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Virtual reality field trip project

Affordances and user experiences of virtual reality technology in actual school setting

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Tiivistelmä - Referat - Abstract

Tavoitteet. Tämän tutkimuksen tavoitteena on tutkia virtuaalitodellisuusteknologian (VR) soveltamista osana ympäristöopin projektia kompleksisessa koulutodellisuudessa ja raportoida niin oppilaiden kuin opettajienkin kokemuksia ja havaintoja sen käytöstä. Tutkimuksen keskiössä ovat VR teknologian havaitut toiminnan mahdollisuudet ja käyttäjien kokemukset. Vastaavaa on tutkittu aiemmin lähinnä kliinisissä olosuhteissa.

Menetelmät. Tutkimukseen osallistui kolme opettajaa ja 59 5.-6. luokkalaista oppilasta kahdesta eri koulusta. Osanottajat olivat vapaaehtoisia VISIOT-hankkeeseen osallistujia. Hanke on valtakunnallinen ponnistus kokeilla ja kehittää virtuaalitodellisuuteen-, lisättyyn todellisuuteen ja esineiden Internettiin liittyvien teknologioiden opetuskäyttöä. Hanketta koordinoi valtakunnallinen Innokas-verkosto. Tutkija ja kaksi opettajaa suunnittelivat yhteistyössä ja designtutkimuksen periaatteita noudattaen VR-teknologiaa soveltavan oppimisprojektin. Opettajat ottivat käyttöön VR-järjestelmän, joka koostui *HTC Vive* -laitteesta ja *Google Earth VR* -sovelluksesta.

Aineiston keruu tapahtui pääasiassa verkkokyselyin projektin alussa, sen aikana ja projektin päätyttyä. Lisäksi tutkimuksessa mitattiin oppilaiden avaruudellista hahmotuskykyä, ja kuultiin opettajien havaintoja innovatiivisten verkkohaastatteluiden avulla. Pääsääntöisesti laadullista aineistoa analysoitiin sisällönanalyysin varassa teemoitellen aineistoa, ja analysoiden eroja ja yhtäläisyyksiä osanottajien kirjallisesti kuvaamissa kokemuksissa. Tutkimuksessa seurattiin kuinka opettajat keksivät soveltaa VR-järjestelmää osana ympäristöopin projektia. Projekti alkoi joulukuussa 2017 ja päättyi huhtikuussa 2018. Oppilaat arvioivat VR-järjestelmän käyttöä ja siihen liittyviä omia kokemuksiaan niin projektin aikana kuin sen päätyttyäkin.

Tulokset ja johtopäätökset. Opettajat kohtasivat vaihtelevasti oppimisen orkestroinnin haasteita, teknisiä vaikeuksia, sekä tilallisen - ja ajallisen ulottuvuuden rajoitteita projektin aikana. Vaikutti siltä, että sovelletun VR järjestelmän sujuva käyttöönotto vaatisi olemassa olevien skriptien purkamista, sekä toisenlaisia ja jouhevia tilallisia, ajallisia ja pedagogisia ratkaisuja, kuin mihin kouluissa oltiin totuttu. Tästä huolimatta oppilaat omaksuivat VR teknologian käytön varsin nopeasti ja kokivat sen erittäin myönteisesti. VR järjestelmää käytettiin projektissa lähinnä motivoivana lisänä. Roolileikkien ja maapallon visuaalisesti tehostetun tutkimisen lisäksi VR järjestelmän havaitut toiminnan mahdollisuudet sisälsivät oppilaiden mielenkiinnon heräämistä, teknologian käytöstä nauttimista, todentuntuisuuden ja mielen uppoutumisen kokemuksia, sekä onnistumisen kokemuksia. Oppilaat pitivät VR laitetta erittäin mukavana ja VR ohjelmaa käyttäjäystävällisenä. Näytti siltä, että sovellettu VR järjestelmä ja sen käyttötavat projektin aikana vaikuttivat oppilaiden käsityksiin virtuaalitodellisuudesta. Tästä huolimatta oppilaat kykenivät kuvittelemaan monenlaisia virtuaalisia maailmoja, joissa haluaisivat vierailla ja opiskella. Tyypillisten kategorioiden lisäksi he kuvittelivat korkean fantasian maailmoja ja aikamatkustusta tulevaisuuteen.

Yleisesti ottaen oppilaat vaikuttivat halukkailta jatkamaan VR teknologian käyttöä tulevissa opinnoissaan. Projektin jälkimittauksissa heidän itseraportoimansa minäpystyvyys ja osallistumisen into olivat korkeat. Poikien raportoima pystyvyys oli tilastollisesti merkittävästi tyttöjä korkeampi. Oppilaat pitivät VR ohjelman maailmaa luotettavana lähteenä lähinnä kokemusperäisesti; joko järjestelmän tuottaman todentuntuisuuden takia tai koska virtuaalimaailma vaikutti vastaavan täsmällisesti heidän kokemuksiaan fyysisestä maailmasta. Kaiken kaikkiaan vaikuttaisi siltä, että tutkimukseen osallistuneet 11-12 vuotiaat oppilaat ottaisivat VR teknologian mieluusti osaksi omaa oppimisympäristöään, toisaalta opettajat oikeutetustikin kokivat, että sovellettu VR järjestelmä olisi siihen vielä liian monimutkainen ja vaativa.

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Tiivistelmä - Referat – Abstract

The purpose of this study is to implement immersive virtual reality (VR) technology as part of an environmental studies project in the actual complex school reality and analyze both the students' and their teachers' experiences and observations on the use of VR in learning and teaching. This study focuses on the user experiences and affordances that the appliance of VR technology brings forth in education. There are but few earlier studies on similar topics, most of which have been conducted in clinical settings.

Three teachers and 59 students, 5-6th graders, from two different Finnish elementary schools participated in this study. The participants were all volunteers and took part in a nationwide VISIOT-project, coordinated by a nationwide Innokas Network. Its main purpose was to provide opportunities for trying out and developing virtual reality, augmented reality and Internet of things -technologies in education. The three teachers in this study applied a VR system that consisted of *HTC Vive* -device and *Google Earth VR* -program.

The different ways in which the teachers ended up implementing the VR system turned out to be an important research topic in this study. The project went on for over three months, spanning from December 2017 to April 2018. The students assessed the use of the VR system during and after the project. Their experiences became another key research area in this study. Data was gathered with online questionnaires, pre- and post-surveys for students, a test of the students' spatial reasoning abilities, and with a pre-survey and innovative post interviews for the teachers. This mostly qualitative data was analyzed with clustering content analysis, where I would find similarities and differences in the participants' answers and place them in schematized categories.

The teacher's encountered technical, spatial and temporal challenges, as well as challenges in orchestrating the implementation of the VR system. It appeared that VR's implementation in education demanded more innovative scripts and different spatial, temporal and pedagogical arrangements than the two studied schools were used to. Albeit, the students adapted to the use of VR technology rather quickly and had a very positive emotional experience with it. The VR system was mostly used as a motivational addition to learning. Besides the visually enhanced exploration of the Earth and tourist role-play, the VR system's actualized affordances included enjoyment and interest, realism and mental immersion, and mastery experiences. Students found the device as very comfortable and the program as user-friendly. Their conception of virtual reality was evidently affected by the applied VR system and its uses during the virtual field trip project. Despite of this, the students were able to imagine diverse learning worlds for VR. In addition to typical categories, they imagined high fantasy worlds and time travelling to the future.

By and large, the students appeared willing to use VR technology again in the future. Their post-survey measures for self-efficacy and interest to engage with the technology were relatively high. The self-reported self-efficacy of boys was statistically significantly higher than the girls corresponding. The students found the VR program to be a credible source mostly due to the virtual world’s realism or resemblance with their experiences of the real world. Altogether, VR technology appears to be something that these 11-12-year-old students would gladly include in their learning environment, on the other hand, the teachers rightfully felt that the implemented VR system was too complex and demanding for permanent inclusion.

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virtuaalitodellisuus, virtuaalitodellisuusjärjestelmä, toiminnan mahdollisuudet, mukaansatempaava oppiminen, käyttäjän kokemus, käyttökokemus, mielen uppoutuminen, minäpystyvyys

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1 Introduction

What is virtual reality technology (VR for short)? How does it relate to education? What introductory VR systems are appropriate for children to begin with? How do they influence the everyday pedagogical, spatial and temporal arrangements in schools? What possibilities of learning actions and tasks will educators and students perceive for VR? How do the educators orchestrate the implementation of VR in educational settings? And, what kind of an impression will it leave on the students? These are the questions that I look to answer as part of this thesis.

By and large, previous research on educational VR technology has composed of complex and clinical VR setups, as we will soon discover. Thus, we are currently unaware of how students will react when new VR technology is implemented in their actual learning environment. The purpose of this study is to analyze and interpret the experiences and changes that a commercially available VR system brought to the actual educational environments of two separate Finnish elementary schools. This study was backed by a nationwide development project called "VISIOT", by Innokas Network, where volunteering student groups all around Finland took to trying out and developing different VR, augmented reality (AR) and internet of things (IoT) technologies in education.

Since at least the 1970's, VR has been used for training pilots in the U.S. Air Force (Bricken & Byrne, 1993). The idea to use VR technology to enhance the learning process in regular classroom settings was not introduced to the public until advancements were made in computing power in the 1990's. Despite the increase of computing power, the researchers of VR ended up dismissing VR technology as too raw and unrefined. Hype surrounding VR was dialed down and the technology entered a period where it was primarily developed only on a theoretical and conceptual level. (Bricken & Byrne, 1993; Briggs, 2002; Kipper & Rampolla, 2012) The call for more comfortable and immersive VR solutions was answered in 2016 when new VR devices were released to the public. Since then, the VR market value estimations have grown and are expected to continue to climb steadily for years to come (Statista.com, 2018).

Figure 1. Recent virtual reality devices. The Oculus Rift on the left and the HTC Vive on the right.

Evidently, the latest push of VR has also opened a new market for products and accessories that look to enhance the VR experience (e.g. treadmills, haptic vests, wireless solutions, controller add-ons, etc.). Even computers (i.e. PCs, consoles and smartphones) are more powerful nowadays with a greater capability to run high quality VR. Consequently, new VR devices, such as the Oculus Rift and HTC Vive (see Figure 1), should be more comfortable, operational and make for a more lucrative business than their predecessors ever did.

At this point, it is worthwhile directing our attention to examine what this latest peak of VR technology has brought forth in the educational domain. I find that it is important for today's educators to become aware of the possibilities that various technologies have to offer for enhancing the students' learning process. Likewise, it seems important that the developers of these technologies receive users' feedback on the usability, i.e. the comfortability and user-friendliness, of their products and pay attention to the users' wishes for future improvements.

Despite of the apparent improvements in VR technology's availability and versatility, a widespread educational implementation of VR has not yet occurred. Then again, the educators' patience and cautiousness might be justifiable. Having examined commercially available VR content, it has become apparent that even with seemingly unlimited possibilities for content creation the VR software development has been slow to produce useful educational content. Furthermore, there could be much more opportunities made available for users to create their own content and interact cooperatively in virtual environments.

At this point in time, it seems that all that educators can do is to introduce the technology to students, encourage their self-efficacy beliefs, i.e. one's perceived self-expectations about one's capabilities in a certain task that affect their behavior and willingness to participate in related activities (Bandura, 1997), in relation to engaging with VR technology, and inspire them to resolve future tasks and challenges with the help of VR. Then perhaps one day some of them might have the determination and competence to participate in the development of VR's educational content.

I present the theoretical background for this study in the upcoming sections in the form of a narrative review of literature. According to Cronin, Ryan and Coughlin (2008, p. 38) the main purpose of a narrative literature review is to provide the reader with such background information that contributes to the understanding of the current research and its purpose.

After presenting the necessary background information and research questions of this study (Chapter 1), I will introduce the reader to the current study; its participants, the implemented VR system, the virtual field trip project and finally the data acquisition and analysis methods (Chapter 2). The research questions of this study form separate research topics; educational implementation of the VR system, credibility of the VR program, and the students' user experiences. Thus, the results chapter is divided accordingly to three sections (Chapter 3). In the final chapter I will argue for the validity of this study, provide deliberation of the results, and consider important future research directions and topics (Chapter 4).

1.1 What is virtual reality?

Whilst many of the most contemporary research on augmented reality (AR) refer to Milgram and Kishino's (1994, p. 1322) reality-virtuality continuum (see Figure 2) the studies on virtual reality (VR) hardly ever mention this continuum. Could this mean that VR is something more specific than merely a virtual environment?

Figure 2. Milgram and Kishino's reality-virtuality continuum.

When researchers have offered their definitions of VR, they have tended to broadly refer to an artificially generated environment; a virtually real world (Kipper & Rampolla, 2012; Lorenzo, Pomares, & Lledó, 2013; Pan, Cheok, Yang, Zhu, & Shi, 2006; Selwood, Mikropoulos, & Whitelock, 2000). This computer-generated environment can be created to resemble a real-world environment (Kipper & Rampolla, 2012) or any imaginary world (Lorenzo, et. al., 2013). However, Selwood and others (2000) and Pan and others (2006) also offer a stricter definition; they expect VR to be interactive in ways that lead to active participation and immersion in the virtual environment. Furthermore, they clarify that a VR environment should be three dimensional and multi-sensory. Thus, VR appears to be something more specific than merely a virtual environment.

To put it coarsely, VR is an attempt to (temporarily) replace its user's actual environment with a synthetical multi-sensory 3D world, where the user will have an active role. Lorenzo and others (2013) distinguish this immersive form of VR from other computer-generated virtual environments that can be displayed for instance on desktop PCs (e.g. MMO and MMORPG -games' virtual environments). In this study I will use the term and abbreviation of VR when referring to immersive virtual reality. I do so fully aware that the levels of interactivity and system immersion of different VR system setups can differ (see Section 1.2).

Simply put, a VR system is the combination of hardware and software used to immerse the user to the VR environment (for more elaborative description see Burdea & Coiffet, 2003). Evidently, differences in these components can lead to differences in the usability and perceived possibilities between various VR systems and in their capability to capture their user's attention. Consequently, researchers should associate the discovered possibilities and limitations of the technology to the more specific VR system that was used in their study.

Although the new immersive VR devices (see Figure 1) have seemingly improved in comfortability and display resolution, some issues and concerns remain. As Dan Ackerman (2018), an early adopter of new immersive VR and a CNET reporter, explains, these new immersive devices have not addressed issues with locomotion (i.e. the user's motions in the virtual environment are not totally natural and embodied, as movement from one place to another in the virtual environment is typically unnatural, such as teleportation) and wirelessness (i.e. the users are still connected to computers via hefty cables and the current wireless solutions appear to be merely clumsy add-ons). The prior is not necessarily an accurate observation as there are multiple developers who are addressing the issue of locomotion and have developed treadmill-like add-on devices that allow for more realistic movement.

Ackerman (2018) believes that mobile VR technologies have had a much bigger upside. Although an affordable choice, mobile VR has its own limitations, too, with concerns over the health of its users' eyes. These concerns have become more apparent with the increased availability of the technology. According to Hoffman, Girshick, Akeley and Banks (2008, abstract) the so called "vergence-accommodation conflict" results from our eyes focusing on a mobile display at a closer range rather than where the actual depth of the scene would have our eyes focused on in real life. This may result in an overwhelming strain on the human eyes as the scenes and their depth change whereas the display is always at a set distance. To address the issue, the developers of the mobile VR goggles have recommended that they should be used only for short periods of time (up to 15 min) and by people over 12 years old (Chester, 2017).

1.2 How is virtual reality and its features related to education?

In recent years virtual reality (VR) technology has become more available and familiar to the public, as new immersive devices and mobile VR devices have been made commercially available. But, why should educators consider implementing VR technology in education? After all, it is still seemingly an expensive, complicated and understudied technology.

To answer the above question, I reviewed scientific articles from several eminent journals from both education and computer sciences with high impact factors. After reviewing close to hundred abstracts, I was left with only a handful of articles which met the criteria I had set for the inclusion to this review, i.e. evidence-based studies on learning experiences with VR.

Many of the reviewable articles were conducted in the 1990's and in recent years, which is not surprising. As mentioned before, the educational use of VR built up hype in the 1990's but cooled down after a while when researchers warned that the technology was still too rough (Briggs, 2002; Kipper & Rampolla, 2012, p. 22). As a matter of fact, Bricken and Byrne (1993) reported that their study's participants experienced symptoms of motion sickness due to the awkwardness of the VR technology. And now with the latest development of new and commercially available immersive VR devices the educational hype has built up again.

Virtual reality environment and its features

All VR environments have measurable features (Salzman, Dede, Bowen Loftin, & Chen, 1999). Thus far, researchers have identified the following features: *system immersion* (Huang, Rauch, & Liaw, 2010; Salzman, et. al., 1999; Southgate & Smith, 2017; Roussos, Johnson, Moher, Leigh, Vasilakis, & Barnes, 1999; Tamaddon & Stiefs, 2017), *multisensory cues* (Salzman, et. al., 1999), *interactivity* (Dalgarno & Lee, 2010; Huang, et. al., 2010; Roussos, et. al., 1999; Southgate & Smith, 2017) and *alternative frames of reference* (Chen, 2010; Roussos, et. al., 1999; Salzman, et. al., 1999; Southgate & Smith, 2017). (see Figure 3.)

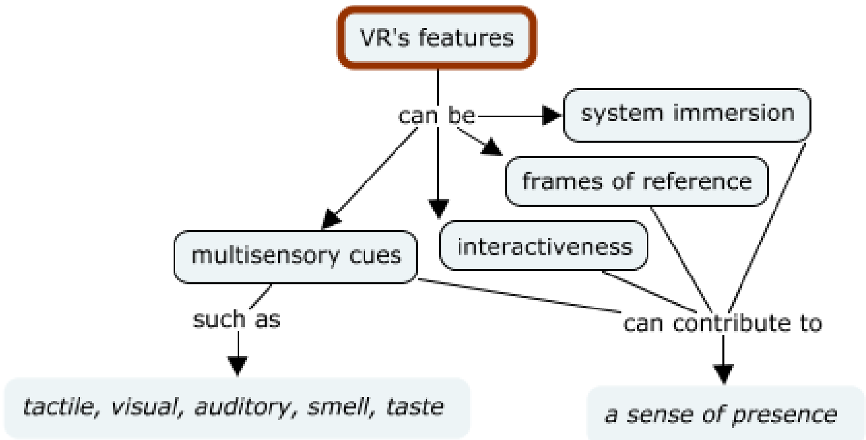

Figure 3. Known features of virtual reality.

With education in mind, all these features are said to influence the learning process and how users experience their VR environment. Furthermore, Burdea and Coiffet (2003, p. 3) point out that VR environments success often also depends on human imagination.

System immersion and the sense of presence

According to Slater, Usoh and Steed (1995, p. 204), user’s response to VR’s *system immersion* (e.g. how capably it tracks and responds to user actions) is called *the sense of presence.* Slater (1999) later clarified that the sense of presence can be caused by system immersion if it leads to the user feeling like being within the VR environment, reacting to the events in it or afterwards feeling as if they had visited another place.

Researchers Dalgarno and Lee (2010, p. 13) maintained that a strong sense of presence is due to the fidelity of the VR representation and the interactive capabilities present in the VR environment. Sherman and Craig (2003, p. 9) called this feeling of involvement and deep engagement “mental immersion” and referred to the sense of presence as being mentally immersed. For Dalgarno and Lee (2010, p. 13), mental immersion is a potential outcome of VR’s other features rather than a unique property of VR. In this thesis I will use the concepts of mental immersion and sense of presence interchangeably.

The effects of mental immersion on the meaningfulness of one’s learning experience in VR environment remains unclear. Then again, one could argue that sense of presence resembles the state of flow (i.e. when one meets an appropriately challenging task relative to their perceived competence, they may lose track of time and become deeply engaged with the task or activity, see Csíkszentmihályi, 1997). Therefore, mental immersion could understandably provide motivation and volition to engage in activities available in the VR environment. As a matter of fact, Huang and others (2010, p. 1173) claim that “a strong sense of presence motivates and thereby causes the learner to cognitively process the learning material more deeply”. On the other hand, Salzman and others (1999, p. 309-310) found out that motivation alone did not predict learning.

Multisensory cues and alternative frames of reference

Salzman and others (1999) conducted several studies on VR's features' effects on conceptual learning. By analyzing the data and comprising findings from their five studies, the researchers managed to develop and refine a hypothetical introductory framework for the relationship between VR's features and conceptual learning (see Figure 4). Moreover, they urged future researchers to challenge and develop this framework (p. 314-315).

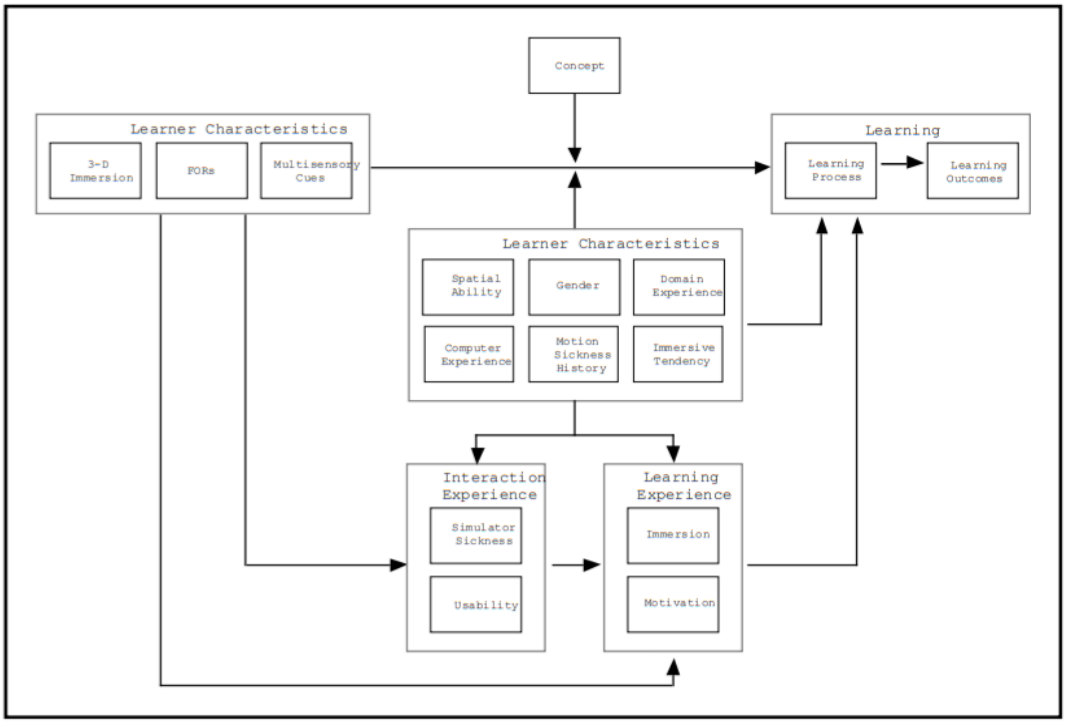

Figure 4. Salzman, Dede, Bowen Loftin and Chen's (1999, p. 312) introductory framework on virtual reality's features effects on conceptual learning.

Salzman and others (1999) developed VR environments that contained learning tasks on physics related phenomenon. By altering the availability of VR's features the researchers discovered that the participants learning experiences were enhanced by the possibility to alter the frame of reference and by the availability of multisensory cues (p. 305).

Those "participants who received *multisensory cues* (e.g. visual, auditory and haptic) appeared to be more engaged in activities…than students receiving only visual cues" (p. 305). In fact, Burdea, Richard and Coiffet (1996, p. 6) have stated that a rich and accurate sensorial interaction can contribute to the sense of presence.

Frames of reference, on the other hand, can refer to the different viewpoints a VR system allows the user to take, the capability to visit places one cannot physically access, or the visualization of abstract phenomenon (Southgate & Smith, 2017). According to Roussos and others (1999, p. 261) a VR system's capability to provide alternative cognitive frames of reference could be its most significant contribution to enhancing a learning experience.

