2018). Of these psychomotor skills were found to least benefit from usage of virtual reality. This mostly because of the differences between real and the virtual world, and to bring them closer would require expensive technology or new solutions. Both cognitive and affective skill acquisition could benefit from VR, even in teaching of younger students. Cognitive skills play major part in primary education and HMDs were found to be useful in acquisition of them, especially when combined with traditional teaching mediums. Affective skills are greatly benefitted from VR, as virtual environments provide new possibilities. Simulations targeted for affective skills are also best suited for cheaper low-end HMDs, since they require quality simulation, rather than extensive peripherals. Usage of VR also provides unique experiences from different perspectives which cannot be experienced from 2D screens. These unique VR methods can be helpful in primary education, especially on some subjects.

Even with all the developments, VR still has to this day many challenges to overcome to be adopted in education at large. Major problem has been related to economy and technology (Fransson et al., 2020). While the prices of VR devices have come down, it is still costly to equip whole schools with necessary virtual reality equipment. The VR technology and the concept of VR itself are still new to many and will require effort from both teachers and students alike to understand and use properly. Teachers especially need time to familiarize themselves with virtual reality before they can begin to use it in teaching. Education focused VR apps are still quite scarce and may also not be suited for classroom use. There are many practical problems related to the use of HMDs in schools. They are related to the integration with curriculums and learning objectives as well as practical usage in everyday teaching.

VR devices can also have varying effects between people (Jensen & Konradsen, 2018). Some experience heavy physical discomfort while using VR, while some have no problems at all. The physical discomfort some people have with VR, especially HMDs, is called cybersickness. Cybersickness causes nausea, has negative impact on learning and may even cause a need to stop the VR simulation (Jensen & Konradsen, 2018). Some VR solutions in primary education may also require students to use their own smartphone, which may affect the quality of the experience. For these reasons, virtual reality in education may not be an equal experience to everyone.

Even with all its challenges, a lot of effort has been poured into bringing VR to primary education. Most of the challenges can be resolved with planning and smart usage of VR. It is important to carefully design how the VR should and could be implemented in teaching. Another important point to remember is that the VR devices itself do not bring the added benefit to education, rather the simulation happening inside VR and how it is utilized in teaching. The drastic advances in VR technology seem to continue and many problems may disappear in few years. For now at least, the virtual reality will not overthrow the traditional teaching mediums, but will provide new experiences and unique benefits when used alongside them. VR can be adopted in primary education, but many challenges need to be considered. As such, the educative context needs to be carefully evaluated to find out whether using VR is actually useful.

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