Interactivity

Understandably, the existence and quality of VR environment's features are first and foremost due to the choices and design of the applied VR hardware and software (i.e. the devices and the program). According to Selwood and others (2000, p. 233), VR devices can be classified based on the technology by which a VR environment is made accessible (i.e. simulators and emulators, CAVE systems, fully immersive systems, mobile headsets, etc.).

VR programs, on the other hand, can be divided into three subgroups according to the amount of user participation that they allow (Selwood, et. al., 2000, p. 233). If the program does not allow the user to interact with the VR environment nor move within it freely, and the user is reduced to just being an observer, the program can then be categorized as *passive*. When the user has more control over their own movement and can venture in the VR environment, the program can be categorized as *explorative*. Next, if the user also has the possibility to create, move and/or shape objects, or engage with other users in the VR environment then the program can be categorized as *interactive*.

Huang and others (2010, p. 1179) learned through their case studies that interaction has a significant impact on learning performance. They argued that if knowledge is based on active experience, then an active role in an immersive VR environment could help users construct knowledge through interacting with the learning material in it. Thus, it appears that out of the three abovementioned categories, interactive VR programs have the most potential to facilitate active learning experiences and impact learning outcomes.

Furthermore, Salzman and others (1999) revealed that having control and influence over VR's environmental factors (i.e. interacting with the VR environment) can lead to a deeper sense of presence and thus have more profound positive motivational effects. In fact, Roussos and others (1999) had noticed that those participants who had the most control over the events in the VR environment, were the most engaged in a learning activity and enjoyed the experience the most.

Virtual reality's educationally relevant affordances

Amongst other early researchers of VR in the 1990's, Mikropoulos, Chalkidis, Katsikis and Kossivaki (1997, as cited in Selwood, et. al., 2000, p. 234) suggested that VR should be developed further in education, since it can allow for the exploration of such phenomenon and surroundings that are unreachable without altering the scale in size, time or distance. This could bring forth opportunities for such unique participatory activities that can only exist in these kinds of artificial environments with altered qualities. They added that teaching with VR makes for a great alternative when practicing in the actual environment would be impossible or otherwise dangerous, and when mistakes in the real life could turn out to be harmful to others or to the environment.

More than that, Pan and others (2006, p. 20) believed that VR has the capability to facilitate learning. For them the main facilitator of learning was the virtual learning environment. They considered it to be a medium that can provide such enriched educational strategies and content which can help the learner develop their problem-solving skills and explore unfamiliar concepts. According to Pan and others, the VR medium, with its immersion, interactiveness and enhanced imagination, could serve as a virtual learning space where learners are able to create, build and share knowledge together. Similarly, Mikropoulos and others (1997, as cited in Selwood, et. al., 2000, p. 234) also believed that VR makes it possible for the user to interact with virtual models and beings in multiple different ways, and that this type of experimentation can be motivating. All in all, these assessments describe the potential affordances of VR technology.

As mentioned before, it is important to realize that VR systems can be quite different from one another. It should be acknowledged then that different combinations of hardware and software are likely to support some of the above-mentioned factors better whilst disregarding others, resulting in different affordances. And that at the end, it is up to the user, which affordances actualize.

It is worth mentioning that the concept of affordances was originally suggested by Gibson (1979). He used it to describe the possibilities for physical actions that a person perceives in a certain space. For Mehan (2017, p. 18-19) the affordances of a space extended beyond the possibilities for physical actions and included potential social, emotional, and cognitive actions and outcomes. They further explain that potential affordances, which exist regardless of a person's perception, become actualized affordances only when they manifest because of an individuals' actions. To summarize, Hammond (2010, p. 12) stated that in general "an affordance is the perception of a possibility of action provided by the properties of (an object)". In this study that object will be the applied VR system.

It is also worth mentioning that according to Dalgarno and Lee (2010, p. 17) educational technologies themselves do not cause learning, but they may afford certain learning tasks which in turn may lead to the facilitation of learning. Moreover, they suggest that the following potential affordances are true for all kinds of 3D virtual learning environments, desktop and VR alike (p. 11; 18-23);

3D virtual learning environments can be used to facilitate:

1. learning tasks that lead to the development of enhanced spatial knowledge representation of the explored domain
2. experiential learning tasks that would be impractical or impossible to undertake in the real world
3. learning tasks that lead to increased intrinsic motivation and engagement
4. learning tasks that lead to improved transfer of knowledge and skills to real situations through the contextualization of learning
5. learning tasks that lead to richer and/or more effective collaborative learning than is possible with 2-D alternatives

Of course, these potential affordances are generalizations, and their achievability may vary based on the composition of the VR system. Furthermore, their manifestation depends also on the user's and/or implementer's perceived possibilities for action. For instance, lets imagine that a VR system, which is used to introduce volcanoes to a learner, has the potential affordances to engage the learner in the learning task and provide them with learning experiences that would otherwise be impossible to undergo in the real world. The user is very engaged in learning about volcanoes and studies them while virtually walking on the hillside of one volcano. What they have failed to recognize is the possibility to fly up and view the volcano from above, or to dive down inside the volcano and experience a volcanic eruption by being tossed upwards with a discharge of lava and gas from a volcanic vent. In this example, the user does not perceive the possibility to experience and study volcanoes from different, and "impossible" perspectives. Thus, that particular potential affordance does not actualize for the user.

Learners and educators have differences in their needs and know-how that may result in them perceiving the possibilities of action with VR technology quite differently. These factors and other user characteristics can impact a user's experience with VR (Salzman, et. al., 1999; Slater, 1999). Along the same lines, some actions may be encouraged and some constrained by the instructions and scaffolding (or lack thereof) provided within a VR system, or in the applied pedagogical arrangements and set learning goals outside of it.

According to Wood, Bruner and Ross (1976) scaffolding is a type of assistive tool; a written instruction, a supportive knowledgeable person, etc., which is used to adjust the challenges of learning tasks closer to a learner's actual competence level, i.e. the learners existing cognitive functions, or what the person already knows and can do (Vygotsky, 1978). For Vygotsky (1978) learning and development occur in a zone of proximal development (ZPD), where, by interacting with others, the learner's cognitive functions are developed, and a new stage of actual competence can eventually be attained. Scaffolding can be a useful tool to adjust the challenge for the learner so that they can operate on their ZPD. For instance, Hauptman (2010, p. 130) discovered that the addition of guidance through self-regulating questions did in fact improve the quality of learning with VR. According to his research findings scaffolding was perceived as effective, especially, when the learners faced complex learning tasks.

The role and characteristics of instructions and scaffolding in a typical learning environment vary based on an educator's choice of applied pedagogy. According to Murphy (in Murphy, Hall, & Soler, 2008, p. 35) pedagogy broadly refers to "the interactions between teachers, students and the learning environment and learning tasks". They added that to know whether certain pedagogical arrangements are effective, we should first be able to agree on what the goals of education are. It is common knowledge that teacher's implement different digital and non-digital technologies in the learning environment, thus, making them a part of their pedagogical arrangements. Therefore, the effectiveness of pedagogy is at least partly related to the effectiveness of those implemented technologies' potential and actualized affordances that draw us closer to the overall goals of education.

Li, Gu and Chen (2010, p. 232) remind us that it is important to understand that VR systems are just tools. Thus, choosing the optimal tool for a certain learning process, and implementing it properly, should be guided by information about the specific VR system, prior research and contemporary pedagogics. In like manner, one ought to account for the spatial and economic resources of their educational institute when making those choices (Roussos, et. al., 1999, p. 261).

Southgate and Smith (2017, p. 2) also pointed out that the possibilities of research will ultimately be determined by what different schools can afford. Furthermore, according to them, all researchers must understand that schools can be in a very unequal position when it comes to their financial capabilities.

This study features two different schools, one urban and one rural, both of which received funding and support from the nationwide VISIOT -project, and Innokas Network. Nonetheless, as we will later discover, the two schools still had clear differences in the way that they were able to set up and implement similar VR systems.

1.3 Previous studies and associated learning theories

In this section, I briefly describe some of the previous studies that have been conducted regarding various VR systems and their user experiences in a chronological order. I will also highlight some of the most notable learning theories that have typically been associated with the educational use of VR. Subsequently, I will present a refined framework for VR's features' effects on learning possibilities based on what I have learned so far from the review of literature.

Chronological recap of previous educational virtual reality studies

At a time when commercial VR systems had very limited capabilities, Bricken and Byrne (1993) conducted a mixed-methods research on children's VR experiences and on the appeal of a VR visit to a self-made 3D world. Their study's 59 participants were 10-15-year-olds who had signed up for a digital technology summer camp.

During the summer camp the children worked in groups and got an opportunity to build their very own 3D worlds. None of the children had prior experiences in 3D modelling. The modelling tools were also new to their instructors and they all had to rely on co-discovery strategy when learning on how to use them.

On the final day of their summer camp the children travelled to their 3D worlds one by one through a VR system that consisted of first generation *VPL Eyephones*™ and a right-handed *DataGlove*™, both connected to a *Macintosh FX* (see Figure 5). Amongst other things, the researchers asked the students to imagine fantasy VR worlds that they would like to visit. They learned that students enjoyed their visits to their self-made VR worlds, even though the technology was still quite primitive and made some of the children uncomfortable at times. Furthermore, the researchers laid out a path to survey a VR system's usability.

Figure 5. Apple Macintosh II/FX on the left and VPL Eyephone™ and DataGlove™ on the right.

Roussos and others (1999) had created an open virtual world set on an island where participants could grow and tend a virtual garden. Those participants were 44 second-grade students from an urban school and eight case studied children from other schools. This was a novel attempt to implement VR technology with an entire classroom of students.

To be able to act in the virtual world the participants were divided into groups of seven or eight students. They devised a design plan for the garden together, before being separated into two smaller groups. One of those groups operated on a device called *ImmersaDesk*™, a large screen tapped into the virtual garden environment. From the other group, a “leader” was chosen to operate a device called the *CAVE*™, a multi-person theater with blank walls and floor where images of the virtual world were projected (see Figure 6). A second-grade teacher also participated from a separate *ImmersaDesk*™ and appeared as a virtual avatar in the virtual garden to provide scaffolding.

In their novel attempt to implement VR with a full-sized student group, amongst other things, the researchers discovered how important sound pedagogical arrangements and meaningful learning goals can be for successful VR enhanced learning. Only a handful of the students felt engaged in the activity. The teachers were unable to provide any scaffolding in the virtual space since they were too busy maintaining order.

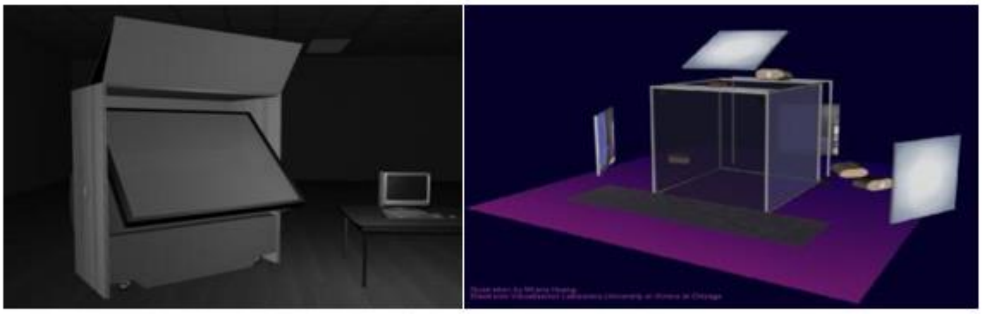

Figure 6. Illustrations of the ImmersaDesk™ on the left and the CAVE™ on the right as depicted on the University of Illinois at Chicago website.

As mentioned earlier, Salzman and others (1999) conducted five studies on their self-designed VR programs called *NewtonWorld, MaxwellWorld* and *Pauling-World*. Their programs were meant to educate on physics phenomenon. The pedagogical idea was to ask students to make predictions before attempting an activity in VR, have them observe the results of their actions, and then compare their predictions with what happened. Multiple different participants took part in their studies ranging from students to physics professors.

Over the years, the researchers managed to uncover a great deal about the characteristics and connections of VR's features, and their role in conceptual learning. Moreover, they put together the hypothetical introductory framework for VR's features and learning (see Figure 4). They suggested that VR features' impact on learning outcomes is not straightforward, but that there are variables that influence this relationship, such as: *learner characteristics* (i.e. gender, domain experience, spatial ability, computer experience, motion sickness history and one's immersive tendencies), *interactive experience* (i.e. usability and simulator sickness), *learning experience* (i.e. motivation and immersion), and *prior knowledge*.

A decade later, Hauptman (2010) conducted a quantitative research on spatial thinking and its development via a VR program called *Virtual Spaces 1.0*. Additionally, he intended to research whether self-regulating questions (SRQ) could assist the learning process. Almost 200, 10th grade students (avg. age of 15.2) from six different schools volunteered to participate in the study. Only students who owned and actively used computers were accepted to participate in the project. They were randomly assigned to different groups: Group 1, N=52, used *Virtual Spaces 1.0* with VR and SRQ. Group 2, N=52, used *Virtual Spaces 1.0* only with VR. Group 3, N=45, used booklets and SRQ. Group 4, N=45, acted as the non-treatment group. *Virtual Spaces 1.0* contained 3D exercises set to develop the capabilities that affect spatial thinking.

During the project, students in Groups 1 and 2 solved tasks with Virtual Spaces 1.0 for short periods of time (approximately 15 minutes per student). The VR system consisted of a stereoscopic *5DT HMD* and *a three-dimensional mouse* (see Figure 7). It turned out that *Virtual Spaces 1.0* was a more effective learning tool than booklets in advancing the students' spatial thinking. The relationship between the students' spatial thinking skills and their experienced usability of a VR system remains to be determined. But, thanks to the study, researchers know that scaffolding appears to be beneficial for learning even in a VR environment and especially if the learning tasks are complex and challenging.

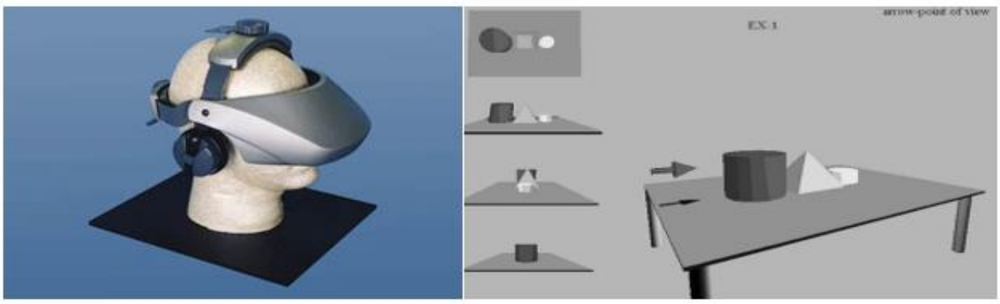

Figure 7. 5DT Head Mounted Display on the left. A black and white view of an exercise within virtual spaces 1.0 on the right from Hauptman (2010, p. 132).

In more recent years, virtual reality technologies have taken a leap with the introduction of such commercially available devices as the Oculus Rift and the *HTC Vive* (see Figure 1). Aiming to provide authentic experiences of gravity and microgravity, Tamaddon and Stiefs (2017) designed a small user study with a unique virtual reality setup (see Figure 8). An experimental group of eight 13-year-old students participated in a role-playing exercise where their avatar was an astronaut floating near the International Space Station. Immediately after the experiment the students took a test where they were asked to predict the outcomes of actions taken in microgravity. A control group of 14 students of the same age took the same test without the virtual reality experience prior to it. The researchers found out that the simulation had indeed enriched the predictions of the experimental group which were more varied and more on point than those of the control group (Tamaddon & Stiefs, 2017, p. 4).

Southgate and Smith (2017) conducted a literature review on current theories surrounding research with immersive head-mounted-displays (HMDs) in educational settings. In addition, they claim to have designed and conducted research in an Australian school community with VR HMDs. Their article introduces seven ethical advices for VR research in actual school settings (p. 1-2). These advices are based on their literature review and reflection of their own experiments. Amongst other things they point out that schools are natural and "messy" settings where results of more clinical studies might not necessarily apply.

Furthermore, schools have unique spatial and temporal structures and resources that can make the implementation of certain VR systems more difficult than others. For example, if we would take the VR system of Tamaddon and Stiefs (2017), with all its full-body tracking and bungee ropes (see Figure 8), it is hardly something one could implement in the actual school settings with ease, let alone, without proper regulations and safety measures.

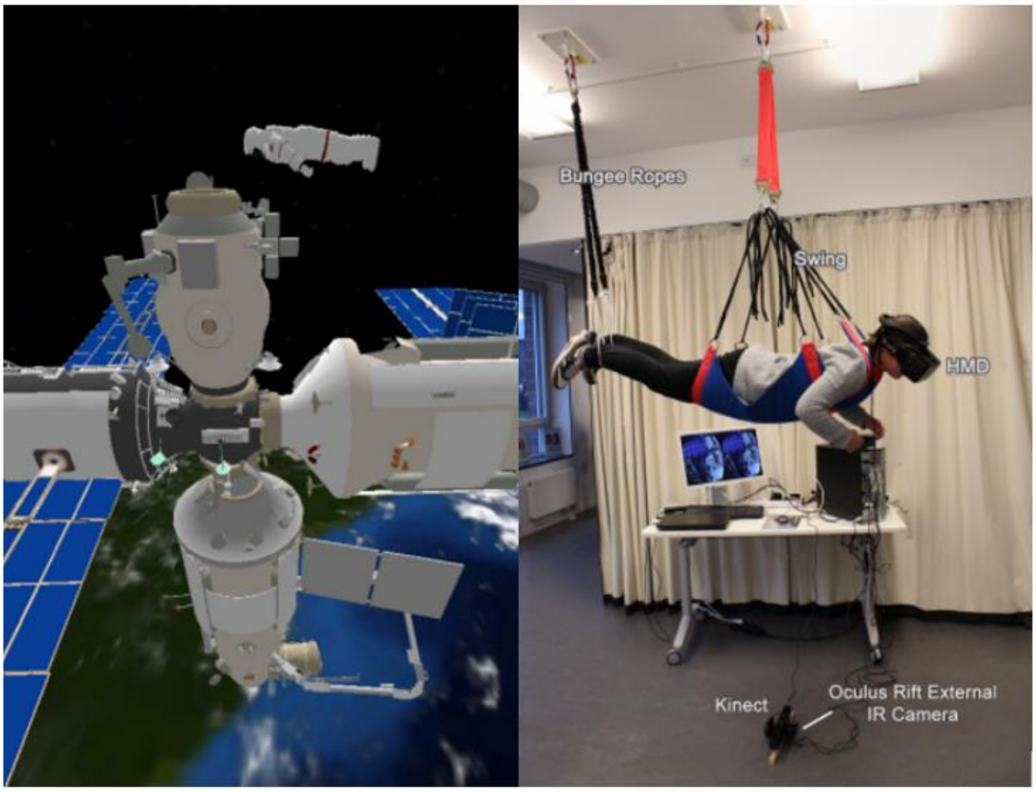

Figure 8. Tamaddon and Stiefs' (2017, p. 2-3) virtual reality setup to teach young students about microgravity.

Southgate and Smith (2017) also echoed the suggestion that those conducting new studies on virtual reality in school settings, should ask themselves whether their research is “on, with or by children”. They spoke on behalf of more empowering roles for children and teachers as part of future studies. Southgate, Smith and Scevak (2017, p. 13, 15) also pointed out that educators must consider the *ethics-in-practice* – i.e. they should stay alert on the children's mental and physical states when using immersive VR. It is worth noting that not all VR environments are suitable for children. Neither I nor the participating teachers want any harm to come to children. Furthermore, they should never be exposed to harmful content nor should they be forced to use tools they do not feel comfortable using.

By and large, the studies presented above have been conducted in rather clinical and experimental setups. Furthermore, the students and teachers have contributed mostly as objects of these experiments with a few exceptions where a teacher’s observations were accounted for. In this current study, I attempted to empower the participants as part of a design experiment’s first iteration and research the effects of the implementation of a commercially available VR system in actual school settings in an ethical way.

Implementation of virtual reality and related learning theories

According to Dalgarno and Lee (2010, p. 24), the way that a VR system is being applied in education eventually determines how VR’s features are experienced and what possibilities of learning actions become available. These actions become the actualized affordances of a VR system once they are perceived and acted upon by the learner. Pedagogical arrangements, i.e. in what way does the educator organize a learning project and the learning environment, and more importantly for us now, how they plan on applying the VR tool, become key factors in accessing VR system’s potential affordances. For instance, applying a VR system with a passive VR program that lacks in interactivity, could make it unsuitable for tasks aimed at promoting active engagement in learning if visiting in it would be the students’ only learning task.

It is relevant for educators to assess VR environments beforehand and evaluate how they might best be used as part of proper pedagogical arrangements. For example, a learning space equipped with one VR device might not make the best learning environment for group projects, since that setup allows for only one active operator of the VR device at a time. The other group members could end up sitting idly by, unless they could contribute to the group's work by some other means. As mentioned before, Roussos and others (1999, p. 258) noticed that in situations where the control over the events within the VR environment was unequally divided between participants of a group project, only those who had the control remained constructively engaged in the learning activity. Theories of intrinsic motivation second the stand that pedagogical arrangements supporting autonomy and facilitating feelings of control can have a positive effect on students becoming intrinsically motivated to act (Pink, 2011; Ryan & Deci, 2000, p. 58).

One common way that educators often use to direct their students' collaborative learning is known as scripting, whether it be social or epistemic (Weinberger, Ertl, Fischer, & Mandl, 2005). Weinberger and others (2005, p. 28-29) found that social scripts, i.e. instruction on how the collaborators should interact during a learning task, can be beneficial in facilitating individual's acquisition of knowledge. Moreover, they noticed (p. 29-30) that epistemic scripts, i.e. the strategies by which a task can be solved, did not have the desired learning benefits. Furthermore, it appears that the degrees of freedom may vary between different scripts (p.12). Therefore, it is possible to over-script collaboration by limiting the learners in learning activities in such a way that confines the learners' conversation and interferes with their creative cooperative problem-solving.

Another important factor to consider when applying VR technology in education is to establish clear learning goals. Roussos and others (1999) found out that when the learning goals were unclear to the students, the entire learning activity lacked direction. They also concluded that when using VR in education, the learning goals should be both challenging and important enough for the students. Chen (2010, p. 72) believes that although VR systems have differences, and bring forth different possibilities of action, it is possible to identify the best available tool for a specific learning purpose.

All this goes to show that the pedagogical arrangements and instructions embedded in VR systems and in the physical learning environment outside of them are important components in the learning process. For instance, how appropriately one implements (and/or designs) a VR system could determine its actualized affordances and their efficiency to facilitate learning. Chen (2010, p. 72) was convinced that if a VR system is properly implemented it will bring forth many educational benefits. I will now explore some of the related learning theories mentioned in previous VR research, whilst moving towards an idea of what it means to implement VR technology properly in educational settings.

“Deep learning”

Currently the concept of deep learning is used to describe techniques by which computational models such as artificial (or augmented) intelligence learn to utilize natural data from their immediate environments better, for instance, through speech recognition, object detection, etc. (LeCun, Bengio, & Hinton, 2015, p. 436) However, the concept had a different meaning for the researchers of VR back in the 1990’s.

Roussos and others (1999) proposed that the capabilities and features of a VR system should first and foremost be used to facilitate “deep learning”. According to them (p. 261) this meant focusing on facilitating “learning which requires the rejection of inadequate and misleading models based on everyday experience, which have proven resistant to conventional pedagogy, and which are the source of persistent adult misconceptions”. They claimed that this could be achieved with the help of VR systems that allow us to experience and explore phenomenon from various cognitive frames of reference different from our everyday perspective. The researchers’ speculation does not, however, inform us about the efficient and practical ways to organize these learning activities beyond merely exploring different perspectives, nor what type of pedagogical arrangements and learning tasks could help students reject their existing misguided beliefs and create new “models” based on their learning experiences with VR.

Furthermore, Dalgarno and Lee (2010, p. 24) remind us that this entire assumption needs further empirical exploration. They say it is unclear whether users will even trust their experiences in VR environments sufficiently enough to be able and willing to begin modifying their previous beliefs and assumptions.

Tseng and Fogg (1999) noticed that researchers often use the concepts of trust (i.e. dependability) and credibility (i.e. believability) inconsistently. It appears to me that when Dalgarno and Lee (2010, p. 24) use the verb “trust” they refer to the credibility (i.e. believability) of a VR environment. I will now take a moment to present the reasoning behind this conclusion.

Finding a VR environment as a credible source is merely a first step towards modifying one’s beliefs. Nonetheless, it is a challenging step. As humans we tend to hold on to our existing beliefs and conceptions. Moreover, we are prone to seek and embrace information which supports our existing mental models, i.e. beliefs and representations of real-world phenomena, even over conflicting new information - this cognitive error is known as *confirmation bias* (Nickerson, 1998, abstract; Hakkarainen, Lipponen, & Lonka, 2004, p. 38). Therefore, the trust as dependability that a learner projects upon a VR environment might solely be based on its consistency with the learners existing mental models. But, a credible VR environment should be believable even when it offers the learner what seems as incompatible information, thus causing a cognitive conflict, i.e. when a person receives new information about a phenomenon that conflicts with their existing mental models (see Johnson & Johnson, 2009, p. 39). In other words, credibility (i.e. believability) appears to be a more reliable indicator of how effective a VR environment could be in facilitating Roussos and other’s “deep learning”.

I emphasized the word “could” because a VR environment on its own is not guaranteed to lead to any type of learning. It requires proper pedagogical arrangements both within and outside of the VR environment. (Winn, 1997, as cited in Hauptman, 2010, p. 215; Dalgarno & Lee, 2010, p. 24) Thus, I leave the concept of “deep learning” behind for now and move towards theories and concepts that recognize the importance of pedagogical arrangements in facilitating learning.

Constructivist learning

Researchers Wu, Lee, Chang and Liang (2013) conducted a meta-analysis to investigate the educational uses of augmented reality (AR). Their analysis indicated that the afforded learning tasks led to desirable learning benefits (e.g. collaborative and engaged learning) mainly when the technology was used with learner oriented pedagogical arrangements emphasizing either roles, places, tasks or a combination of them along with distinct educational goals (p. 43-45). It is yet unknown whether these results also apply to other educational technologies, such as VR. This should become clearer when more research into VR as an educational tool is conducted in actual educational environments.

For Winn (1993) and Chen (2010, p. 73), the best educational VR systems allow the learners to have first-person experiences and experimentation through which they can begin to construct knowledge. They both agree that with appropriate design and implementation a VR system could facilitate learning in accordance with the constructivist learning theory, i.e. the features of VR could assist the learner when making observations and constructing knowledge of the world's phenomena based on their experiences.

In constructivism all knowledge is based on active experience. Huang and others (2010, p. 1173-1174) identified five constructivist learning strategies that could be suitable for the implementation of VR in learning. These five strategies include; *situated learning* (i.e. educators include and augment the learners authentic experiences attained with VR technology in the learning process and ensure that the learners are able to actively construct knowledge through interaction), *role playing* (i.e. educators arrange the learning environment enhanced with VR technology where the learners are allowed to safely imagine and create new and playful identities), *collaborative learning* (i.e. educators set up learning activities in a way that enables the students to interact with each other both in and out of a VR environment, and learn from one another in their zone of proximal development), *problem-based learning* (i.e. educators use this strategy to encourage students to collaborate and develop their individual thinking abilities, the real-world problems can be presented, researched and solved in a VR environment) and *creative learning* (i.e. educators aim to create such conditions that facilitate self-reflexive learning and student creativity with practices, for example, in a modifiable VR environment). The researchers were convinced that VR technology could be used efficiently for learning purposes if implemented with these strategies. Nowadays, when applying these strategies, educators have also begun emphasizing the importance of social interaction and view the students' as active participators who can direct their own learning.

From experiential to immersive learning

As mentioned in an earlier chapter, Dalgarno and Lee (2010, p. 19) suggested that VR environments have the potential affordance to facilitate experiential learning tasks that would otherwise be impossible to undertake in the real world. Based on Kolb's (1984, p. 26, 38) theory on experiential learning, humans learn through forming and re-structuring ideas based on our experiences. According to the theory, learning is not just a mere memorization of facts, but a process that involves metacognitive activities such as the purposeful reflection of one's experiences, and the adaptive re-organization and testing of one's conceptual believes. According to Lewis and Williams (1994, p. 9), meaningful learning can occur in experiential and authentic learning classrooms, where "students can process real-life scenarios, experiment with new behaviors, and receive feedback in a safe environment".

Immersive learning draws not only from constructivist, socio-cultural and authentic learning, but also from self-regulation and social cognitive theories (see Blashki & Nichol, 2008, p. 382). Blashki and Nichol (2008, p. 383) attributed students learning possibilities to the design and use of the learning environment, and to the teacher's choices of instructional strategies. Furthermore, when defining key concepts, they refer to immersive learning as a philosophic approach to organizing the learning environment and instructions in such a way that empowers the students by handing them ownership and autonomy over their own learning process.

It should come as no surprise by now that VR technologies have the potential to offer unique immersive experiences and engage their users. According to Dede (2009, p. 66) these technologies can be used to design such educational experiences altogether that "build on student's digital fluency to promote engagement, learning, and transfer from classroom to real-world settings". For today's children, who use digital devices daily and to whom the online life seems to be a vital extension of their offline-life (Savin-Baden, 2015, p. 2), savoring "real-world" moments, and practicing mindful being and perceiving might be lost concepts. A well-rounded immersive VR system should, however, be able to capture a child's attention to the learning activities at hand and, thus, help provide an unexpectedly mindful learning experience. Such a tool might just be welcomed to an immersive learning environment, which, according to Blashki, Nichol, Jia and Prompramotes (2007, p. 410-411), is learner-centered, i.e. “the learners participate, direct and implement engaging and immersive learning activities both for their own use and the use of students who follow in their footsteps”. In this study, amongst other things, I research the students’ experiences with VR technology and, for instance, their interest in engaging with the technology again in future studies, which could indicate whether this technology can make for a desirable tool in immersive learning environments.

Synthesis of the review of literature

Based on the information obtained from the review of literature, I modified Salzman and others (1999) introductory framework (see Figure 9). More research has gone into VR and other related technologies since their studies in the 1990’s. Furthermore, more contemporary research has also been conducted regarding learning and pedagogy. It now appears that without proper pedagogical arrangements VR’s features are not enough to bring forth such affordances that efficiently facilitate learning as proposed by Salman and others framework.

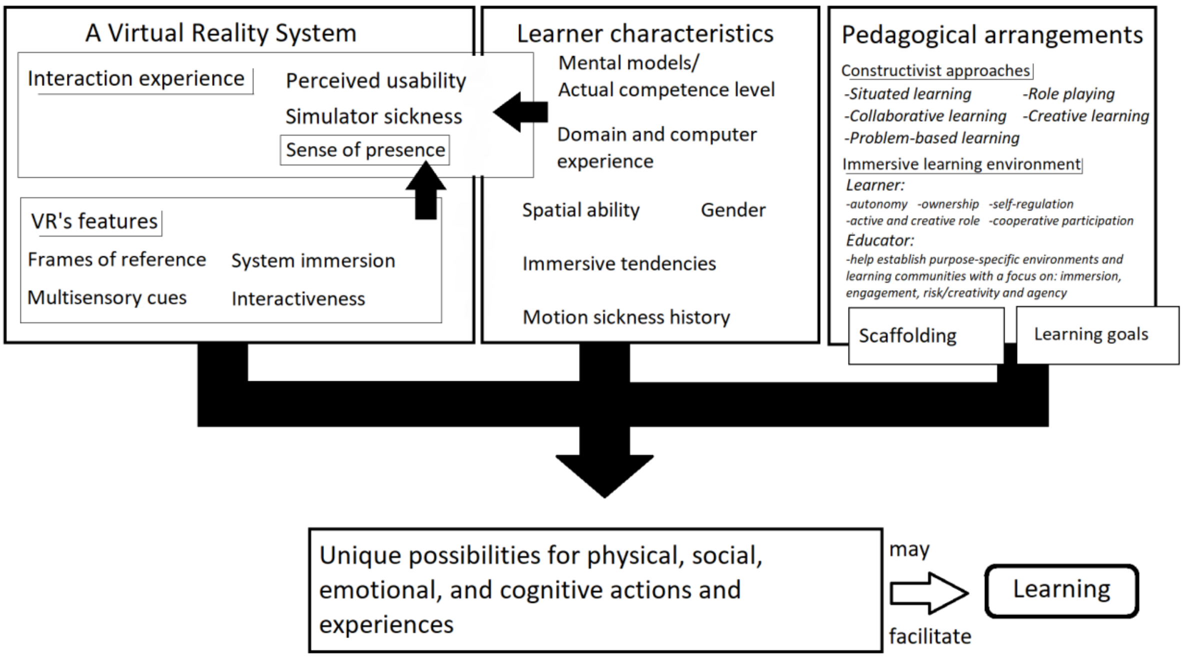

Figure 9. A modified framework of a virtual reality system’s connection to unique affordances that might facilitate learning.

I propose that by incorporating proper pedagogical arrangements, scaffolding and learning goals, and by considering the students' learner characteristics and agency, together with an appropriate choice of a VR system, it is possible to build such a learning environment where a VR system is used to offer unique, immersive, and engaging possibilities for physical, social, emotional and cognitive learning actions and experiences that may help facilitate learning.

This modified framework associates the differences in VR's features to the applied VR system. Similarly, the interaction experience may vary with the applied VR system and based on how a learner perceives it through their unique characteristics and past experiences. Furthermore, VR's features now also recognize and include interactiveness, and immersion is properly addressed as system immersion. So far, I have not included imagination, as it is unclear whether it should be called a VR's feature, a learner characteristic or counted as an interactive experience. This modified framework also acknowledges that when successful, a combination of VR's features may contribute to a learner's sense of presence which is a part of their interaction experience. Lastly, learner's prior knowledge is seen as part of their characteristics in the form of existing mental models, which could also be referred to as their actual competence level.

1.4 The purpose and research questions of this study

This research is a part of the Innokas Network's VISIOT-project, funded by the Finnish National Agency for Education. Its purpose is to assess the possibility of virtual reality's (VR) use in education, by analyzing the impacts that a commercial VR system had on the students' everyday learning experiences when implemented in their learning environments.

This study was a team effort. I wanted to empower the participants by offering them important roles in the research of the VR system. Three teachers orchestrated the implementation of a VR system and acted as observers. Their students assessed the VR system, their experiences with it, and the technology's suitability for learning. I analyzed and interpreted versatile data obtained with mixed methods throughout the implementation process. This included but was not limited to data on the participants' experiences, the students' evaluations of the VR system, and the answers to open-ended questions and online interviews. Further elaboration of the data gathering, and analysis methods will be in section 2.4.

To begin understanding what actualized affordances manifested when the teachers arranged environmental study projects and implemented the commercial VR system in the actual school environment, it seemed important to begin by asking:

1. *What kind of virtual reality enhanced environmental studies projects did the teachers orchestrate, and how did the implementation of a virtual reality system affect the students' typical learning arrangements?*

To answer this question, I gathered, analyzed, and classified qualitative data about the students' typical environmental studies arrangements, as well as, the challenges and changes that the implementation of the current VR system brought forth (see Section 3.1).

In the review of literature, I examined different learning theories and pedagogical arrangements related to VR technology. Amongst other things, Roussos and others (1999) notion of "deeper learning" was challenged by Dalgarno and Lee's (2010) call for more studies on the credibility of VR environments. Furthermore, I learned that, ideally, immersive learning environments are learner-centered, where students' voices matter, i.e. their interests and engagement should play a vital role in what tools and methods are implemented in the learning environment (Blashki, et.al., 2007). I was curious to study whether VR technology is something that today's students would consider useful and would want to have available in their learning environments. These factors prompted me to ask:

2. *What was the reasoning like behind the students' credibility assessments of the Google Earth VR program's virtual world, and how willing would they be to engage again in virtual reality technology's use for learning?*

To answer this question I analyzed, interpreted and categorized data from students' self-reported reliability assessments and answers to open-ended questions, such as; "What made the *Google Earth VR* projection reliable?", and "What is the most reliable use for the *Google Earth VR* program?". Moreover, I used a questionnaire with a Likert-5 scale in the post-survey to inquire about the students' self-efficacy beliefs and their willingness to engage with the VR technology again in their future studies at school (see Section 3.2).

Lastly, since this was a rare VR technology study in the field, it was important to focus on the student's user experiences with the applied VR system. I was interested in their perception of the VR system's usability, what emotional effects it might have had on them, and the impressions it had left on the students' conceptual understanding of VR and their fantasies about VR worlds. Thus, I set the following final research question:

3. *What kind of user experiences did the students have with the applied virtual reality system, from the perspective of usability, emotions, and impressions?*

To answer this question, I thoroughly analyzed the students' self-reported user experiences during and after the project; the applied VR system's usability, the students' emotional responses to it and the impressions it had left on them (see Section 3.3).

2 Methods

Although this is mostly a descriptive study, it partially followed the idea of a design experiment. According to Cobb, Confrey, diSessa, Lehrer and Schauble (2003, p. 9) the goal of a design experiment in the educational field is to develop theories on how to support learning. They acknowledged the complexity of actual school settings and explained that the designable elements include (p. 9) “the tasks or problems that students are asked to solve, the kinds of discourse that are encouraged, the norms of participation that are established, the tools and related material means provided, and the practical means by which teachers orchestrate relations among these elements”. I decided to use the design experiment approach, because it seemed to suit the novelty of this study, where virtual reality (VR) technology was implemented for the first time in actual school settings in Finland. By conducting such experimental research, I hope to be able to provide good scientific insight and research suggestions, and expand our knowledge of the possibilities of this technology in educational environments.

In this study, I focus on assessing the experiences and affordances that actualized when new tools and material means were provided for young students in the context of an environmental studies project. For academic integrity and transparency, I will now describe with whom and how the research was conducted, what type of VR system was implemented, how it was initially planned to be applied, and most importantly, I will present the data acquisition and analysis methods.

2.1 The participants

Three teachers and 59 of their students (11-12 -year old) from two Finnish elementary schools, one from an urban area and one from a rural area, voluntarily participated in this study. About 40 of the students were from the English-speaking urban school and the remaining 19 from the Finnish-speaking rural school. 18 of the 40 students from the urban school were 6th graders, all the rest of the participating students were 5th graders. When quoting the participants in this thesis, I have used brackets to indicate when I have translated Finnish to English.

The teachers had taken part in a nationwide VISIOT-project. The overall purpose of the project was to try out and develop new technologies in education, such as augmented reality (AR), internet of things (IoT), and virtual reality (VR), which is the focus of this current study. One of the main goals of the VISIOT-project was to determine whether these technologies could assist teachers and learners in achieving some of the transversal competence goals for growing as a person and as a citizen set by the Finnish National Agency for Education.

2.2 The implemented virtual reality system

The review of previous studies revealed that not all VR systems are alike, nor should they be expected to possess identical potential affordances. I also learned that the actualization of those affordances depends on the pedagogical arrangements (i.e. what are the intended and guided pedagogic uses for the VR system in the learning environment), as well as on the learners' characteristics (such as. their age, gender, actual competence level and need for scaffolding, former digital and VR experience).

The commercially available VR system that the participants implemented in their actual learning environments in this study, consisted of the *Google Earth VR* program (hereafter GEVR in this section) and the *HTC Vive* device (see Figure 1).

The *HTC Vive* device is a VR device that has a headset which connects to a computer via cables. The headset contains a 2160x1200 OLED screen with a frame rate of 90*Hz* and should provide a 110-degree field of view. Furthermore, it comes with two base stations, which are used to track the movements of the user within a tracking area. The tracking area is at its largest 4.5 by 4.5 meters (or 15 by 15 feet). The *HTC Vive* has two identical controllers, one for each hand, they contain several buttons which result in different actions based on the program that is being used. The device also supports add-ons such as the user's own headphones. In fact, both schools' VR systems included headphones. Thus, the students were able to listen to the program's music and receive some auditory feedback based on their actions within the program.

Figure 10. A view of the earth at the start of a tutorial in the Google Earth VR - program.

Based on the categories presented in the introduction chapter (see Section 1.2), GEVR could be categorized as an *explorative* program. The user controls where they want to travel within the virtual world by clicking and dragging, holding down a button and directing their movement, or via a sub-menu's pre-set destinations. GEVR's virtual world is a projection of the planet Earth (see Figure 10) and the possibilities for exploration are much the same as the program's desktop version. The main difference is the immersiveness of the VR system.

Another GERV's feature is the possibility to change one's frame of reference. Not only is the user able to zoom in or out from the Earth, which already enables for countless of possible perspectives different from our everyday view, but they also have the option to choose between two different body positions regarding the Earth (see Figure 11 and Figure 12).

Figure 11. View 1, where the user observes the earth as if they were belly-flying towards the surface.

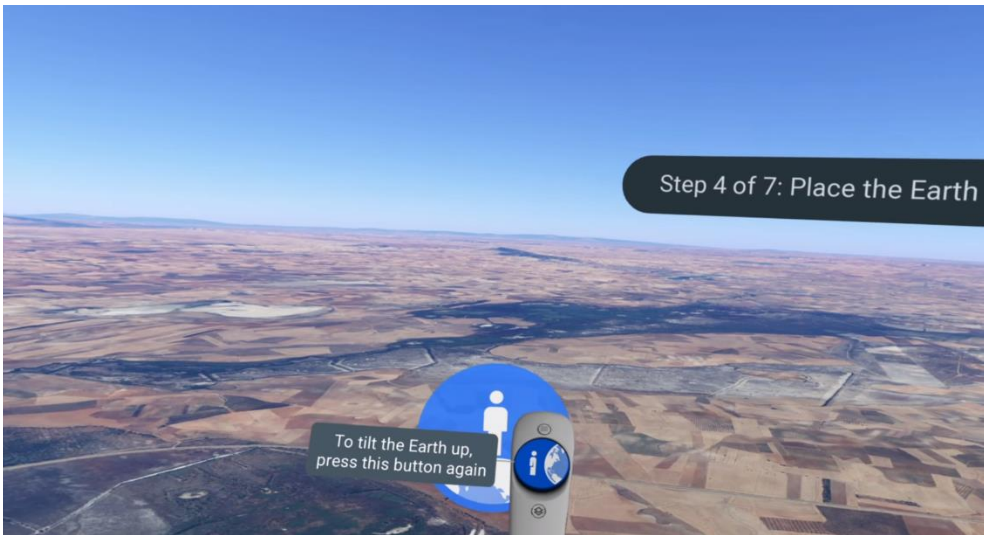

Figure 12. View 2, where the user is positioned much like a skydiver after opening their parachute.

On the other hand, GEVR could also be categorized as an *interactive* program where the object a user moves and manipulates in front of them is the projection of the planet Earth. Immersion to the 3D space can cause the user to lose sight of this and feel as if they are the ones flying around within the virtual world. This could be enabled by the user's suspension of disbelief, i.e. when one overlooks any evidence of the contrary. For instance, in Figure 12, where an immersed person could imagine floating in air with a jet-pack, they have tapped into their imagination whilst disregarding the evidence in their environment, such as the wording on the instruction: "To tilt the Earth up...". This indicates that the Earth is the object that the user interacts with instead of just exploring a virtual world by moving within it. Then again, after the user has completed the tutorial, they are able to "fly" wherever by holding down a button and directing the flight with their right-hand controller. This method of movement certainly contributes to the impression that the user is exploring a virtual world instead of interacting with an artificial object.

Additionally, by grabbing the sky and dragging it, the user can cause a change in the time of day, when in fact they are rotating the Earth around its imaginary axis. Thus, the understanding of our actions within GEVR can vary based on the frame of reference where we are acting from. For instance, a person who is zoomed in on Earth, looks up, grabs and drags the sky, could get the very ordinary (and false) sense that the Sun orbits the Earth. Whereas a person, who is zoomed far away from the Earth, can observe the Earth's rotation around its imaginary axis with the Sun on the background. Thus, different frames of reference support different perceptions, and could on one hand provide opportunities and experiences to construct new knowledge, but on the other hand, they might just re-enforce prior beliefs and assumptions.

It is worth mentioning that GEVR has no built-in educational instructions. Therefore, the learning tasks must be set outside of it and a learner must put in cognitive effort to be able to bring those tasks and goals with them into the virtual environment. The more attuned, i.e. interesting, clear and meaningful, those tasks and their purpose are for the learner, the easier it should be to keep them in mind and act based upon them in the virtual world. Then again, the lack of scaffolding within the virtual environment could very well cause one to give up on the learning task, especially if they deem the tasks to be too complex. Educators should be aware of this when designing a learning task for the GEVR program. In this current study, only seven students reported having previous experience of using the GEVR program. Overall, 27 of 58 students reported having used the GEVR and/or its desktop version Google Earth -program before.

2.3 The virtual reality field trip project

The teachers implemented the current VR system as part of a cooperatively designed long-term environmental studies project. That project was initially known as "the cooperative virtual field trip". It was an attempt to engage the students to an immersive learning project, where they would be the ones setting their own learning goals, constructing knowledge with a pair, and cooperatively assembling and taking a virtual field trip.

Roussos and others (1999, p. 261) emphasized that relevant VR research draws from research in the learning sciences and current educational practices, whilst also factoring in the realities of the school organization. Furthermore, they claimed that VR technology should first and foremost be applied to achieve learning goals we struggle to attain with conventional methods.

This study's VR system has the potential to offer more various and immersive perspectives to experience the Earth than any regular environmental studies text-book has. I had hoped that it would be used to challenge the students' pre-existing beliefs and stereotypes about other regions of the world. In this section, I briefly describe the initial plan for the virtual field trip project.

The original idea of the project was to have the entire student group cooperate in planning, creating and conducting a shared virtual field trip on an online *Thinglink*-platform (https://www.thinglink.com). Initially, the project was also designed to have a common end date on which the entire learning group would take their self-made virtual field trip, and act as tour guides for fellow classmates.

The students were initially supposed to download 360-degree scenes of interesting sights where they would like to take their classmates to for the virtual field trip. They would have uploaded those scenes to the Thinglink-platform. There student pairs were supposed to add icons containing audio and text to their scenes where they would answer their self-set questions and present what they had learned during the environmental studies lessons that transcends to their scenes. Finally, those refined 360-degree scenes would have been connected to one joint world map. This world map could then be explored together by the learning group on the final day with mobile VR glasses. For this activity the teachers had purchased various mobile-VR glasses, which they would have used to visit and explore the refined scenes. These plans fell apart when I learned about the possible health concerns regarding VR glasses (see Section 1.1) and when the students in the urban school noticed that most of the different headsets made them feel sick when trying them out.

With the coordinating teachers, we agreed that the teachers would consult their students on how they want to resolve the newfound challenge of finishing the virtual field trip project, and that the students would have the final say in on how to bring the project to a close. The rural school gave up on downloading and operating on the 360 images all together, as according to their teacher, the less new programs that needed to be mastered and accounts that needed to be created, the better. In my view, and in accordance with immersive learning theories, the world map could have bridged the two schools together and served as an artifact passed down to the next 5th and 6th graders who could have developed it even further.

The actual teacher orchestrated projects were influenced by these plans. Eventually, the virtual field trip projects were conducted differently with each student group. I will present the various ways in which the project was eventually conducted, and how the teachers orchestrated the use of the current VR system as part of it, in section 3.1.

2.4 Data acquisition and analysis methods

In this section I present the data acquisition methods that were used in the study. I aimed at gathering a diverse data-set, mostly through self-report questionnaires. The research was conducted with the participants, as encouraged by Southgate and others' (2017, p. 16) ethical principles. The teachers planned and conducted their versions of the virtual field trip project and observed the students at work. The students assessed the virtual reality (VR) system and their own experiences on an e-log, i.e. an online questionnaire. I will now go through all the methods for data acquisition in a chronological order and then discuss the analysis methods as well as the ethics and reliability of this study.

Phase 1. Before the virtual field trip project

Most of the participants answered pre-surveys by the end of 2017, some at the beginning of 2018. With one missing response, the overall sample size was 58. The pre-surveys were first and foremost designed to gather information on the learner characteristics of students, such as gender, computer experience, domain experience, and previous virtual reality experiences. It was also used to gather information on the students' preconceptions of virtual reality and the continent they were planning to research during the project.

To learn more about their preconceptions, I asked the students to describe VR by using five words that first come to their mind when hearing the concept. Additionally, the students were asked to describe their typical lesson of environmental studies and their beliefs on planetary phenomenon, such as the changes in the time of the day and changes in seasons.

Before filling out the pre-surveys, the teachers reminded the students that it had to do with their background and use of digital technology. All in all, that self-report questionnaire included three scaled Likert-5 statements (e.g. 3. Tell us your thoughts towards the use of (digital) technology: “I am good at using (digital) technology”, etc.), five open-ended questions (e.g. 8. Describe your typical lesson of Environmental Studies?), four questions about the usage rates of digital technology and maps (e.g. 2. How often do you use (digital) technology for the following activities: a) studying at home, Never, A few times a year, Monthly, Weekly, Daily or Many times a day., etc.), and two binary questions about whether the student had used the *Google Earth VR* and the *Google Earth* programs before or not (see Appendix A). The pre-survey questions drew from previous Innokas Network research and development projects with children and digital learning technologies that inquired about their access to different digital technologies and how often do they use different digital technologies.

The three teachers took their pre-surveys in January 2018. It was comprised of five open ended questions that inquired about their educational philosophy, typical pedagogical arrangements for past environmental study courses and their expectations for the upcoming VR project (see Appendix B). For instance, I asked the teachers to “4. In short, describe your educational philosophy?” and “6. Describe what a typical 5th grade environmental studies lesson is like?”

The students (N=57) also took a test with the Spatial Reasoning Instrument (SRI), by Ramful, Lowrie and Logan (2016), in January 2018 (see Appendix C). It was designed to measure the students’ spatial abilities, which might be an important learner characteristic regarding learning in a VR environment, as hypothesized by Salzman and others (1999, p. 313). I had converted the instrument to an online form with *Qualtrics survey software*. I had also translated the instrument into Finnish. Before using the translation, I conducted some pre-testing on it with close relatives and friends of various ages and mathematics expertise, and had the questions and answers validated by a University of Helsinki didactics of mathematics professor and researcher Anu Laine. According to studies of Ramful and others (p. 724-725), the reliability and validity of their instrument is high. Furthermore, they assured that it can be used as a research tool to measure 11-13-year-old children’s spatial reasoning abilities.

Phase 2. During the virtual field trip project

After the student pairs and groups had selected the countries they wanted to investigate, they were asked to fill out forms with some scaffolding questions (see Appendix D). Those questions were intended to help the pairs to access and discuss their prior knowledge about their chosen country and to set their own goals and questions for the project. Those forms also inquired about the student pairs expectancies towards the use of the VR system. One of the teachers thought that these handouts might have helped orientate the students to the upcoming project but declared that setting their own questions was "[a truly difficult task for students of this age]".

The virtual field trip project provided a context for the students to assess the VR system and for the teacher to observe its apparent effects. During the project, the students reported their assessments of the VR system and their user experiences to the online questionnaire. After each visit to the *Google Earth VR* -program's virtual world the students took the online questionnaire using their mobile device or school's tablet. In the online questionnaire they answered questions regarding their latest VR experience. Among other things, those questions inquired about the usability of the system and whether they found the learning activities to be enjoyable or boring, and why (see Appendix E).

I decided to use the students' answers on the VR system's enjoyability (see Appendix E, questions 5-8) to create a sum of variables for emotional experience. I used the IBM SPSS Statistics software to analyze whether the students found the questions on enjoyment and boredom too identical or whether they would make for a good factor to study the nature of the students' self-assessed emotional experience. I began by inverting the two statements about the VR system's boredom to fit the sum of variables. Then, I accounted for the missing values and checked the reliability of the variables (see Table 1).

Table 1

Reliability Analysis' Result for Emotional Experience with the Virtual Reality System.

Emotional experience	Cronbach's Alpha
Variables	.768
Enjoyed using HTC Vive	
Using HTC Vive was boring	
Enjoyed learning with Google Earth VR	
Learning with Google Earth VR was boring	

Note. 56 valid responses were included. A Cronbach's alpha score of over .700 is acceptable.

Since the Cronbach's alpha score was over .700, this sum of variables can be considered as an acceptable indicator of how strongly the students agreed with having had an enjoyable emotional experience with the applied VR system. See results in section 3.3.2.

The online questionnaire was also used to capture the students' assessments of the perceived credibility of the *Google Earth VR* program. They were presented two statements and asked whether they disagree or agree with them on a verbal Likert-5 scale:

1. I believe that the Google Earth VR projection of our world was accurate.
2. I trust that the information presented about our world in Google Earth VR is up-to-date.

These questions were explorative, and they were merely used to help the online questionnaire direct one or both of the following questions to the user; "What made the *Google Earth VR* projection reliable?" or "What made the *Google Earth VR* program unreliable?". I had coded such display logic into the online questionnaire that only those who had agreed or strongly agreed with both statements were asked more about what made the program reliable. Further elaboration of the results follows in section 3.2.

Phase 3. After the virtual field trip project

After the project came to an end, the students answered a post-survey. The post-survey comprised of five open ended questions and two sets of Likert-5 statements. The students were asked to imagine having a conversation with a person who is unfamiliar with their project and has not heard about the concept of "virtual reality" before (see Appendix F). The two sets of Likert-5 statements measured the students' self-efficacy beliefs and interest in engaging with VR technology for studying in the future.

Researchers who organized a *Mind the Gap between Digital Natives and Educational Practices* -project (2013-2016) constructed a questionnaire to measure students' attitudes, self-efficacy beliefs and school engagement towards information and communication technologies (Hietajärvi, Seppä, & Hakkarainen, 2016). It comprised of seven statements. I modified the statements of their scale for the post-survey so that they would specifically concern the use of VR technology.

I used a total of seven statements for self-efficacy and a total of three for interest in engaging with VR technology. I used the IBM SPSS Statistics software to create the sum of variables for two factors: self-efficacy and interest to engage. I inverted three self-efficacy variables to fit the sum of variables for self-efficacy. I also accounted for the missing values and checked the reliability of the variables. (see Table 2 and Table 3.)

Table 2

Reliability Analysis for Interest to Engage Sum of Variables.

Interest to engage with virtual reality technology	Cronbach's Alpha
Variables	.865
I would like to use virtual reality devices more often when working at school	
I am more excited working at school when I get to use virtual reality devices	
I am willing to try harder at school when I get to use virtual reality devices	

Note. 53 valid and completed answers were included. A Cronbach's alpha score of over .800 is good.

The reliability analysis excluded one student's partial answers in both cases. Moreover, five students were absent when the students took the post-survey. Based on the reliability analysis, and the Cronbach's alpha score over .700 for self-efficacy and over .800 for interest to engage, both sums of variables can be considered to reliably measure their respective topics, i.e. in both cases the variables that comprise the factor, effectively measure similar yet not too identical aspects of the same phenomenon (Reunamo, 2010).

Finally, in May 2018 I conducted interviews with the two teachers who had helped design the project and were present when students had used the VR system. The teachers acted as the main observers in this study and thus it was important to capture their perspective of events. The interview method was an innovative and experimental Google Docs interview with one teacher at a time (see Figure 13).

Table 3

Reliability Analysis for Self-Efficacy Sum of Variables.

Self-efficacy of using virtual reality technology	Cronbach's Alpha
Variables	.763
I am good at using virtual reality technology	
*I am afraid of making mistakes on virtual reality devices that I am unable to fix	
*Using virtual reality technology makes me feel insecure	
*I plan to avoid using virtual reality technology	
I enjoy using virtual reality technology	
I am willing to try hard in order to learn something about virtual reality technology	
I have confidence in my abilities to learn to use virtual reality devices	

Note. *-marked variables were reversed. 53 valid and complete answers were included. A Cronbach's alpha score of over .700 is acceptable.

Google Docs is a free online office tool that enables multiple people to edit a document at the same time in real time (i.e. one can see the changes that the others are making as they occur in writing). Accordingly, this interview required a working computer and access to the Internet. As far as I can tell, this was a novel attempt at conducting this type of innovative interview where the interviewers' non-verbal communication (see e.g. Argyle, 2013) cannot affect the interviewees answers or state of mind.

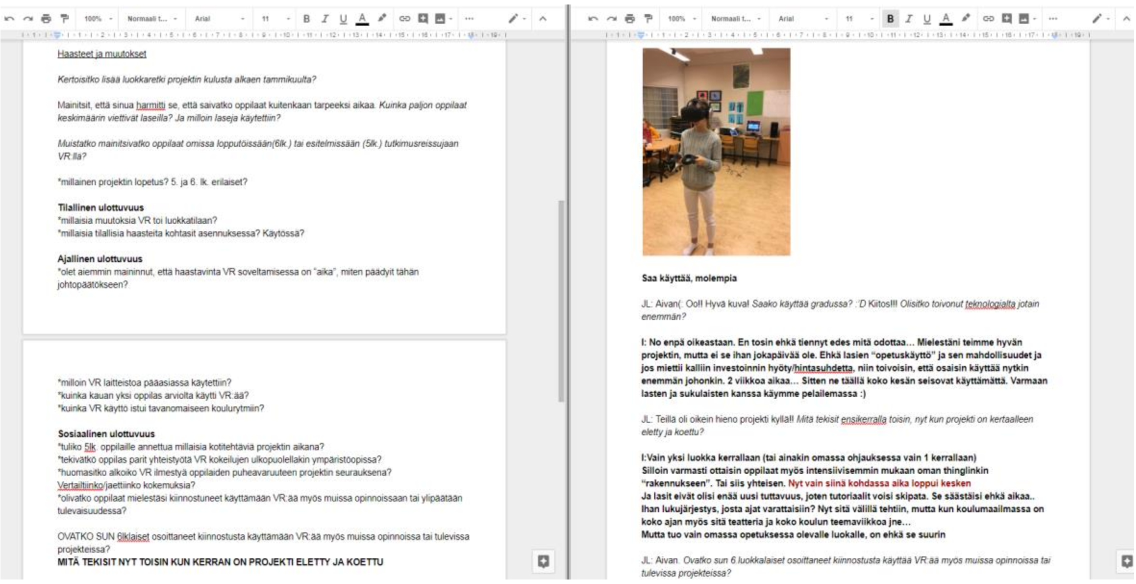

Figure 13. A screenshot of the online interview from the interviewer's perspective.

I had planned a semi-structured and thematic core for the interview. I was particularly interested in the possible changes in the learning environments spatial, temporal and social dimensions, and the challenges that the teachers might have faced during the implementation of the VR system. During the interview, I used the split-screen capability of the computer to place the thematic core on the left side of the screen and the shared document on the right side of the screen (see Figure 13). The document where the interview took place was carefully structured beforehand (see Appendix H).

I began by explaining the reasoning behind this method and by giving instructions to the interviewee. I encouraged the interviewee to ask questions at any given time. They were instructed to write their train of thought and were encouraged to use emoticons if they wanted to. These interviews were conducted in Finnish. Furthermore, I highlighted all my questions by *italicizing* them.

The document makes it so that it is easy for both the interviewer and the interviewee to go back and glance at what was said before if need be. This is particularly useful for the interviewer as they can track the interviewee's train of thought and reiterate something that they had already told, at any given time.

Having the thematic core on the left side of the screen allowed me to plan further questions for the teacher, based on what they had already mentioned, and without interrupting them mid-thought. It also allowed me to keep track of the thematic core and make sure everything on it would end up being discussed. Thus, to some extent the assistive thematic core acted as an augmented intelligence-like artifact.

This type of chat-like online interview suited our situation very well. One of the teachers was working from home and the other had a busy school schedule. Even though we were physically in separate cities, we managed to share a virtual space where the interview took place. Consequently, the flexibility of the online tool allowed us to find a suitable time to conduct the online interviews.

The method also enabled for the participants to share web-links, pictures and other attachable media. This took me by surprise as I had no intention of utilizing this feature that much, but one of the teachers realized this capability on their own and used it fully. Furthermore, I was able to begin analyzing the interview right away after recording it, as the “transcript” of the interview got stored instantaneously.

To protect the teachers' anonymity and personal data I copied the transcript to a new document in a private folder and deleted the original shared documents. Furthermore, we avoided using any names during the interview. One of the most important factors that might have contributed to the success of these interviews was the fact that I had met with both teachers before, thus we were not complete strangers to one another.

On the other hand, this method could be described as a live questionnaire and it remains debatable whether the scientific community accepts it as a form of interviewing. The next experimental step closer to a real-life interview, with slightly reduced possibility to affect the interviewee through non-verbal means, would be to conduct an interview in a cooperative VR space.

Overall, I gathered a large body of data through various self-report questionnaires and the innovative online interview. A compilation of the data acquisition methods and phases is provided in this paper's appendixes (see Appendix I).

Analysis methods

The gathered data from both pre-surveys, the students' post-survey, the online questionnaire, and the online interviews was mostly qualitative. When analyzing qualitative data, I applied the clustering content analysis method where I broke the data down to manageable units, looked for similarities and differences before assembling it all back together into separate observable clusters and categorized the analyzed data into comprehensive matrices for the readers (Krippendorff, 1980).

I conducted the analysis of qualitative data in Microsoft Excel (for the data from Qualtrics) and in Google Drive (for the online interviews). To assort and brake the data into sortable pieces I assigned color codes to mark occurrence of relevant themes in the material. Then, I quantified the data by counting the frequency of occurrence of each category and by comparing the outcomes to the overall frequency of answers. I was able to discover many similarities in the students answers that made naming the categories that much easier. More on them in the results chapter. Sometimes, to help in the classification of the answers I relied on previous research.

One such instance was when I studied the students' credibility assessments of the VR program. According to Hertzum, Andersen, Andersen and Hansen (2002, p. 576-577), trustworthiness and reliability are often closely connected to perceived quality. To perceive something as high quality, Tseng and Fogg (1999, p. 41-43) suggested that there are four different types of credibility: *presumed*, *reputed*, *surface* and *experienced*. *Presumed credibility* has to do with the general assumptions and stereotypes in the human mind that can make us believe something or someone. *Reputed credibility* is symbolic as it is often an assurance of some third party that makes something, or someone appear trustworthy. *Surface* *credibility* is believability based on the mere inspection of superficial factors. *Experienced credibility* has to do with one's first-hand experiences (of others' trustworthiness and expertise, humans and computers alike) which can build up or diminish over time. I used these four types when analyzing and categorizing the students' answers (see Section 3.2).

As previously described, some of the results were also obtained by quantitative methods, namely for the self-efficacy and interest in engaging with VR technology sum of variables, for students' usability assessments on a likert-5 scale, and their emotional experience sum of variables. I analyzed the quantitative data with the IBM SPSS Statistics software v. 24. I presented the procedures and results for the reliability analyses I had conducted for the sum of variables earlier in this section (see Table 1, Table 2 and Table 3). To sum up, I used the "analyze/scale/reliability analysis" command of SPSS to examine the sum of variables and learned that all the items fit their respective scales. As established earlier in the section, the Cronbach's alphas indicated that the reliabilities of the scales were either acceptable (.768 for emotional experience and .763 for self-efficacy) or good (.865 for interest in engaging). Each sum of variables was calculated by "transform/compute variable" command of SPSS. They were calculated by summing the different variables scores together and then dividing that with the sum of items answered, for example: (variable A + variable B + variable C)/3.

For the students' self-efficacy and interest assessments, and the students' usability assessments, I used the non-parametric Mann-Whitney u-test for comparing the means of two independent groups and the non-parametric Kruskal-Wallis test when comparing the means of several independent groups. They work as non-parametric substitutes to t-tests. According to Nummenmaa (2009, p. 168) a t-test is used to analyze whether a statistically significant difference exists between the means of different groups. I used the Mann-Whitney and Kruskal-Wallis tests for the similar purpose. They were used because when I compared the means of genders and the means of student groups, the sample sizes were relatively low, and the normal curves were skewed.

The ethics and reliability of the study

I attained all the necessary research consents and permissions from the participating students’ parents (see Appendix J) and from the schools’ municipalities before the research project. I respected the privacy of all the participants and used the students’ names only privately to give them identification numbers to help connect their answers in different self-report questionnaires to one another. That also helped me to identify any duplicate entries. After I had erased the incomplete and duplicate entries and had all the data sorted with the students’ identification numbers, I erased all the names from the data.

Other sensible and private information was not intentionally gathered. Nonetheless, after collecting the online questionnaire and post-survey data with the help of the *Qualtrics online survey* –software, I learned that their program collects all kinds of unnecessary metadata, such as, the location of the participant and their IP-address.

To act in accordance with the European Union’s latest policies on gathering personal information (i.e. the GDPR), I removed and erased all the gathered data from the *Qualtrics*-online platform, before the GDPR came into effect. I had previously stored the necessary data to a local computer and to a personal USB-device where I created secure password protected folders for it. Furthermore, throughout this study and when addressing the participants, I made sure that their anonymity and privacy was respected.

Not all gathered data ended up being relevant for the current study. The qualitative data from open-ended follow-up questions in the pre-survey helped assess the validity of the quantitative questions. For instance, I learned that the students had misunderstood the questions about their self-efficacy beliefs towards using offline and online maps. I did not use such data in this study.

Besides revealing whether questions were understood correctly, the qualitative data also added depth to the quantitative data that I eventually used when analyzing the participants answers regarding the usability of the VR system.

In the confines of the current study I managed to gather a complementary set of qualitative and quantitative data. The reliability of this study might have benefitted from an inclusion of a co-researcher. Then again, I developed a way to compensate for that and uphold the scientific standards. I assessed, analyzed and interpreted all the data at least twice with time in between the analyses. Each time I analyzed the data I took a step back and assessed it from an objective point of view to the best of my abilities. Furthermore, I have attempted to describe my research methods in a transparent way in this section, and I have used quotes from the qualitative data to demonstrate my interpretations in the upcoming results chapter, so that readers, too, can assess their reasonability. Overall, I upheld the common criteria for scientific research throughout the research process. This study and its results are falsifiable, ethical, replicable, precise, unbiased and diligent.

In conclusion, I mostly used previous well-established studies' measures and questions when forming the self-report questionnaires for this study. Additionally, for the quantitative measurements of different sum of variables, I conducted reliability analyses that I openly described previously in this section.

The multi-faceted bodies of data that I gathered complemented one another's weaknesses well. The questions and measures of all the questionnaires of this study were inspected by my supervisors and more experienced researchers. Overall, this entire study was the first iteration of a design experiment, and a novel attempt to research the experiences and actualized affordances of the implementation of a commercially available VR system in two Finnish elementary schools. In the upcoming chapter I present the results of this study.

3 Results

Each of the following sections are devoted to one research question at a time. Quantitative data will be presented in a straightforward manner and all deliberation is reserved for section 4.2. Qualitative results contain both analysis and interpretation, but further deliberation is likewise reserved for the abovementioned section. Initially (see Section 2.3), I was involved in designing this study's classroom experiments in collaboration with the teachers. Eventually and understandably, the instructions and design of the project departed from the original plan. The teachers orchestrated the implementation of the virtual reality (VR) system mostly on their own and to the best of their abilities. This presented me with an opportunity to study the orchestration and VR's affordances from an objective perspective.

In section 3.1, I present the teacher orchestrated projects and analyze the changes that VR's actualized affordances brought to typical environmental studies setups. In section 3.2, I focus on the analysis of the students' assessments of the applied VR system's program's credibility and on their willingness to use VR technology again in their studies. In section 3.3, I present the students' self-reported user experiences with the VR system and its impacts on their conceptual understanding of VR and imagination of VR learning worlds.

3.1 How did the teacher orchestrated project turn out?

To analyze what possibilities of action did the applied virtual reality (VR) system bring forth, I begin by examining what their typical lessons and periods of environmental studies have been like in the past by analyzing the students' and teachers' answers to their pre-surveys. Furthermore, I will present the way that the various virtual field trip projects were conducted with each student group, based on the students' post-survey answers and the teachers' online interviews. Then, I will proceed by comparing the two and point out the main changes that had occurred and the apparent added possibilities of action. Lastly, I will present the main challenges that the teachers had encountered when implementing the current VR system, based on their online interview answers.

Typical environmental studies arrangements

The students were asked about their typical environmental studies lessons in the pre-survey in December 2017. The teachers were also asked about the typical lesson and period plans in their pre-survey in January 2018. I began by analyzing the answers separately for the rural school and the urban school.

Based on the answers of the rural school students, their typical lessons of environmental studies have consisted of reading a textbook chapter and doing tasks. It remains unclear what kind of tasks they were and whether they were assignments from the textbook or something that their teacher had come up with. A few of the students also mentioned having taken 360-degree photographs and having sometimes used VR-goggles. Based on their teacher's answers, a typical lesson begins with a recap of the previous learning topic. Then, they use textbooks and conversation to move on to a new topic. According to the teacher, their lessons have also often contained different experiments and exercising or "[moving around]" such as going on a nature trip. They believe that it is important to provide the students with versatile means for learning.

The urban school teacher has thought the 6th grade regularly but had this particular 5th grade group for the first time for this project. Thus, they could not tell what the typical lessons of environmental studies have been like for the 5th graders. Based on the answers of the students alone, their typical lesson resembled that of the rural 5th graders. They do quite a lot of reading of textbooks or handouts, complete (writing) exercises, and discuss new topics. Unlike in the rural school, these students pointed out that a typical lesson also consists of checking previous homework and receiving plenty of it. Some explained that the lessons are a bit noisy and some stated they are "*normal lessons*" without nothing too special. Although, one student contradicted this by mentioning that they sometimes do projects. It appears that for the most part the typical lessons for both groups of 5th grades have followed a similar pattern. Learning topics are tied together through recap or homework, new topics are familiarized with by reading textbooks or handouts, doing exercises and occasionally by having a conversation.

The answers of the 6th graders established a much different reality. Based on their answers, they have been much more accustomed to carrying out projects on different environmental studies related phenomenon. According to their teacher, the 6th grade students participate in planning of their projects as well. Furthermore, they often implement tablets or other computers in their studies. Their teacher explained that this type of studying came to be out of necessity at first, since there were no textbooks in English that were compatible with the national educational curriculum of Finland. The teacher had decided to try and empower the students by allowing them to discover and research on their own a lot more, emphasizing the learning process over learning outcomes. According to the teacher this way of studying has worked well.

Altogether, based on the analysis of the typical lessons of environmental studies for the participants, it appears that the 6th graders typical learning arrangements resemble the initial ideal of the current project the most, where students, for instance, would have participated in setting up their own learning goals (see Section 2.3). Furthermore, it appears that the 5th graders are used to a much different type of studying, one that follows a more predetermined repetitive pattern. Nonetheless, the urban school 5th graders might welcome something out of the ordinary and the rural school 5th graders might benefit from having already familiarized with VR technology beforehand.

Before the project

Each student group had familiarized themselves with the VR system and its controls before the project began. After the device was set up at the urban school in late December 2017, some of the students got to take the standard tutorial of the *HTC Vive* device as well as the *Google Earth VR* program's tutorial. Others would get a go at the tutorials in January 2018, after the winter holiday.

The set up took longer at the rural school where they faced several adversities. Eventually, their students also got to try out the VR system and learn the controls before the start of their project. A teacher assisted the students during these practice runs and made sure that all the students had the chance to learn how to control the system before they began working on the actual virtual field trip project.

After each student had acquainted themselves with the VR system, they were divided into working pairs or groups who would do research on their target countries. The 5th graders countries were all from Europe, but the 6th graders picked any one country in the world.

The projects began with an orientation lesson. That is when the pairs and small groups assessed their previous knowledge on their selected countries and were encouraged to come up with questions they wanted to find answers to about their chosen countries (see Appendix D). Originally, they were also presented with a common goal for their *Google Earth VR* work:

"Your goal is to locate a place where You'd want to take the rest of your group on a virtual field trip. Mark its location down so that You can find Your way back there again later."

A teacher was always present when students operated and assessed the VR system for the first time during the project. During the project the student pairs or small groups worked together familiarizing themselves better with their chosen country and the continent it belongs to. Those learning sessions were led by the teachers as they saw fit. I will now examine how the *Google Earth VR* program was applied with the different student groups.

Implementation of the virtual reality system

By analyzing the students' answers to the post-survey open-ended questions, I learned more about the various possibilities of action that the VR system presented in the actual school environment. The teachers' interviews added more detail to how the virtual field trip project was conducted with each student group. First and foremost, I learned that despite having a common initial design for the project all the participating student groups eventually conducted the project in their own unique way.

The urban 6th graders project

During the actual project, the 6th graders gathered general information about their chosen countries and planned how they wanted to present their countries to others. The teacher had handed out a script of what kind of information they expected the presentations to contain. As a result, the content of the presentation was thoroughly scripted. Moreover, the students' experiences in the VR environment were not a part of that script. Thus, the two were separate activities.

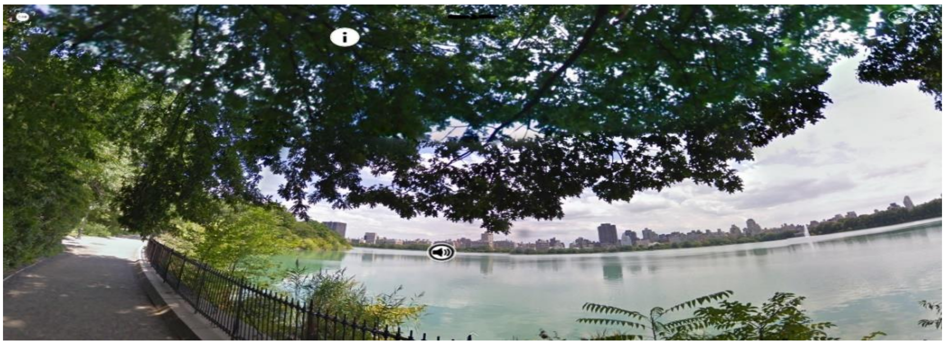

Figure 14. The students added audio recordings to their scenes.

The 6th graders were instructed to use the VR system as they pleased. They used it to explore their chosen countries while searching for a meaningful scene. Those scenes were later downloaded with a program called "Street View Download 360". The students recorded audio explanations for their favorite scenes (see Figure 14). Finally, the teacher assembled each scene and their audio recordings onto a self-made 360-degree world map in Thinglink (see Figure 15). At the end of the project the student group decided to visit those scenes with mobile VR goggles, even though, they had previously noticed that most of the goggles were uncomfortable and made them feel sick.

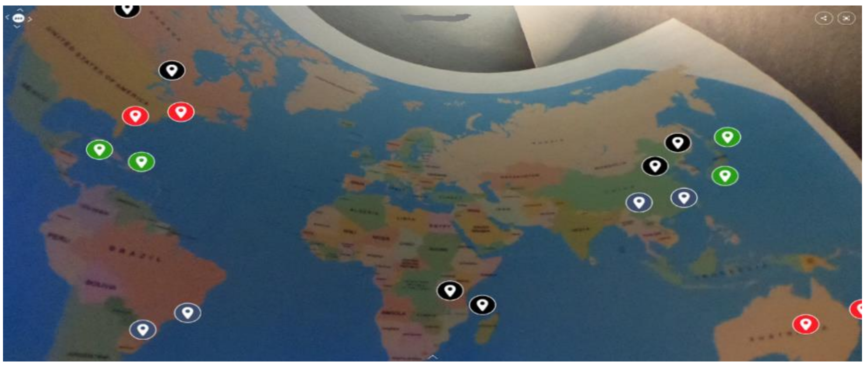

Figure 15. A Thinglink scene of a 360-degree world map with student captured and modified locations for the virtual field trip.

The urban 5th graders project

The urban 5th grade student pairs were assigned a task to plan a week-long trip to one freely chosen European country. Each student pair drew an imaginary budget that they used in planning their trips. They got to plan everything from the means of transportation and accommodations to which sights they wanted to visit. When ready, they presented their trip plans and general information about their chosen country to others. Finally, the VR system was used to virtually travel and visit the locations and sights they had chosen for their trip, but only after the students' presentations. They too downloaded 360-degree scenes of meaningful locations they happened to encounter on their virtual trips. Their teacher assembled those scenes on a template 360-degree world map in Thinglink (see Figure 16). The 5th graders also visited each scene with mobile VR goggles.

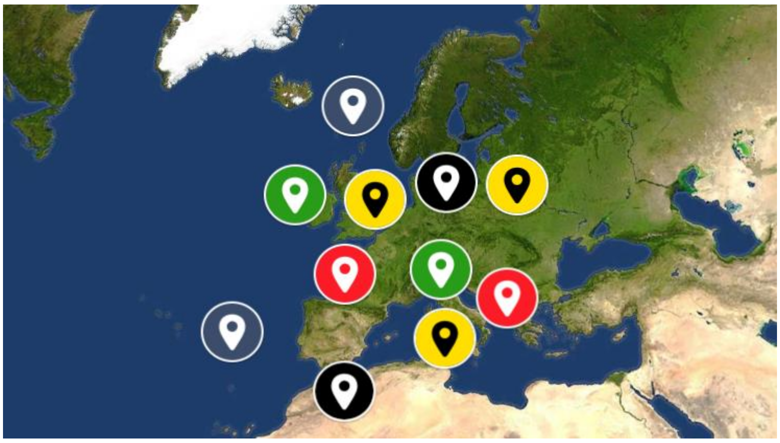

Figure 16. Urban 5th graders chose scenes that were assembled onto a Thinglink template world.

The VR system was set up at the back of the 6th graders classroom. During the interview, the teacher clarified that the use of the VR system required moving some of the students' desks out of the way. Besides that, and the addition of a new computer, the inclusion of the VR system did not lead to any major spatial changes. According to the teacher, on average an urban school student spent approximately 15-20 minutes in VR. Each week student pairs would use the VR system during their two environmental studies lessons, during daily "siestas", before their school day began, or after school. The teacher was present for the student pairs' first visits, but after that the students could use it on their own if they wished. Neither student group utilized their self-set questions or prior conceptions beyond the orientation lesson.

The rural 5th graders project

The rural school teachers reserved two hours for the project each Thursday for three to four weeks. During the project their students worked independently with groups of three or four and were assigned a target country from Europe. Moreover, each group member had their own target city within the country. Students were given handouts that acted as scripts. Those handouts consisted of questions and topics that their teacher expected the students to gather information on and present to others.

According to the interviewed teacher, the students had struggled with recollecting their prior knowledge and coming up with their own questions about their target countries during the orientation lesson. It seems that the students were not used to such tasks. Thus, adjusting the task closer to each students' zone of proximal development (ZPD) by including personalized scaffolding might have been necessary to engage them with the orientation task.

The rural school's VR system was set up in a separate cabinet - a smaller room along the hallway. This caused the tracking area to be smaller than what the device would have allowed for. Before entering the cabinet, student groups were supposed to plan their visits to VR. They were asked to locate the main sights in their target cities. Each student used a tablet and the regular *Google Earth* -program to prepare for their VR visit. Their task in the cabinet was to use the VR system to locate the target city in their country and go visit its main sights.

The program was setup so that when a student put on the device they found themselves in a 360-degree "Street View"-scene in front of their own school. While one student at a time used the *HTC Vive* device to navigate to their target city to visit the sights, the other members of the same group either followed the trip from a monitor or prepared for their own trips with a tablet. One teacher was always present in the cabinet and re-set the program for each student, i.e. used the VR system to move back to the "Street view"-scene in front of their school.

The students could use the VR system for 10 minutes. According to the teacher, a few of the students left VR earlier than that, but most of the students would have preferred to use it for longer. At the end of the project the student groups held presentations about their countries. The teachers' original idea was to have the students invigorate their presentations with the help of the VR system. Unfortunately, they could not manage to get the VR system to work in the classroom, and the cabinet was too small, and could not have accommodated the entire student group.

Changes in the typical pedagogical arrangements

By comparing the different projects with each student groups typical environmental studies lessons, it appears that the urban 6th graders' and the rural 5th graders' projects were not too different from what they were used to. The 6th graders worked independently as they have often done and were given a lot of autonomy as to how to use the VR system. The rural 5th graders also worked independently on the assignment that their teacher had come up with and moved around when they went to visit their cities with VR. Even the actual task within the virtual environment resembled exercising (orienteering in a virtual world), which seems to be a typical integration for their student group.

On the other hand, the rural 5th graders answers to their typical environmental studies arrangements revealed that this project introduced a new and a more out of the ordinary order of things to their classroom. Where their typical lessons seemed to follow a common path for all students (e.g. when the teacher decides it is time to discuss a new topic, each student partakes in the activity at the same time), within this project one small group was in an entirely different physical space during each one of the project lessons. And in that space only one group member at a time was using the VR system while others waited. When asked about the social aspects of the project, the interviewed rural school teacher mentioned noticing that students often commentated to others what they were seeing and doing while still within the virtual world.

The urban 5th graders project differed vastly from their typical environmental studies lessons. Where their typical lessons also followed a common path with an emphasis on reading a textbook, and checking and receiving homework, within this project the students were encouraged to make more autonomous choices whilst role-playing tourists. Thus, they got to practice everyday skills related to travelling. Furthermore, the students received no mandatory homework during the project, unlike during their typical environmental studies lessons.

The implementation of this VR system introduced an opportunity to experience visually enhanced exploration of the Earth. Instead of just reading about a country or a city the students were virtually able to visit them. This capability presented an opportunity to learn from those experiences, which I am not convinced that the student groups took full advantage of. Most of the planned learning activities seemed to focus mostly on gathering, reproducing and delivering pre-determined facts and information that the teachers expected. The VR experience was not purposefully used to challenge existing ideas or to formulate new ones together with others.

Evidently, this VR system itself does not contain any educational instructions that would determine how it is supposed to be used. Thus, the nature of the learning process will be dependent on the learning tasks and pedagogical arrangements set outside of it. If given the opportunity to re-do the project, the urban school teacher mentioned that they would include the students more in the creation of the shared Thinglink world and encourage them to refine the 360-degree scenes more, much like it was intended in the original project plan (see Section 2.3).

Potential and actualized physical affordances

In this part I briefly focus on the actualized and intended physical and social learning possibilities. To repeat, the 6th graders used the VR system to find a personally meaningful scene and to explore the world and their chosen countries from various perspectives. The urban 5th graders role-played tourists and used the VR system to take their self-planned trips to other countries. The rural 5th graders used the VR system as a navigational tool with an orienteering challenge and intended to use it as a prop to enhance the realism of their presentations. These seem to be the actualized affordances of this VR system that manifested mostly because the teachers resorted to such pedagogical arrangements that resembled their personal teaching philosophies and preferences (see Figure 17).

Apart from the role-playing activities of the urban 5th graders, the VR system offered a visual supplement to the student groups' typical pedagogical arrangements. It was not being purposefully used to create constructive controversy or to support some collaborative knowledge building or progressive inquiry activities. Further deliberation in section 4.2.

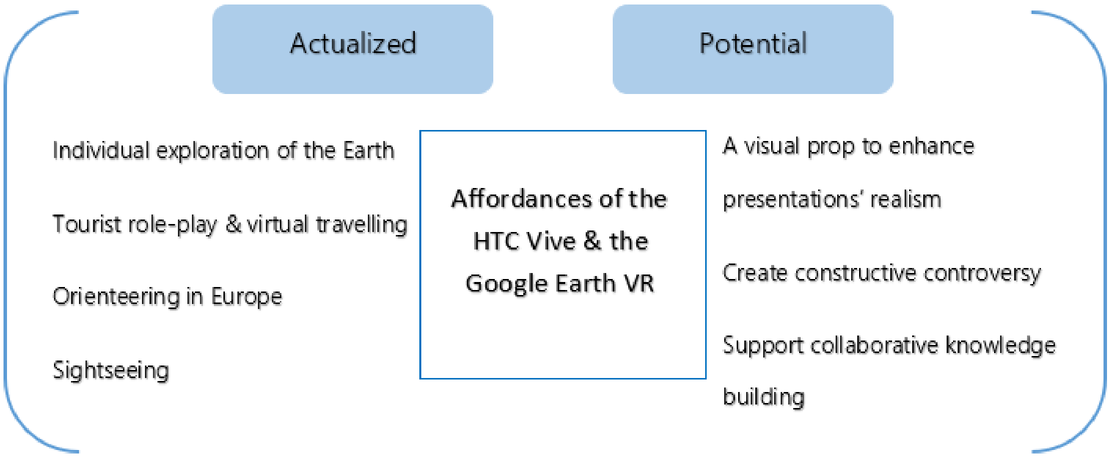

Figure 17. The actualized physical and potential social affordances of the applied virtual reality system.

Challenges of implementing the virtual reality system

The preferences of the teachers were not the only factors that played a part in on how the virtual field trip projects eventually turned different from what we had originally planned. Based on the teacher interviews, it became clear that the implementation of this VR system did not come without some challenges.

The rural school teachers faced many technical difficulties in part because of their district's information technology (IT) and network policies. According to the interviewed teacher, it took two months for their supplier to deliver the *HTC Vive* and one month for their IT-department to set it up. Furthermore, their school district's network policies prevented them from properly using *Steam* - a digital distribution platform by Valve Corporation, through which the Google Earth VR -program was accessed. They had to connect their restricted computer to one of the teacher's personal networks to be able to log in on the computer and to use *Steam*. Sometimes logging in and updating *Steam* or *Google Earth VR* took quite a while. Thus, they felt like they had squandered a lot of time, which seemed to be the most precious and depleted resource for both schools.

The urban school teacher did not experience similar technical difficulties. The device was set up in the teacher's own classroom by professionals who made sure that the computer and the internet connection were not restricted in any way that would disturb the use of the VR system. This goes to show that the technical difficulties of the rural school were all solvable. However, the urban school teacher, too, was concerned about the inability of the school's typical timetables to adjust to a long-term project that included the use of this single VR system. The urban school teacher explained that it took a lot of organizing to make sure that all 40 students would get to operate this one VR device.

On the other hand, according to the interviewed teachers, the students were able to adapt quickly to the technology and had benefited from getting to complete the device's and the program's tutorials. Nonetheless, both teachers agreed that these VR setups were not yet convenient enough to be worth using with such large student groups. As one of the interviewed teachers stated:

"[*it makes more sense to implement learning technologies that are fool proof and easy to use, instead of technologies that are quite complex and demanding.]*"

Despite the apparent inflexibility of having just one *HTC Vive* device, one of the teachers was determined to implement it again next semester. One teacher pondered that perhaps a differently paced school day (longer lessons) could accommodate such a VR system. The other jokingly suggested that the apparent scarcity of time could be resolved if each student had their own VR device.

3.2 How engaging and immersive was the virtual reality system?

As mentioned before, the students reported their experiences to the e-log, i.e. online questionnaire, in which they would, among other things, report on the perceived credibility of the *Google Earth VR* program. The idea behind that was to comprehend better how the students respond to an immersive environment. And furthermore, whether this program could be considered as a suitable learning tool for creating constructive controversy. As established before, for our existing mental models to be affected and any of our current beliefs to be influenced, it matters whether one finds the new and possibly conflicting information and its source trustworthy or not.

Twelve students provided uninterpretable answers (such as, “*Everything*” and “*I don’t know*”) to a follow-up open-ended question on what had made the program reliable. Those answers were set aside. If a student’s answer was incomplete or lacking in this manner, I checked whether they had provided a more complete answer in their second or third online questionnaire entry.

A total of 29 students offered clear explanations for what had made the program reliable in their mind, either after their first, second, or third VR system use. I applied the clustering content analysis method (see Krippendorff, 1980) to those answers and arranged the students’ answers according to Tseng and Fogg’s (1997) categories (see Section 2.4 and Table 4).

Table 4

Synthesis of the Types of Credibility Displayed by the Students about the Google Earth VR -Program.

Credibility type	Example sentences	N
Experienced	*"It seemed very real"* *"Street had people and cars that moved along with some pictures"* *"Because I have seen those places before"*	17
Reputed/Pre-sumed	*"Because teacher said"* *"It makes it reliable that is made by google"* *"That many people said it was good"*	8
Surface	*"The picture was accurate"* *"It made it reliable by showing everything very nicely"* *"Graphics"*	4

Note. 29 total answers were analyzed.

Altogether it turned out that 17 students (i.e. ≈59% of all accounted answers) offered an explanation displaying experienced credibility. Most typically for them the believability of the virtual world was due to the realism, or resemblance and accuracy of the virtual world with their experiences of the real world. It is worth noting that this category of credibility is considered as the most dynamic, i.e. prone to change.

Up to eight students (i.e. ≈28%) offered explanations displaying reputed or presumed credibility. They either trusted their teacher's assessment of the virtual world, the statement of others or assumed that the company behind the program is reliable. I treated these two types as a single category as it seemed to me that those who attributed reputed credibility to the *Google Earth VR* program based on others' suggestions might first have to presume that those others are trustworthy and that they have enough expertise. Lastly, four of the students (i.e. ≈14%) clearly attributed their trustworthiness to superficial factors. Their explanations mostly addressed the perceived high quality of the display.

The way this current study was setup makes it impossible to directly measure how mental immersion might have affected the students' credibility assessments of the program. Then again, Huang and others (2010) have used the perceived realness of the virtual world as a variable that indicates successful mental immersion. If that is accurate, then the credibility that was associated to the program because of the experienced "realness" must have been affected by successful mental immersion. Altogether nine students (i.e. ≈33% of all answers) directly mentioned that the program was reliable because of the "realness" of the virtual world. Therefore, at least some of the students had experienced successful mental immersion with the VR environment. And mental immersion seems to have influenced some of the students' credibility assessments.

In conclusion, the reasons behind what made the *Google Earth VR* projection reliable were various. Different users focused and relied on different qualities. This time around the main reasons had to do with the perceived high quality of the program that came from the consistency of the VR experience with real world experiences, the realistic and enjoyable appearance of the virtual world, and presumed trust in the developer or in positive statements of other users. Furthermore, successful mental immersion experiences appear to have influenced some of the student's reasoning regarding the VR program's credibility.

Most reliable uses for the VR system

None of the participants at any of their online questionnaire assessments demonstrated utter disbelief towards the program, thus, no one was presented with the question of what made the program unreliable. Some of the students were asked about what they thought would be the most reliable use for the program. The suggestions they gave had to do with sightseeing (15), exploring (8) or school projects (8). Thus, these students described the type of activities they had been conducting during the current project all along.

To sum up, majority of the students had found the VR program's projection of the Earth to be accurate and up-to date. The students reasoning behind the credibility of the *Google Earth VR* program's projection were categorizable to three distinct categories; experienced, reputed/presumed, and surface credibility. For a clear majority the main reason had to do with either the overall realism or the perceived equivalence of the virtual and actual worlds. When asked about the most reliable uses for the VR system, the students gave answers that described similar activities to their current virtual field trip projects.

Self-efficacy beliefs and interest to engage with virtual reality technology

To learn more about the students' desire towards including VR technology in their learning environment, I measured and analyzed their self-reported self-efficacy beliefs and interest to engage with the technology, in the post-survey. According to Bandura (1997, p. 18), people tend to put more effort to the task at hand, even when facing adversity, if their self-efficacy beliefs have been encouraged. Furthermore, if a person has low self-efficacy towards a task or an activity that they do not find valuable, they might not be willing to participate in that activity. Thus, the students' self-reported self-efficacy beliefs and interest in engaging with the technology could indicate their overall willingness to use the VR technology again in the future.

My intention was to discover if VR technology would be a desirable addition to the students learning environment, if it is the “something very cool” that students might feel confident using and would want to engage with in their immersive learning environments (see Blashki, et. al., 2007, p. 410). Moreover, I studied whether there were any notable differences between the different student groups or genders in their self-efficacy beliefs or interest to engage with VR technology.

A total of 54 students participated in the post-survey. After checking the reliability of the sums of variables (see Section 2.4), I continued the analysis by verifying the normal distribution curve. The normal curve of the “interest” -factor appeared to be more skewed than the “self-efficacy” -factor. In fact, with closer inspection the skewness in both cases more than twice exceeded the standard error of skewness. This meant that the distributions could not be treated as normal and thereby the data should be analyzed with non-parametric means only (Reunamo, 2010).

Overall, the mean scores of both factors on a Likert-5 scale were relatively high. For self-efficacy, the mean score was *4.11* and the standard deviation was .648. And, for interest to engage, the mean score was *4.09* and the standard deviation was .961. This would indicate that, by and large, the students felt like they are capable of handling VR technology and that they would be interested in using it again at school.

High self-efficacy beliefs are fostered mainly through mastery experiences (Bandura, 1997, p. 2). It is possible that during their virtual field trip projects the students gained such vital mastery experiences with the implemented VR system.

To analyze the data further, I decided to compare the means of the different student groups and genders. I used the non-parametric Mann Whitney’s U-test for independent samples to determine whether the difference between the means of different genders was statistically significant. It turned out that the distribution of self-efficacy beliefs was statistically different for the two genders (see Appendix K). The self-reported self-efficacy of boys (M=4.34, SD=.605) was statistically significantly higher than the girls corresponding (M=3.91, SD=.627).

Similar significant differences were not detected between the genders' interest to engage with VR technology again at school. Furthermore, the comparison between the different student groups' means yielded no statistically significant differences (see Appendix L). Albeit, it appeared at first that the urban 5th graders mean for interest in engaging with the technology was much higher than the other student groups' means (see Table 5).

Table 5

Student Groups' Means (M) and Standard Deviation (SD) in the Interest to Engage -Factor.

Grade	M	SD	N
5th Urban	4.43	.724	21
6th Urban	3.85	.935	16
5th Rural	3.90	1.160	17
Total	4.09	.961	54

Note. The maximum score is 5.00.

Overall, it appears that the students would feel confident and willing to include VR technology in their learning environments. This is a good sign with the immersive learning pedagogical arrangements in mind. Further deliberation in section 4.2.

3.3 What kind of user experiences did the students have with the applied virtual reality system?

In this section, I will analyze the user experiences reported by the students in the e-log, i.e. online questionnaire, and the post-survey. These results should help identify any needs for improvement with the virtual reality (VR) system. In this study, the students' user experiences comprise of their perceived usability of the applied VR system (Subsection 3.3.1) and their self-reported emotional responses regarding the VR system and the learning activity (Subsection 3.3.2). Furthermore, I will present the results and analysis of the impressions that the various virtual field trip projects and the implemented VR technology made on the students' conceptual beliefs about the technology itself. And lastly, I will take a closer look at student imagined VR worlds for the first time since the early 1990's (Subsection 3.3.3).

3.3.1 Usability

A total of 56 students offered their assessments in the online questionnaire about the comfortability of the *HTC Vive* device and about how user-friendly the *Google Earth VR* program was. The students filled out the online questionnaires after every use of the VR system. I analyzed the students' self-reports from their first complete recorded use of the VR system. Regarding the usability of the VR system, they were asked the following two questions:

1) How comfortable was it to use the *HTC Vive* device?

2) How easy was it to use the *Google Earth VR* program?

These questions were intended to help inform about the overall perceived usability of the VR system, i.e. its comfortability and user-friendliness.

The participants gave their answers by dragging a bar underneath a smiley face. It had five different positions showing different emotions from very displeased to very happy. (see Appendix E.) The students' choices were recorded and interpreted on a 1-5 scale, from very uncomfortable or very difficult to use to very comfortable or very easy to use. Similar indicators have worked well with children in previous Innokas Network developmental projects' questionnaires in Finland.

In the first question, 34 of 56 students rated the *HTC Vive* device as very comfortable (i.e. ≈61%), 18 rated it as comfortable (i.e. ≈32%), three rated it in between and one reported having experienced some discomfort. The total mean score on a 1-5 scale was *4.52,* and the standard deviation was .687.

In the second question, 26 of 56 students felt that the *Google Earth VR* program was very easy to use (i.e. ≈46%), 25 thought it was easy to use (i.e. ≈45%), four rated it in between and one reported having difficulties. The total mean score was *4.36*, and the standard deviation was .699.

I continued to analyze the data with non-parametric tests in the IBM SPSS Statistics software. I detected no statistically significant difference between the two genders' assessments means. The only statistically significant difference ($p=.048$, $p<.05$) that I discovered was between the means of the rural 5th graders

(M=4.00, SD=.503) and the urban 5th graders (M=4.59, SD=.894) assessments of the user-friendliness of the *Google Earth VR* program (see Appendix M). It appears that the VR program was perceived to have been more user-friendly by the urban 5th graders than by the rural 5th graders, although, it is worth noting that both groups' means were highly positive.

In conclusion, based on the students' self-assessments, it appears that the *HTC Vive device* and the *Google Earth VR* program were very comfortable and easy to use. By and large, the students displayed an overwhelming please towards the VR system. A slight statistical significance was found between the means of the rural 5th graders and urban 5th graders assessments of the VR programs user-friendliness.

Reasoning behind the perceived usability

The participating students were also presented with follow-up open-ended questions in the online questionnaire based on how they assessed the usability of the VR system. I will begin by examining the reasoning behind what made the device uncomfortable and difficult to use for a few of the students before analyzing the rest of the students' answers to what had made it comfortable and user-friendly.

Adversity and simulator sickness

There were three answers to the question about what had made the device uncomfortable to use. One of the students felt uncomfortable because of "*scary places*" and one stated that they had "*felt a little dizzy and didn't feel good*".

All together five students provided answers to the question about what had made the program difficult to use. They reported having difficulties when trying to switch between the two body positions (see Section 2.2), when moving around, or because they got confused at times. When given the opportunity to provide reasoning behind their assessments, the sole student who had reported having experienced both discomfort and difficulties answered "*Nothing*" and "*No*" to the open-ended questions. The reasoning in each of this student's other online questionnaire open-ended questions were as non-descriptive.

As mentioned before, the students' spatial reasoning abilities were measured at the beginning of the project with an online version of Ramful and others (2016) Spatial Reasoning Instrument (SRI). The SRI is designed to test the three main components of the spatial reasoning ability: Spatial orientation (SOR), mental rotation (MR) and spatial visualization (SVS). SOR is a mental operation where one uses their mind to picture an object or a situation from another perspective, meaning they imagine viewing an object or a scene from another point of view. MR is a process where one uses their mind to imagine rotating, turning, moving or spinning objects whilst their point of view remains the same. Lastly, a person uses SVS in all other situations that require mental picturing, and in situations where one could use either one of the other abilities, or a combination of them.

Salzman and others (1999, p. 313) suggested that the spatial abilities of a learner, i.e. "the cognitive ability that enables individuals to perceive patterns and to manipulate and rotate that information relative to one's own position in space" (McGee, 1979, as cited in Salzman, et. al., 1999, on p. 313), might affect their interaction experience with a VR system. According to them, the interaction experience consists of the perceived usability of the VR system and any VR simulator sickness one might experience.

Based on the students' answers to open-ended questions in the online questionnaire, I learned that four of the students (i.e. ≈8% of all students) had experienced simulator sickness in form of headaches or slight dizziness when using the VR system.

I combined these students' SRI scores to a matrix (see Table 6). Turned out that, the two urban 6th grade students (A & B) had both scored well below their student group average of 21.00 (see Table 7). The mean score of all the rural 5th graders was low to begin with, 15.41. One of the two rural 5th graders had scored below that (C), but the other had scored way above (D). All these students scored mediocrely in mental rotation, and the three with the lower than average scores did poorly on spatial visualization. Then again, this sample size is too small to make any definite conclusions whether spatial reasoning had anything to do with the students' simulator sickness, and overall interaction experience.

Table 6

The Spatial Reasoning Instrument Scores of Those Students Who Reported Symptoms of Simulator Sickness.

			Spatial reasoning instrument scores			
	Headache	Dizziness	MR	SOR	SVS	Total
Urban 6th A	X		5	9	2	16
Urban 6th B		X	4	9	3	16
Rural 5th C	X		4	5	3	12
Rural 5th D	X		6	9	8	23

Note. MR means mental rotation, SOR means spatial orientation, and SVS means spatial visualization. The maximum score in each is 10, and the maximum total score is 30.

Table 7

Student Groups' Spatial Reasoning Instrument Scores' Means (M) and Standard Deviation (SD).

Grade	M	SD	N
5th Urban	19.05	4.63	21
6th Urban	21.00	4.30	18
5th Rural	15.41	3.71	17
Total	18.57	4.76	56

Note. The maximum score is 30.00.

Comfortability

Next, I proceeded to analyze the reasons behind the rest of the student self-reports on the comfortability and user-friendliness of the VR system. Overall 54 students provided an answer.

Nearly half of the students, 25 (i.e. ≈45%), gave reasons for device's comfortability that had more to do with the program than with the device. They mostly expressed how their experiences were made comfortable by the ability to visit and view various places and sights. For a few the comfortability stemmed from the ability to move around and explore the virtual world freely. In fact, only 10 students (i.e. ≈19%) attributed their comfortability to the device alone. For the most part, their reasoning had to do with the quality of the display. Moreover, one student mentioned that the comfortability stemmed from the device being "*fascinating*". In addition, six students offered reasons that would have required more elaboration if they were to be understood. (see Table 8.)

Table 8

The Reasoning Behind the Students' Reported Comfortability.

Attribution	Example sentences	N
The program	*"You could go where you wanted"* *"I enjoyed going to different countries"*	25
The device	*"The quality of the pictures"* *"I got to control it myself"*	10
Immersive VR system	*"It felt almost the same as real life"* *"That it felt as if you were there"*	13
Other	*"The conditions"* *"That we used it in a place where you wouldn't expect it to be used"*	6

Note. Overall 54 students' answers were included in the content analysis.

The remaining 13 students (i.e. ≈24%) offered explanations that I connected to the whole VR system and to its successful mental immersion. These students reported that the comfortability was due to the realness of it all or because it felt as if you really were within the virtual world. A few of the students also reported that the ability to fly within the system had made it comfortable, these answers could also be counted on as reasons relating to the program alone as it allows for the users to navigate their way through the virtual world by "*flying*".

User-friendliness

When asked about what made the *Google Earth VR* program easy to use, two reasons stood out above all others. Overall 16 students (i.e. 40% of all answers) felt that clear instructions and the built-in tutorial of the program made the program easy to use. It is possible that some or all those students who mentioned "*instructions*", meant the tutorial of *Google Earth VR*.

Furthermore, 14 students (i.e. 35%) praised the controllers and the simplicity of its buttons. Again, it appears that the properties of the device intertwined with the program's properties. The rest of the students, nine (i.e. ≈23%), simply stated that the program or the device was easy or simple, and one thought that it was "*very well thought through*".

In conclusion, the *Google Earth VR* program appears to be a simple program that is well designed and easy to use on the *HTC Vive* device. In addition, the program's built-in tutorial helped many of the students to quickly adjust to their new virtual surroundings and learn all the available basic actions. Based on the reasoning behind both usability questions, I can now tell that this VR system is comfortable and user-friendly, the virtual environment is easy to look at because of the good quality of the display, and most notably the system is able to provide a mentally immersive experience for the user. Then again, educators and future researchers should keep in mind that four of the students reported that they had experienced some dizziness or headache when using this VR system.

3.3.2 Emotions

I continued to analyze the students' self-reported enjoyment and boredom. In the online questionnaire, the students were asked whether they agreed or disagreed on a verbal Likert-5 scale with the following statements:

1) I enjoyed using the HTC Vive device
2) I got bored using the HTC Vive device
3) I enjoyed learning with the Google Earth VR
4) Learning with the Google Earth VR bored me

Similar statements were used to measure Pekrun's (2006) academic emotions in a user experience study about an augmented reality (AR) application for history learning (see Harley, Poitras, Duffy and Lajoie, 2016). Harley and others (2016, p. 12) insisted that emotions predict learning outcomes by influencing person's motivational, cognitive and metacognitive processes. This makes it important to evaluate educational VR environments' capabilities to promote positive activating emotions. Overall, 56 students offered assessments of their academic achievement emotions (see Table 9). The results reveal an overwhelmingly positive emotional response from the students. They reported relatively high mean retrospective levels of enjoyment and relatively low mean retrospective levels of boredom.

Table 9

Mean Scores (M) and Standard Deviation (SD) for the Academic Emotion Statements Display Enjoyment Over Boredom.

Statements	M	SD	N
I enjoyed using the HTC Vive device.	4.66	.478	56
I got bored using the HTC Vive device.	1.45	.711	56
I enjoyed learning with the Google Earth VR program.	4.59	.596	56
Learning with the Google Earth VR program bored me.	1.45	.630	56

Note. Likert 5 -scale was used. The maximum score was 5.00.

In the previous subsection I discovered that the different components of a VR system often intertwined in the students' answers. Some of the reasoning for the perceived comfortability of the device had to do with the program or the mental immersiveness of the VR system and vice versa with the assessments of the programs user-friendliness. This observed phenomenon might have also applied to the enjoyment and boredom assessments. The students' might have perceived the device and program as somewhat equivalent. Thus, I decided to analyze the data further and create a sum of variables for an overall emotional experience out of the four variables seen in Table 9. As the reliability analysis for emotional experience with the VR system revealed (see Table 1), the Cronbach's alpha score was acceptable. And I was able to construct the new factor; emotional experience.

Based on a frequency analysis, 23 out of 56 students (i.e. ≈41% of all answers) strongly indicated that they had had a positive emotional experience. Their sum of variables mean was 5.00. Correspondingly, the mean of all students' answers was also relatively high, M=4.59, whilst the standard deviation was .468. Moreover, even the lowest mean of an individual student was 3.25.

The students' likes and dislikes

About one third (n=16) of the students' answers depicted emotion-related answers to the following open-ended question: "What did you like about this activity of finding a suitable location for a virtual field trip with the Google Earth VR?" All 16 answers displayed positive emotion states, such as: "*It was exciting and easy.*", "*Finding new places was fun.*" and "[*I liked that it was easy to use and that it was fun.]*".

In response to the following open-ended question: "What did you dislike about this activity of finding a suitable location for a virtual field trip with the Google Earth VR?" Four students (i.e. 8% of all answers) reported that they had experienced a mild negative emotion. Examples of negative emotion states included: "*I disliked that I can't go to the sun in google earth.*" and "*It was scary and it did not work at first.*"

For 29 students (i.e. 58%) there was nothing at all that they had disliked about the activity with the program. In fact, eight students (i.e. 16%) reported that they had "liked everything". These answers are not unprecedented as Bricken and Byrne (1993) had already discovered that children enjoyed conducting activities within VR environments. It appears that his VR system is no exception.

Roussos and others (1999, p. 258) remind us that excitement might contribute to any testing and measuring that is made right after a VR experience. On the other hand, the emotional response of the students to the VR system is something that I wanted to capture in the first place.

The teachers were also present for the students' first VR uses and observed the emotional effects of working with the VR system. They revealed in online interviews that most of the students displayed excitement right after the VR activity, while others remained neutral and collective. None had displayed negative emotions.

3.3.3 Impressions

In this subsection I present the results of the analysis on the type of impressions that the applied virtual reality (VR) system had made on the students. More precisely, how it appeared to have an impact on the students' conceptual beliefs about VR, and what kind of imagined virtual worlds for learning purposes did the students come up with after completing the project.

The students' conceptual beliefs regarding virtual reality

Pre-survey

In the pre-survey the participants were asked to describe "virtual reality" by using five words that first come to mind when hearing the concept. I received 55 appropriate answers, and 21 of them (i.e. ≈38% of all answers) were subjective and focused mostly on positive emotions and descriptive expressions, for instance: "*cool, fun, interesting, new, future.*" Nearly as many answers, 20 (i.e. ≈36%), were mostly materialistic and focused on VR hardware, such as "*virtual, reality technical and headphones and glasses*". There were 13 answers (i.e. ≈24%) that dealt mostly with the realism of VR, for example "*fun, feels real, not real*". Only one student raised concern over the possible negative effects that the technology might have on human eyes.

Moreover, one of the students displayed a negative subjective stance towards VR. Then again, judging by their other answers, this person might have mistaken VR for some other technology, and, thus, I left their answer unaccounted. For instance, they claim to have used VR devices or goggles at a hobby monthly for "Instagram", a social media program which to the best of my knowledge contains no such features besides the capability to share 360-degree photos.

Post-survey results

When analyzing the answers to the students' post-survey, I managed to find some similarities from the students' answers (N=53) when they were asked to explain an unaware person what virtual reality means. Interestingly, 16 students (i.e. ≈28% of all students) explained the concept of virtual reality mainly through the learning task and VR system that was used during this project. They gave answers such as:

"*It means like that you put glasses and earphones on and you will see for example the world and you can move there and go to street view. In street view you can see some place in front of you. You can also play different games there.*"

"*Virtual reality is reality made by humans. If you put on VR glasses you can see and explore the earth from space or on the ground. It looks pretty realistic in my opinion.*"

18 students (i.e. ≈34%) described VR with the help of one of its interactive experience components; mental immersion. None of them used the actual concept, but their answers focused mostly on how virtual reality can make you feel as if you were in another place, which is a telltale sign of the sense of presence (see Slater, 1999). Additionally, six out of eight students who had never used any VR devices before the project were among those who described the concept mostly through mental immersion. For example:

"*Virtual reality is like a world where you can see places like you really were there.*"

"*Virtual reality is that you can go with the glasses to 'another dimension' and the 'dimension is in the internet and you can see things like you could see them in real life.*"

Majority of the students (28, i.e. ≈53%) also mentioned technical aspects to describe VR. VR glasses or goggles were mentioned most often, some also included the controllers in their answers. For example:

"*It's a software, where everything looks real. You put on some goggles and controllers, and that's how you control everything you do and see.*"

Seven rural school students (i.e. ≈13%) described the concept only briefly by explaining that it is artificial reality or "*not true reality*". A few of the other students offered unique answers, such as:

"[*For me virtual reality means that you can live somewhere else than in your own home when you buy the glasses. They are very comfortable to use, especially at school, with it you can live almost anything at all.]*"

To sum up, it appears that the students' understanding of the concept of VR was influenced most by the implemented VR hardware, by the way that the VR system was applied in these virtual field trip projects and by the sense of presence that the features of the implemented VR system seem to have successfully provoked.

The students' imaginary worlds

According to Huang and others (2010, p. 1172) VR programs can be designed to provoke imagination in problem solving situations. In the context of this study and now that the students had developed a basic understanding of the VR technology and its capabilities, I was intrigued by what kind of fantasy worlds the students would come up with and for what learning purposes they would be able to imagine using this technology for. Seeing how the understanding of the concept of VR was largely influenced by the implemented VR system, I predicted that for the most part the students' fantasy worlds would be influenced by it as well.

The students were asked to answer the following questions in the post-survey: "If you could go into any virtual world that you can imagine and learn about anything at all, what would it be? And what would that world be like?". The answers took me by surprise as for the most part students described various intriguing and unique fantasy worlds.

Despite the hard, multileveled question, some students also provided explanations to what they would want to learn in these worlds. Much like in Bricken and Byrne's (1993) study, the variety in the students' answers could indicate that VR technology has the capability to appeal to a child's sense of adventure. By analyzing the students' answers, I managed to divide most of the 49 answers to four distinct categories: learning about the real world (23), learning in a fantasy world (16), gaming (6) and other ideas for VR (4).

Similar to Bricken and Byrne's (1993) study, one or more student in this study imagined utopias ("*happy world where everyone is happy*", "*world is full of na-*

ture”), historical worlds (“*I would like to travel to the age where there were dinosaurs*”, “[*I would go to Stone Age world*.]”, “[*old knight era*]”), outer space (“*I would go to the black hole*”, “*other planets in our solar system*”), water world (“[*bottom of water where I would learn different kinds of fish]”*), the physical world (“[*Thailand...to learn about its history and habits]*”, “[*Amazon rainforest and to learn about animals]*”, “*Florida’s biggest gym and learn about USA gymnasts*”.) and games (“*Fortnite*”, “*horror game world*”, “*drive cars and do whatever you want*”).

Unique to this study, many of the students also imagined magical high fantasy worlds (“*imaginary world…different mythical creatures such as unicorns and mermaids*”, “*a world full of candy*”). Furthermore, some imagined high fantasy worlds where they would be capable of supernatural things (“[*Magical world...to learn spells]*”, “[*Harry Potter world where I’d learn how to cast spells]*”). Another new and popular theme in the students’ fantasy worlds was travelling to the future (“[*I’d travel to the future]*”, “*the world would be in the future...technology will be everywhere...learning would be even more fun than now*”).

By and large, the students’ answers reflected their personal learning interests and other fantasies, but also featured some of the most contemporary phenomenon and displayed signs of the most abiding cultural memes in the present-day world (such as, Fortnite-game, movies and books such as Harry Potter, Marvel-universe and Star Wars). This might indicate that, much like with other learning tools and tasks, when one implements VR, it could be beneficial to try and tie the learning activities to each student’s interests and existing structures of experience and consciousness.

Six of the students’ answers (i.e. ≈12% of all answers) displayed unique imagination, but disregard to what is currently possible with the VR technology: “*If I could go to any virtual world I would go into my dreams if it was possible. It would be so that you would sleep in the glasses and once you start dreaming you could be in it and later on when you wake up you could see what happened.*”, “[*there would be an endless supply of good food...I could build my own super-gaming-console]*”, and “*there would be warm and sunny*”.

All in all, the students in the current study displayed interest towards finding out what the world and the universe is like, how other beings experience it and what it would be like to live in an alternate magical reality. Furthermore, what I found interesting was that quite a few of the students' answers (12, i.e. ≈24%) displayed intrigue towards past, alternate or future worlds and state of things. According to Mikropoulos and others (1997, as cited in Selwood, et. al., 2000, p. 234), these kinds of parameters (such as time, size and distance) could be altered with VR technology. This would make VR technology the closest that we have yet been able to get to a real-life time machine.

4 Conclusions and discussion

In this final chapter I plan to assess the reliability and validity of this study. Some remarks will be made concerning the ethics of this study, how the participants were treated and how I took care of the data and assessed it. I will also recap the results and deliberate on them further. Finally, I am going to ponder on the current value of this study, as well as propose directions and design remarks for future research.

4.1 Reliability and validity of the study

This study was a novel attempt at researching the implementation of immersive virtual reality (VR) technology in the actual school environment. To the best of my knowledge this was the first time such scientific study has been conducted in Finland at the elementary school level. The review of literature revealed that for the past three decades researchers all over the world have conducted only a handful of relevant VR studies with children. Many of which were conducted in clinical settings. None of the previous studies had directly paved the way for this current study, but their findings were accounted for. Overall, this study was mostly an exploratory research that relied on the design-based approach of field-testing digital tools in cooperation with teachers and students. It is a common approach when there is a need to approach a learning phenomenon in the real world rather than in laboratory settings (Collins, Joseph, & Bielaczyc, 2004, p. 16).

As mentioned before, some of the measures, such as the assessment of the credibility of a virtual world, were self-constructed from related literature. While others, such as the measures about self-efficacy and engagement, the emotional response measurements, and the question about the student's imagined virtual worlds, were validated through earlier digital technology related studies. All the measures in each questionnaire were assessed and approved by the instructors of this master's thesis. They are experts in conducting research on children and youths' use of digital technologies. Nonetheless, the variables and factors in this study's self-report questionnaires remain open for critique and demand further development.

Future researchers, who develop similar studies as this one and plan to apply its self-report questionnaires, should acknowledge the explorative nature of the current study. For instance, the questions regarding the credibility of the VR environment require further development. I am certain that there are more established ways of measuring credibility, and they should be explored. Fortunately for this study, the parallel qualitative data helped triangulate the studied phenomena and reach the actual concrete experiences beyond quantitative measures.

The study of VR technology is a novel subject, especially after the technology has taken a big step forward in recent years in its capabilities and distribution. Furthermore, the technology was rather new for the students and remains debatable how much the novelty of it alone affected their utterly positive assessments of the VR system.

In upcoming studies, a wider scale for usability and enjoyment measures should be considered. Additionally, if future studies begin to transition away from measuring the user experience and shift their focus in on the learning outcomes, then obtaining a clear understanding of students' domain experience and prior knowledge could prove out to be important factors to measure.

In accordance with research-practice partnership (see Coburn, & Penuel, 2016), I relied on participatory methods of intervention. The participants of this study were treated with the utmost respect for their privacy and human dignity. I attempted to provide empowering roles for students and teachers within the study. In fact, this design experiment relied heavily upon their integrity and efforts. Amongst other things, most of the results rely upon the students' self-reports and thereby on their honesty and metacognitive skills such as reflection (i.e. thinking about their own thinking, actions and feelings). The participatory approach I adopted led to the documented changes to the initial plan, and resulted in some intriguing new study topics, such as the teacher's orchestration of the project, and the actualized and potential affordances.

Previous VR related research states that the researchers should always observe what transpires with the use of VR with children. In this study the teachers operated as the main observers instead. The virtual field trip projects were conducted in two different schools separated by approximately 500 kilometers (i.e. 300 miles). Furthermore, the use of the *HTC Vive* device took place irregularly at the urban school. One way that I could have observed each VR use would have been to equip the rooms with video recording capabilities and have the children record each other's VR uses. Furthermore, it could have proved out to be very useful if the students' activities within the VR environment were recorded. This would have helped identify, for instance, how exactly did the urban 6th graders act in the virtual space and what affordances actualized for them, and whether the rural 5th graders managed to concentrate on their orienteering task through-out their virtual visits or not. Nonetheless, it was important to have an adult present whenever the students first used VR. To conclude, I firmly believe that future studies could get beneficial data by recording the students' actions in VR with the help of a screen capturing or a streaming software.

4.2 Summary of the results and deliberation

This virtual field trip project introduced the students (N=59) to an immersive virtual reality (VR) system that comprised of a *HTC Vive* device and a *Google Earth VR* program. I set out to study (1) what kind of VR enhanced projects the teachers had orchestrated and how they affected the students' typical learning arrangements, (2) what made the projection of the VR program reliable according to the students and would VR technology be something that they would be willing to use in their future studies, and (3) what kind of user experiences did the students have with the applied VR system. The mainly qualitative data was gathered primarily remotely with self-report questionnaires. Moreover, the teachers acted as observers and they were interviewed after the project. I analyzed the gathered qualitative data with the means of clustering content analysis as described with greater detail in section 2.4.

Orchestration

The student groups' virtual field trip projects were all slightly different from one another as the teachers found different uses for the VR system. All in all, the technology was integrated to the local information ecologies (see Nardi & O'Day, 1999) in a relatively short period of time. Thus, it is not surprising that the existing resources and community's needs guided its implementation. For a first iteration of a design experiment this is perfectly ordinary.

Besides facing some technical difficulties, the teachers from both schools revealed that they had difficulties in adjusting the use of this VR system to the temporal constraints and resources available in their schools. It appears that trying to make long-term learning activities fit to these schools' existing rigid timetables and pre-existing scripts might have resulted in a perceived lack of time. In addition, both interviewed teachers felt that the current VR system was not convenient enough for student groups with approximately 20 students, unless of course, if they had more sophisticated learning environments that could accommodate the *HTC Vive* device more conveniently or if each student had their own device.

Based on the findings about the typical arrangements of the students' environmental studies' lessons, it seemed that the 6^{th} graders were used to long-term projects where the learning process is valued much more than mere memorization of facts. However, this time around the experiences that the VR system provided for the students were used to entertain them rather than to engage them in a process of collaborative learning. Albeit, the urban 6^{th} graders did use the VR system to locate a personally meaningful scene and explored the world autonomously from new perspectives. Then again, their discoveries were not included in their presentations of their studied countries. Thus, the VR system was implemented in a way that hardly impacted their other environmental studies arrangements at the time of the project. The students used it to tour their countries without a specific explicit learning purpose. Their self-set goals and questions from the orientation lesson were not utilized.

This could be a noteworthy concern, as Winn (1997, as cited in Hauptman, 2010, p. 125) has stated that by simply letting students roam free in a VR environment, hoping that they construct knowledge on their own, is unlikely to yield preferable results. It is even possible that without appropriate feedback and scaffolding students' learning experiences might lead to misconceptions. Which is a real possibility with this VR program, as discussed in section 2.2. On the other hand, over-scripting learning activities might also lead to a major loss in the quality of learning, as mentioned in section 1.3. The urban school teacher later regretted not involving the students in an activity where they would have applied the VR system and their selected locations in a more purposeful and learning oriented way.

The rural 5th graders assignment was much stricter and narrower. One group at a time visited a separate cabinet where they used the VR system as a navigational tool and one student at a time. Each student was assigned a city from their country of interest and was challenged to locate it and its main sights in *Google Earth VR*. Whilst a group was using the VR system, the other student groups prepared presentations about their selected countries and sought answers to their teacher's pre-structured handouts. Due to technical difficulties the student groups' plans of using the VR system as an illustrative prop during their presentations fell apart.

The urban 5th graders experienced the most evident changes compared to their typical environmental studies lessons. It is likely that these changes were mostly due to the new teacher and the different pedagogical arrangements rather than solely due to the implementation of the VR technology. The urban 5th graders applied the VR system in a more integrated way compared to the other student groups. The students role-played tourists; they drew budgets for their trips, thoroughly planned the trips and traveled virtually to their destinations with the help of the VR system. Furthermore, these students used positive expressions when describing their project in the post-survey much more so than in their descriptions of typical lessons of environmental studies.

The VR system seemed to have invigorated the urban 5th grade students' experiences as in addition to planning their trip the students got to take their trips, albeit virtually. Then again, as Shim, Park, Kim, Kim, Park and Ryu's (2003, p. 73) study revealed, students have not only found VR technology as interesting and enjoyable, but also realistic. In fact, this was also evident in the students' assessments of the VR programs credibility and the VR systems usability. To sum up, it can be stated that this VR system's actualized emotional and cognitive affordances include enjoyment and realism (see Figure 18).

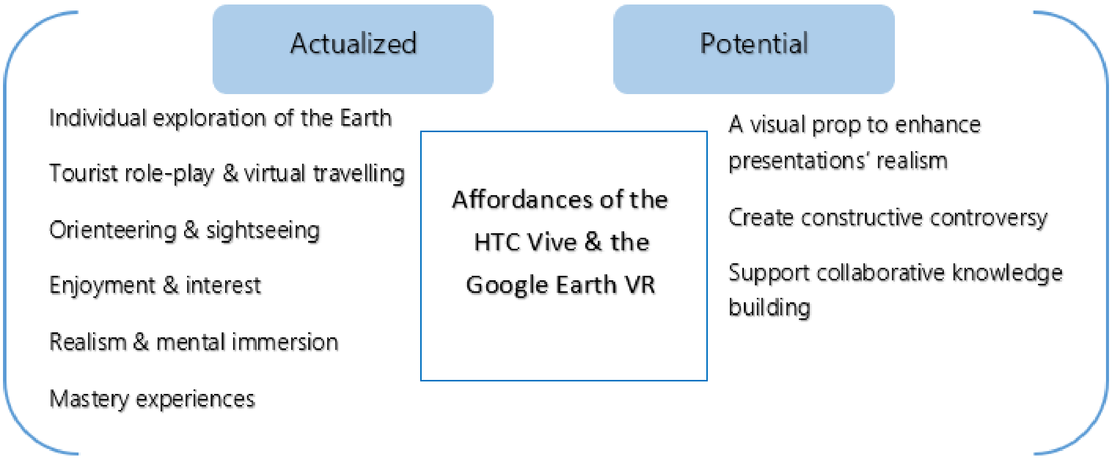

Figure 18. The actualized and anticipated potential affordances of the applied virtual reality system also include emotional and cognitive aspects.

Overall, the teachers resorted to pedagogical arrangements that resembled their personal teaching philosophies and preferences. Because of that, the project took a different direction than what we had initially planned with the teachers. Most of the students' learning activities outside of the VR system seemed to focus on gathering, reproducing and delivering certain informative facts. The 6th graders VR experiences were kept separate from their other environmental studies activities. The rural 5th graders meant to integrate the VR system in their presentations, but circumstances prevented that. Finally, the urban 5th graders did successfully integrate the VR system as part of their collaborative role-playing activities. All in all, this presented a unique opportunity to study the ways in which teachers implemented new technologies to the existing classroom ecologies, and how the students reacted to those alterations in arrangements.

Overall, this project was a valuable first iteration of a design experiment. If there ever was a second iteration of the virtual field trip project, I would have gathered a lot of useful insight during this study that could be utilized when re-structuring the project and the learning activities.

In this iteration, during the actual projects, the VR system appeared to be primarily used on the side and as a motivational addition to build up the students' excitement. Again, this is understandable, as this VR system was a new tool in the teachers' pedagogical tool-kit, which they applied for the first time. Therefore, its possibilities of learning related actions were still quite unfamiliar to them. I believe that with continuous use and student feedback, the teachers might get encouraged to include the VR system even in the more crucial parts of the learning process and learn to implement it in novel ways.

Credibility

Evidently, Google Earth VR does not offer a real time projection of our world, it is more of a combination of still pictures. It shows some areas of the world more accurately than others. Furthermore, there is no way of knowing when in time the pictures were captured and if the scene one explores is up-to-date. Nonetheless, the students found various reasons to trust the *Google Earth VR* -program's projection.

I was able to categorize the students' explanations of the VR system's credibility in three distinct categories (see Table 4); experienced credibility (17), reputed or presumed credibility (8) and surface credibility (4). The main reasons behind the VR environment's credibility had to do with the perceived high quality of the program that was prompted by realistic and enjoyable appearance of the virtual world, the consistency of the virtual experience with real world experiences, presumed trust in the program's developer, or positive remarks from others. It remains unclear how much of the credibility is due to mental immersion, but it is likely that some of the reasons displaying experience credibility were affected by the sense of presence that the VR system's features successfully provoked.

Furthermore, the students also offered suggestions for the most reliable use of the program. They described similar activities that they just took part in: sightseeing and exploring the world as part of a school project.

It is worth noting that the program itself does not contain any educational instruction or scaffolding, for instance, it does not encourage the user to make predictions, ask questions or explain their findings. And as mentioned before, simply allowing students to roam free in a virtual environment, is unlikely to lead to any desired learning outcomes (Winn, 1997, as cited in Hauptman, 2010, p. 215). Thus, the successful use of this VR system to actualize affordances that may facilitate learning could rely on the implementation of proper pedagogical arrangements, scaffolding and clear learning goals in the students' physical learning environment, as hypothesized in Figure 9 (see Section 1.3).

Usability

The students' assessments of the applied VR system's usability revealed that they rated the device as very comfortable (M=4.52, SD=.687) and the program as easy to use (M=4.36, SD=.699). The urban 5th graders (M=4.59, SD=.894) rated the user-friendliness statistically significantly higher ($p=.048$, $p<.05$) on average than the rural 5th graders (M=4.00, SD=.503). This difference might have been partially influenced by the difference in physical space in which the student groups used the VR systems.

The rural school students had a much tighter and restricted physical space where their VR system was set up. Whether it influenced the students' assessments remains unclear. However, if educators plan to apply this VR system, I would recommend that they set up the VR system in a spacious room and utilize the devices maximum boundaries (i.e. 4.5 x 4.5 meters). Albeit, it is worth noting that the urban 6th graders used the same space as the urban 5th graders, and although their mean appeared to be higher than the urban 5th graders, it was not statistically significantly so. In addition, these differences seem quite trivial, as all student groups' means were highly positive.

Curiously, much of the students' reasoning (25, i.e. ≈45% of all answers) behind the comfortability of the device had more to do with the program and its capabilities, than directly with the device. This seems to demonstrate that the students' assessments of the comfortability of the *HTC Vive* device were affected by the properties of the *Google Earth VR* program. Thus, with a different program that has other capabilities and features, the comfortability evaluations of the device might be affected. Moreover, analysis of the students' reasoning revealed that some of their assessments of the user-friendliness of the program were likewise affected by the comfortability and simplicity of the device's controllers. This is an important realization, and one that future researchers of VR systems should consider when working with young students.

Four students reported that they had experienced symptoms of VR simulator sickness, i.e. headache or dizziness. I compared their spatial reasoning abilities scores and noticed that three of the four students had scored below their student groups' average. Then again, all of them had had difficulties in the questions that measured mental rotation (MR, i.e. when a person uses their mental capabilities to imagine rotating and moving objects in their physical or virtual space whilst their point of view remains still). Nonetheless, there is no way of knowing whether it factored in on the students' simulator sickness. Albeit, it should not be counted out either.

To sum up, the small sample of students with this experience makes it impossible to tell with absolute certainty whether Salzman and others (1999, p. 313) suggestion that user's spatial abilities can affect their interactive experience (i.e. usability and simulator sickness) is accurate, and in what way. The matter could have been studied further, had I recorded the students' activities in the VR environment, and the frames of references they explored.

Emotions

The students reported relatively high mean retrospective levels of enjoyment and relatively low mean retrospective levels of boredom about using the VR system. The students' answers revealed that there were significantly more positive emotional statements than negative ones (a ratio of 4:1). Overall, the students reported having had a very positive emotional experience in their first recorded use of the VR system (M=4.59, SD=.468). Thus, it appears that this VR system has the potential to emotionally engage its user to learning activities. According to Pekrun (2000, p. 198), enjoyment can affect a student's task choices, persistence and performance.

The results of this study indicate that the use of the VR system might have been personally fulfilling for some of the students. In fact, quite many of them had reported that they liked having had the freedom and control of exploring the world. Moreover, some of the students had enjoyed being able to view their own house and other familiar places within the virtual world. For Huang and others (2010, p. 1172) successful system and mental immersion "play an important part in creating a successful personal experience".

Moreover, the constructivist pedagogical arrangements of the urban 5th graders, with problem-solving elements and role playing, might have also contributed to the discernible personal fulfillment of the activity on their part. Then again, it remains unclear whether the use of this VR system remains personally fulfilling even with drastic variation to the learning task or after continuous use of the same VR system.

It is also possible that the students' overwhelmingly positive emotional response to their VR experience was the outcome of the novelty of the technology. Looking back at the reasoning that was analyzed in the user experience section, the answers did often demonstrate what Dalgarno and Lee (2010, p. 27) called "impressing the learner with the "niftiness" of the technology and visual realism".

Impressions and engagement

Before the project, the students described VR technology mostly through positive emotions, some mentioned typical VR hardware, and only a few mentioned its realism. After the project, the students' elaborations of the concept revealed that the implemented VR system's hardware and its successful mental immersion had influenced their conceptions of the entire technology. This was evident, because the students' interactive experience and the components of this particular VR system were mentioned in many of the students' answers. Moreover, there was an increase in mentions of realism and hardware.

Many of the students displayed a well-rounded understanding of the technology as they combined these different aspects in their answers. I found it interesting that those students who had previously described VR through positive emotions, now left them out of their descriptions entirely. This might be due to the difference in what was asked; i.e. "Describe by using five (5) words what comes to your mind when hearing the words virtual reality?" in the pre-survey and "Virtual reality? What does it mean?" in the post-survey.

The descriptions by the urban school students were evidently more ambiguous than the rural school students' descriptions. This might be influenced by the fact that the urban school students used VR more often, sometimes even on their own and for longer periods of time during the duration of the project. Moreover, the device was constantly present at the urban 6th graders classroom, whereas the rural school's device was set up in a separate cabinet, out of sight.

It seems to me that for the students to gain a diverse impression about the various capabilities of VR technology, they should be allowed to try different types of VR systems and more often than once. As a matter of fact, post-survey measurements indicate that the students seemed highly willing to use VR technology again in school. Thus, it appears to be a technology that the students would gladly engage with.

The urban 5th graders mean of interest to engage with VR technology (M=4.43) seemed much higher than other groups corresponding means. Albeit, there were no statistically significant differences. Having analyzed the student groups' typical pedagogical arrangements and their changes, I discovered that the urban 5th graders' virtual field trip project was quite different from their typical arrangements and pedagogically different from the other student groups' projects. Therefore, the urban 5th graders' relatively high mean score for interest in engaging with the VR technology again in their studies, although not statistically significantly higher, could be a meaningful result. Perhaps, role-playing along with a VR enhanced experience can elevate the excitement and interest of students to engage in similar future learning assignments. Furthermore, this result indicates that the collaborative constructivist pedagogical approaches mentioned in section 1.3 might make for a successful pairing with VR technology.

Pedagogical arrangements impact on short and long-term learning outcomes should be studied further. This could be achieved by applying the same VR system purposefully according to different pedagogies and then comparing their impact on learning outcomes. Or by integrating such VR programs that were designed according to different pedagogical philosophies that seek to teach the same phenomenon, and then compare the results of the learning outcomes with these different tools. Such a study setup could be used to challenge and specify the modified introductory framework I presented earlier in section 1.3 (see Figure 9).

By comparing the two genders' digital self-efficacy beliefs means, I learned that the boys' mean was significantly higher than the girls' corresponding. Then again, the statistical difference might not be as contextually meaningful. The means of both genders were relatively high. And it is possible that the difference between the genders' mean scores might have resulted from 11-12-year-old Finnish boys' tendency to overestimate their abilities when it comes to handling digital, information and communication technology in general as Hakkarainen, Ilomäki, Lipponen, Muukkonen, Rahikainen, Tuominen, Lakkala and Lehtonen (2000, p. 113) had found out in their study.

Overall, it appears that this VR system makes for a delightful and appropriate introductory system on the capabilities of VR for students of 11-12 years old. Its simplicity and low threshold can help facilitate experiences of mastery in the use of VR technology that are important sources for strong self-efficacy beliefs (see Bandura, 1977, p. 195). Those beliefs in turn might contribute to the students' willingness to engage with different VR tools again in their future studies. These mastery experiences that the implemented VR system successfully facilitated, could be considered yet another actualized affordance of this VR system during the virtual field trip project (see Figure 18).

Now that it appears that the students have constructed a positive base for their self-efficacy beliefs towards the use of VR technology, it would be suitable to have them participate in tasks that are more challenging. According to Bandura (1997, p. 2) a stronger sense of self-efficacy requires successes in tasks where one must exert effort and overcome challenges. To ensure that the students' self-efficacy beliefs of using VR technology would grow and strengthen after this initial introduction, educators could, for instance, engage and encourage them to partake in a learning process where the students would be the one's creating and modifying content for VR.

According to Bricken and Byrne (1993, p. 13) the desire to engage and to construct "expressions of knowledge and imagination" was apparent among students participating in their study. Furthermore, they envisioned a future potential affordance for the technology, where students would use VR to "create a universe of learning worlds that reflected the evolution of the students' skills and conceptual growth".

Finally, the students of this study also imagined various fascinating VR based worlds they would like to visit. It seems to me that behind many of the students' learning fantasies and imaginary worlds lie students' self-set questions. Many of their fantasies appeared to involve personal learning interests either in the real world or in an imaginary world. Similar patterns in the students' imagined worlds were traceable to a previous study in the 1990's (see Bricken & Byrne, 1993). In addition to the usual categories, quite a few of the students unprecedentedly imagined high fantasy worlds with magical creatures and spell craft, and in addition to time travel to historic worlds and alternate timelines, students also imagined travelling to the future. Nearly all the students' imagined virtual worlds seem feasible, and educational VR content designers might want to consider consulting students' needs and desires much more moving forward.

4.3 Future considerations

This current research introduced the readers to the background of virtual reality (VR) technology and to its potential uses in education. Based on a thorough review of literature, I hypothesized a modified framework on a VR system's relationship with the facilitation of learning. Furthermore, this was a novel study on the effects that an educational implementation of a commercially available VR system had in two separate Finnish elementary schools.

I provided the reader with the modified framework on VR's features impact on learning. I proposed that the facilitation of learning depends on the manifestation of appropriate physical, cognitive, emotional and social affordances. Based on the literature review, these affordances' manifestation in VR enhanced education depends on three factors; the VR system, learner characteristics and pedagogical arrangements. This framework remains open for critique and development, but could be of use in both the design, implementation and assessment of educational VR systems and their learning content.

I studied the changes that occurred in the student groups' typical pedagogical arrangements, what challenges the teachers faced when implementing the VR system, what made the VR program credible in the students eyes, how the students rated the usability of the applied VR system and what was the reasoning behind those assessments, and lastly how the students were affected emotionally, conceptually and motivationally by the virtual field trip project and the implementation of the studied VR system.

I urge future researchers to be more specific when attributing VR's shortcomings and affordances, not to the general technology, but to the applied VR system, how it was pedagogically implemented, and for what purpose.

Based on the current study, I concluded that the studied VR system could serve as a suitable stepping stone for individual students when they are getting to know the capabilities of VR technology. On the other hand, it appears that its implementation with an entire student group (approximately 20 students) can challenge the educator's organizing skills and might poorly fit the existing timetables, scripts and pace of some Finnish elementary schools. Smarter learning spaces and flexible timetables could be the key to improving the accessibility and implementation of VR technology in schools. As well as seeking new social and epistemic scripts to accommodate the use of VR technology in the learning environment.

The interviewed rural school's teacher proposed that an ideal space for this VR device would have been much bigger than their cabinet and that ideally a teacher would be able to see into this space from within their own classroom. If this space was separated from the classroom by a glass wall, for instance, then the teacher would be able to monitor the use of the VR devices and provide help when needed.

In my personal view, if we would design learning spaces with multiple VR devices for students, educators should still ensure that learning activities and experiences also retain vital human to human interaction outside of the VR environment. Even if it was seemingly achieved through avatars in virtual cooperative spaces. Some cooperative VR games and platforms that enable multiple users to engage in the same virtual space have already been developed. Their worth in education is yet undetermined but makes for an intriguing future research subject.

The research and design of educational VR content could benefit from more contemporary studies on pedagogical arrangements. For instance, the idea of constructivism has already been developed further. It now accounts for the positive effects that interacting with other beings and agents can have on an individual's all-around development. This socio-cultural approach calls for such pedagogical arrangements that ensure the students get an opportunity to create, build and share knowledge together and learn from one another (Hickey, 1997). It seems like a vital step closer to immersive learning philosophy and arrangements. And if it were to be accounted for when designing VR devices and programs, more educators might turn towards trying VR technology out with their students.

Even though many of the students in this study appeared to find the learning tasks performed with the applied VR system as personally fulfilling experiences, it remained unclear whether the enjoyment and engagement would carry over after multiple uses. Researchers should consider arranging longitudinal studies in the future and seek to conduct such design experiments that constitute of multiple iterations. If for example, a school would establish a learning laboratory space where they would have VR devices, it would be beneficial to longitudinally study how that space is utilized and for what purposes. Moreover, it would be compelling to investigate how such a space would affect the meta-practices and social climate of the school, and how valuable of a tool would it become in the long run for the students or whether interest towards its use withers over time. Furthermore, as researchers would gain more knowledge of VR technology's use and its users' needs, they might want to re-design the space accordingly for the next iteration of the experiment.

From the perspective of quantitative research, the relatively low number of participants in this study turned out to be problematic when I attempted to compare the students' self-efficacy beliefs and interest to engage with VR technology between several groups' means. Thus, from a quantitative research point of view, it would be better to go for larger sample sizes.

This current descriptive study suggested that the students found proper reasons to trust the *Google Earth VR* program. This could indicate that the program can be used for what Roussos and others (1999) insisted that VR technology should be used for in education; to challenge the learners existing misconceptions. On the other hand, many of the students found the projection reliable because it corresponded with their real-world experiences. This reason seems to speak more of dependability than about believability (see Tseng & Fogg, 1999 and Section 1.3). Thus, there is no way to predict if this general perceived dependability towards the *Google Earth VR* world projection translates into credibility in situations where existing mental models are challenged by new and conflicting information. Therefore, this matter requires further examination in the right context. It should be studied further in more specific setups where the *Google Earth VR* would, for example, be used to address some existing misconceptions.

Planetary geography could be a suitable context for this purpose. The relationship between the Earth and the Sun could very well turn out to be a prominent learning topic to be studied with the *Google Earth VR*. As based on the answers of the students on the pre-survey of this study, I observed that 21 students held misconceptions about what makes the time of day change, six gave incomplete answers and eight did not know at all. Furthermore, only six students had completely comprehended what causes seasons to change. On the other hand, it might turn out to be more beneficial to focus on studying VR technology as part of some more contemporary pedagogical philosophies and arrangements, such as immersive learning.

Based on the results of this study, one other prominent research subject in this field could be the study of the relationship between successful mental immersion, learning motivation and lasting learning outcomes. The current study showed that the studied VR system managed to evoke a sense of presence in some of the students. Furthermore, a clear majority of the students reported that they had enjoyed using the technology and seemed eager to get to use it more in their studies. This was anticipated, as immersed users' excitement and immediate enjoyment of the use of VR technology has been observed in many previous studies (see e.g. Bricken & Byrne, 1993; Roussos, et. al., 1999; Shim, et. al., 2003, p. 72-73). How all this relates to lasting learning outcomes remains to be determined in future studies.

Furthermore, it could be worthwhile to study further how mental immersion affects the trustworthiness of an information source. As it turns out, in addition to the immersive *Google Earth VR* -program, there exists a non-immersive version of the *Google Earth* -program for desktop PC. A study setup comparing the trustworthiness and learning outcomes of these two learning tools is entirely plausible. I hypothesize that since the successful mental immersion of the *Google Earth VR* -program appears to have affected some of the students' reasoning, namely the experienced credibility, the non-immersive version of the same program might have less credibility attributed to the experience factor, but more so on the presumed and reputed factors.

Along the same lines, more research effort should be put into discovering how the different types of credibility beliefs are related to the perceived possibilities of action and learning within a VR environment. Furthermore, the credibility of the *Google Earth VR* program seemed to stem mostly from its correspondence to the real world. Thus, it would seem beneficial to study how the students would react to a completely artificial and imagined educational world.

I believe that comprehending what the trade-offs are between learning in an imaginary world versus in a realistic virtual world, could help the designers of educational VR environments to make choices in what kind of content to create. It could also inform educators when they make choices on what content to purchase and implement in the learning environment. All in all, more reliable and well-rounded means to measure a VR environment's overall perceived quality should be developed.

When VR developers design learning related software, they might want to mimic some of the *Google Earth VR* program's functions. Based on this study, it was evident that the students found the studied VR system as very comfortable and user-friendly. Moreover, they praised the program's tutorial and the simplicity of the controls.

Educators should bear in mind that proper pedagogical arrangements are a key factor in producing beneficial affordances for learning (see Figure 9). The present investigation opened many new and vital questions regarding the implementation of the VR technology in education. For example; what solutions enable us to include students in the planning and implementation of educational VR technology? And what type of pedagogical arrangements best support learning with VR enhanced experiences?

This current study revealed that including role-playing elements to the learning activities and enhancing them with the realism of VR can go a long way in exciting and engaging students. After receiving mastery experiences with this VR system, the students seemed eager to use VR technology again in the future. More studies should purposefully design VR enhanced learning activities based on constructivist, socio-cultural or even more contemporary pedagogical approaches that aim at “collective learning with understanding”, where students are included in the design of their own learning process (see Scardamalia, 2002).

Furthermore, future researchers could cooperate with neuroscientists to determine how continuous learning in an immersive environment affects children’s brains, minds, and capabilities. As Savin-Baden (2015, p. 4) has excellently stated: “It seems important to understand how students live and learn across the many digital media available to them, what is new, changed or changing about how they live and learn today, and what evidence there is for these shifts.”

This design experiment could have benefitted from the measurement of effect size. It could have been achieved by having measured the students’ self-efficacy beliefs and interest to engage with VR technology already in the pre-survey, and then having compared those means with the post-survey means. This could have given us valuable insight on the effectiveness of each virtual field trip project experiment. For all I know, the students’ assessments might have been as high or even higher before the project even began. Measuring effect size is something that is important to consider when designing relevant VR technology related design experiments in the actual school environment (see Sullivan, & Feinn, 2012). Effect size could be used as the main indicator of how successful an implementation of VR technology is, in future studies and design experiments.

Conclusion

Due to the clinical nature of previous studies in this field, educators and designers of educational VR content did not have a clear understanding of how students respond to VR technology in their actual learning environments. With the help of the current study’s insights, it has become apparent that students feel at ease with VR and would gladly welcome it to their learning environment. Despite of this, the orchestration of its implementation turned out to be unnecessarily challenging for the educators. The teachers unanimously agreed that the applied technology is not up to par, i.e. it is not simple and straightforward enough. It appeared to fit poorly to pre-existing scripts and school dimensions. It could be that the use of VR technology demands pedagogical arrangements with unconventional scripts. Therefore, research on best practices and adaptable learning environments become vital in the advancement of VR enhanced pedagogy. Furthermore, the relationship between learning and VR's features have proven to be more multidimensional than previously hypothesized (see Figure 9).

The current study showed that attempting an identical project in separate schools, with different student groups and teachers, lead to variation in the projects' arrangements and execution. Then again, pedagogically it made sense to consider the students' unique needs and wishes regarding the learning project. In fact, many of the students reported having enjoyed the project partly because the VR system and their learning assignments supported their autonomy by handing them control over the events in the VR environment.

Even though it seemed that the VR system was not used up to its full potential, the students appeared to form a more comprehensive idea of its possible uses. Having an idea of what an educational tool can be used for, seems like a vital first step to its autonomous implementation for meaningful immersive learning purposes. I believe, that the students of this study are now more capable, and willing, to apply the VR system as they see fit.

The technology itself has certainly taken a big leap forward from the raw and uncomfortable systems of the 1990's. As this study revealed, contemporary VR technology has, for the most part, addressed the issues that students related to it in Bricken and Byrne's study (1993). The resolution received praise, the combination of hardware and software was comfortable and easy to use, and the students' felt that they were in sync with and in control of the VR environment. In fact, for most of the students, the use of VR technology seemed like a desirable activity.

But, as this study established, the implementation of VR technology in actual school settings did not come without some setbacks. For instance, it took a lot of organizing from the teachers to ensure that each student got to operate the VR system. Furthermore, four students reported that they had experienced symptoms of simulator sickness. Overall, it appears that there is still room for development in the adaptiveness of school environments and schedules, and in the affordability and mass-use design of VR devices and content. Furthermore, the suitability and fluency of the technology and its content with different pedagogical arrangements, varying from very scripted to freer collaborative arrangements, such as progressive inquiry and immersive learning, should be assessed in future studies in a more systematical way.

What impressed me the most in the current study, was the students' tremendous capability to imagine virtual worlds for learning purposes. Amongst other things, they expressed interest towards learning how other beings live, feel, act and think. Amongst the students, there appears to be demand for learning to understand the position of others even beyond physical barriers, long distances, confines of our reality, or boundaries of time. With the help of VR technology, we could create appropriate educational content that aims to educate on empathy and compassion skills beyond the above-mentioned boundaries.

Evidently, the capabilities to create content to match most of the students' imagined learning worlds already exists. And although these types of educational virtual worlds are not yet currently available, the students could get inspired to create them themselves in the future or even now if they were provided with the means to do so. Then, perhaps we should consider designing and creating such educational VR programs that assist non-experts in creating their own content and 3D virtual worlds. And by doing so we can hopefully allow them to reach the heights of their imagination, and virtually travel even beyond the boundaries of time and space.

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Appendices

Appendix A. The students' pre-survey in English.

Basics

First name

Surname

Age (in numbers)

School

Locality

Gender ◯ Male ◯ Female

	5th	6th
Grade	◯	◯

Use of technology

1. What technological devices do you have access to? (1= I don't have access to the device 2= I share access with other family members 3= The device is primarily in my use)

	1 No access to the device	2 Share access to the device	3 The device is primarily in my use
a) Desktop PC	◯	◯	◯
b) Laptop	◯	◯	◯
c) Tablet (e.g. iPad, Galaxy T, etc.)	◯	◯	◯
d) Programming and robotics equipment (e.g. Lego EV3, Vex, Micro:bit, etc.)	◯	◯	◯
e) Regular cellphone	◯	◯	◯
f) Smart phone (= has a touchscreen interface, Internet access, and can run downloaded apps.)	◯	◯	◯
g) Handheld gaming console (e.g. PSP, Nintendo 3DS, etc.)	◯	◯	◯
h) Stationary gaming console (e.g. Xbox, Nintendo, PlayStation, etc.)	◯	◯	◯
i) Virtual Reality device (e.g. Oculus Rift, PS4 VR, HTC Vive, etc.)	◯	◯	◯
j) Virtual Reality head mounted display (e.g. Samsung Gear VR, etc.)	◯	◯	◯

2. How often do you use technology for following activities?

	Never	A few times a year	Monthly	Weekly	Daily	Many times a day
a) for studying at home	◯	◯	◯	◯	◯	◯
b) for studying at school	◯	◯	◯	◯	◯	◯
c) for social media (e.g. WhatsApp, Facebook, Instagram, etc.)	◯	◯	◯	◯	◯	◯
d) for entertainment (e.g. gaming, videos, etc.)	◯	◯	◯	◯	◯	◯
e) for programming	◯	◯	◯	◯	◯	◯

Do you use technology for other purposes? For what and how often?

3. Tell us about your thoughts towards the use of technology. (1= Strongly disagree, 2= Somewhat disagree, 3= Don't disagree or agree, 4= Somewhat agree, 5 Strongly agree) ?

	1 Strongly disagree	2 Somewhat disagree	3 Don't disagree or agree	4 Somewhat agree	5 Strongly agree	I don't know
a) I am good at using technology.	◯	◯	◯	◯	◯	◯
b) I am afraid of making mistakes on technological devices that I am unable to fix.	◯	◯	◯	◯	◯	◯
c) Using technology makes me feel insecure.	◯	◯	◯	◯	◯	◯
d) I avoid using technology as much as possible.	◯	◯	◯	◯	◯	◯
e) I enjoy using technology.	◯	◯	◯	◯	◯	◯
f) I am willing to try hard in order to learn anything about technology.	◯	◯	◯	◯	◯	◯
g) I have confidence in my abilities to learn to use technological devices.	◯	◯	◯	◯	◯	◯

4. Tell us about your thoughts towards the use of technology for learning. (1= Strongly disagree, 2= Somewhat disagree, 3= Don't disagree or agree, 4= Somewhat agree, 5 Strongly agree)

	1 Strongly disagree	2 Somewhat disagree	3 Don't disagree or agree	4 Somewhat agree	5 Strongly agree	I don't know
a) I would like to use technological devices more when working at school.	◯	◯	◯	◯	◯	◯
b) I am more excited working at school when I get to use technological devices.	◯	◯	◯	◯	◯	◯
c) I am willing to try harder at school when I get to use technological devices.	◯	◯	◯	◯	◯	◯

Virtual reality

5. Describe by using five (5) words what comes to your mind when hearing the words "Virtual Reality"? ?

6. I have used virtual reality devices or headsets:

	Never	A few times in the past year	Monthly	Weekly	Daily	Several hours each day	If you have, tell us what for?
a) At home							
b) At a friends house							
c) At school							
d) At a hobby							
e) At a library							
f) At a public event							

Have you used virtual reality devices or headsets elsewhere? Tell us where, how often and for what purpose?

7. Are you familiar with Google Earth VR software?

	No	Yes	If you have, tell us more about where, how often and for what have you used it?
I have used Google Earth VR application on a virtual reality device.			
I have used Google Earth application an some other device (e.g. Desktop PC, smart phone, etc.).			

Have you used virtual reality devices or headsets elsewhere? Tell us where, how often and for what purpose?

7. Are you familiar with Google Earth VR software?

	No	Yes	If you have, tell us more about where, how often and for what have you used it?
I have used Google Earth VR application on a virtual reality device.			
I have used Google Earth application an some other device (e.g. Desktop PC, smart phone, etc.).			

Environmental studies

8. Describe your typical lesson of Environmental Studies. ?

9. I have used:

	Never	A few times in the past year	Monthly	Weekly	Daily	Several hours each day	Additional information?
a) Virtual maps (e.g. Google Maps, Reittiopas.fi, Mapcrunch.com, etc.)							
b) Atlas (= a book of maps and charts)							
c) Paper maps (e.g. for orienteering)							
d) Social media applications map features (e.g. Snapchats friend map)							
e) Pokémon Go							

Have you used maps elsewhere? For what and how often?

10. Tell us your thoughts towards using maps. (1= Strongly disagree, 2= Somewhat disagree, 3= Don't disagree or agree, 4= Somewhat agree, 5 Strongly agree) ?

	1 Strongly disagree	2 Somewhat disagree	3 Dont' disagree or agree	4 Somewhat agree	5 Strongly agree	I don't know
a) I can recognise Finland from a world map projection with no labels (e.g. names of countries and state lines).						
b) I can recognise [THE CONTINENT] from a world map projection with no labels (e.g. names of countries and state lines).						
c) I can locate Finland from any type of world map projecting application using technology?						
d) I can locate [THE CONTINENT] from any type of world map projecting application using technology?						

11. Describe by using five (5) words what comes to your mind when hearing the word “[THE CONTINENT]”? ?

12. Tell us in your own words what causes seasons to change?

13. Tell us in your own words what causes the change between night and day?

Appendix B. The teachers' pre-survey in Finnish.

PERUSTIEDOT

* 1. Missä koulussa opetat parhaillaan?

* 2. Kuinka monta vuotta olet toiminut opettajana?

* 3. Millä luokka-asteilla olet toiminut opettajana?

TAUSTAKARTOITUS

* 4. Kuvaile lyhyesti omaa kasvatusfilosofiaasi? ?

* 5. Mitä pidät tärkeänä ympäristöopin opetuksessa ja miksi?

* 6. Kuvaile millainen on 5. luokkalaisten oppilaidesi tyypillinen ympäristöopin oppitunti? ?

6B. Onko 6. luokkalaisillasi erilaisia tottumuksia? Millaisia? ?

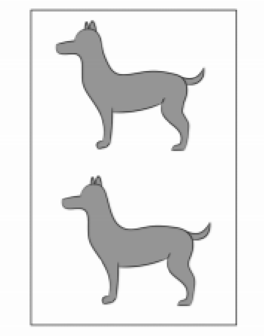
* 7. Kuvaile mitä kuuluu 5. luokkalaisten oppilaidesi tyypilliseen ympäristöopin opintojaksoon? ?

7B. Onko 6. luokkalaisillasi erilaisia tottumuksia? Millaisia? ?

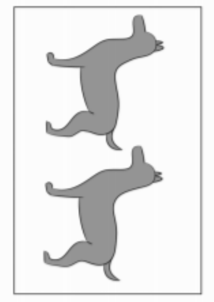
* 8. Millaisia odotuksia sinulla on oppilaiden virtuaaliluokkaretki-projektin suhteen? ?

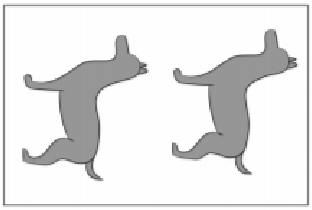
Appendix C. Example questions from the spatial reasoning instrument (Ramful, Lowrie and Logan, 2016) converted to an online form.

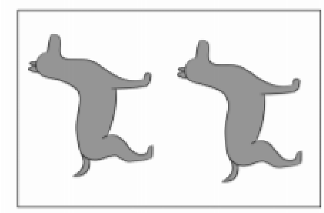
1. Below is a picture of two dogs.

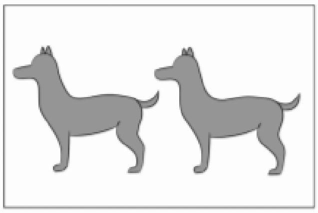


Which of the following shows the picture after a 90 degree turn to the right?

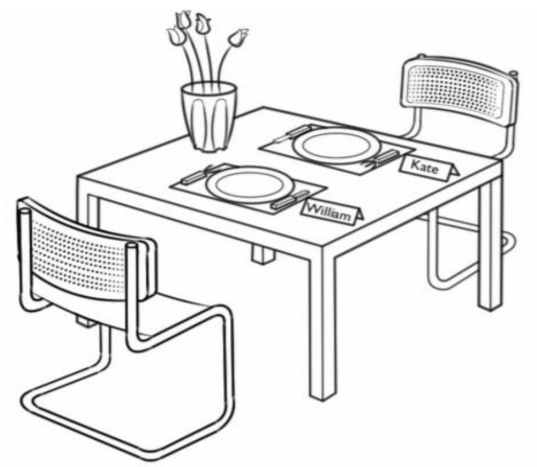
a. 

b. 

c. 

d. 

2. Kate and William's seating positions are as shown below.

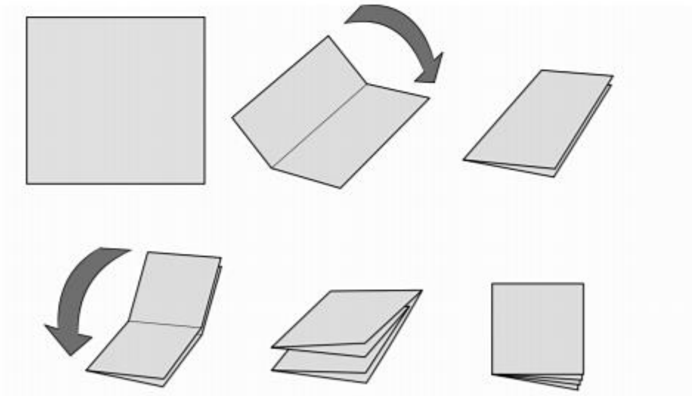


In which position is the flower vase from Kate's view?

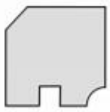
a. **To her right.** b. **To her left.**

3.

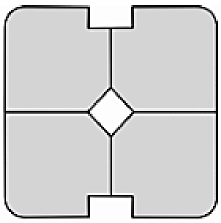
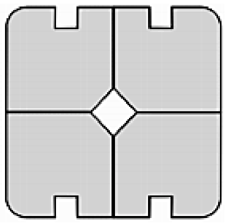
Jane makes a pattern by first folding a square paper into 4 parts as shown below.

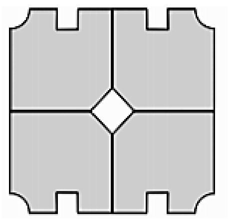
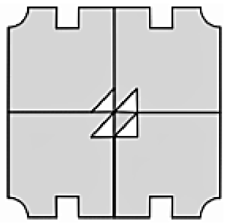


Jane then cuts the folded piece of paper into the shape shown below.



Which one of the following represents the pattern obtained by unfolding the paper?

a.  b. 

c.  d. 

Appendix D. Forms to help student pairs access their prior knowledge, set goals for the project and assess their expectancies. In Finnish and in English.

Koulu ja luokka:
Maanosa:
Alue:

Etunimi:
Sukunimi:

Etunimi:
Sukunimi:

1. Millaisia ajatuksia tutkimuskohteena oleva alue teissä herättää?

2. Mitä tiedätte entuudestaan kyseisestä alueesta?

3. Mitä haluaisitte oppia kyseisestä alueesta?
Vinkki: Millaisia kysymyksiä alue teissä herättää?

4. Millaisia tavoitteita teillä on Google Earth VR käytölle?

Opettajan antama tavoite Google Earth VR käytölle:

"Tehtävänänne on löytää sellainen kohde alueeltanne, jonne haluaisitte viedä ryhmänne virtuaaliluokkaretkelle ja kirjata sen tarkka sijainti ylös, jotta osaatte löytää sinne uudelleen!"

Vinkki:
Kohteen (360-näkymä) valinnassa apunanne toimivat asettamanne kysymykset.

5. Arvioi:
Odotan innolla oppimista HTC Vive VR laitteita käyttämällä.
1-5?:_________
Odotan innolla, että pääsen vierailemaan tutkittavalla alueella Google Earth VR ohjelman avulla.
1-5?:_________

5. Arvioi:
Odotan innolla oppimista HTC Vive VR laitteita käyttämällä.
1-5?:_________
Odotan innolla, että pääsen vierailemaan tutkittavalla alueella Google Earth VR ohjelman avulla.
1-5?:_________

Täysin eri mieltä **1** - Eri mieltä **2** - Ei eri eikä samaa mieltä **3** - Samaa mieltä **4** - Täysin samaa mieltä **5**

School and grade:
Continent:
Area:

First name:
Surname:

First name:
Surname:

1. What comes to Your mind when thinking about the area which You are about to investigate?

2. What do You already know about the area You are about to investigate?

3. What would You like to learn about the area? *Tip: Think of questions about the area You want to find answers to!*

4. What goals do You have for the Google Earth VR activity:

Teacher assigned task for Google Earth VR activity:

"Your goal is to locate a place where You'd want to take the rest of your group on a virtual field trip. Mark its location down so that You can find Your way back there again later on."

Tip:
The questions You have set above should help You in choosing a scene (360 view).

5. Estimate:
I look forward to learning by using the HTC Vive Virtual Reality device.
1-5?:_________
I get excited about going to visit our area with Google Earth Virtual Reality program?

1-5?:_________

5. Estimate:
I look forward to learning by using the HTC Vive Virtual Reality device.
1-5?:_________
I get excited about going to visit our area with Google Earth Virtual Reality program?

1-5?:_________

Strongly disagree **1** - Disagree **2** - Neither agree nor disagree **3** - Agree **4** - Strongly agree **5**

Appendix E. The e-log online questionnaire in English.

1 Please fill in the following basic information

◯ School ____

◯ First name ____

◯ Surname ____

2 How many times have you now used Google Earth VR during the project?

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9+

1. How comfortable was it to use the HTC Vive device?

1
2
3
4
5

1A. What made the device uncomfortable to use?

____

1B. What did you enjoy the most about the device?

____

2. How easy was it to use Google Earth VR program?

1
2
3
4
5

2A. What difficulties did you encounter when using the program?

____

2B. What made the program easy to use?

____

3. I believe that the Google Earth VR projection of our world was accurate.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

4. I trust that the information presented about our world in Google Earth VR is up-to-date.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

4A. What made the Google Earth VR world projection unreliable?

____

4B. What made the Google Earth VR world projection reliable?

____

4C. What is the most reliable use for the Google Earth VR program?

____

5. I enjoyed using the HTC Vive device.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

6. I got bored using the HTC Vive device.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly Agree

7. I enjoyed learning with the Google Earth VR.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

8. Learning with the Google Earth VR bored me.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

9. What did you **like** about this activity of finding a suitable location for a virtual field trip with the Google Earth VR?

____

____

10. What did you **dislike** about this activity of finding a suitable location for a virtual field trip with the Google Earth VR?

____

____

Appendix F. The students' post-survey open-ended questions for 5th graders.

English ▼

1. Please fill out the following information.

First name

Surname

Age (in numbers)

School

Gender

Male

Female

English ▼

Imagine you are having a conversation with a person (e.g. your grandparent) who doesn't know more about your virtual field trip project. Additionally, they have never heard anything about virtual reality. Tell them about your thoughts, experiences and what you have done by answering their questions.

"I heard you participated in a project in environmental studies, would you be so kind and tell me more about it?"

"Virtual reality? What does it mean?"

"What did the project teach you about Europe?"

"How did virtual reality effect your learning?"

"If you could go into any virtual world that you can imagine and learn about anything at all, what would it be? And what would that world be like?"

Appendix G. The original ICT self-efficacy statements and modified self-efficacy and interest to engage statements for VR technology.

	Finnish	English
Instruction	Kerro teknologian käytöstäsi (mobiililaitteet, tietokoneet, pelikonsoli).	Think about your ICT related activities in general.
Items & subscales	1. Minusta on hauskaa oppia tietoteknologiaa, koska se tarjoaa jatkuvasti uusia haasteita. 2. Olen valmis näkemään paljon vaivaa oppiakseni jonkin tietoteknologiaan liittyvän asian. 3. Ratkaisen mielelläni haasteellisia tietoteknologiaan liittyviä ongelmia. 4. Luotan omiin kykyihini oppia tietoteknologiaan liittyviä asioita. 5. Haluaisin käyttää tietoteknologiaa enemmän **koulutyössäni**. 6. Olen **koulutyöstäni** innostuneempi silloin, kun saan käyttää tietoteknologiaa. 7. **Opiskelen** kouluasioita paljon ahkerammin, kun saan käyttää tietoteknologiaa.	1. It's fun to learn ICT use, because it offers continuously new challenges. 2. I'm ready to work a lot to learn new ICT related skill. 3. I enjoy solving challenging ICT related problems. 4. I trust my own skills to learn ICT. 5. I would like to use more ICT in my **school work**. 6. I am more excited about my **school work** when I can use ICT. 7. **I study** much harder when I can use ICT.

1. Kerro ajatuksistasi virtuaalitodellisuusteknologian käyttöä kohtaan.

	1 Täysin eri mieltä	2 Jokseenkin eri mieltä	3 En eri enkä samaa mieltä	4 Jokseenkin samaa mieltä	5 Täysin samaa mieltä
Olen mielestäni hyvä käyttämään virtuaalitodellisuusteknologiaa.	○	○	○	○	○
Pelkään tekeväni virtuaalitodellisuusteknologialla virheitä, joita en osaa korjata.	○	○	○	○	○
Virtuaalitodellisuusteknologian käyttö saa minut tuntemaan oloni epävarmaksi.	○	○	○	○	○
Aion välttää virtuaalitodellisuusteknologian käyttöä niin paljon kuin mahdollista.	○	○	○	○	○
Pidän virtuaalitodellisuusteknologian käytöstä.	○	○	○	○	○
Olen valmis näkemään paljon vaivaa oppiaakseni jonkin virtuaalitodellisuusteknologiaan liittyvän asian.	○	○	○	○	○
Luotan omiin kykyihini oppia käyttämään virtuaalitodellisuuslaitteita.	○	○	○	○	○

2. Kerro ajatuksistasi virtuaalitodellisuuslaitteiden käytöstä opiskelussa.

	1 Täysin eri mieltä	2 Jokseenkin eri mieltä	3 En eri enkä samaa mieltä	4 Jokseenkin samaa mieltä	5 Täysin samaa mieltä
Haluaisin käyttää virtuaalitodellisuuslaitteita lisää työskennellessäni koulussa.	○	○	○	○	○
Olen innostuneempi koulun käynnistä kun saan käyttää virtuaalitodellisuuslaitteita.	○	○	○	○	○
Olen valmis yrittämään enemmän koulussa kun saan käyttää virtuaalitodellisuuslaitteita.	○	○	○	○	○

1. Tell us about your thoughts towards the use of virtual reality technology.

	1 Strongly disagree	2 Somewhat disagree	3 Neither agree or disagree	4 Somewhat agree	5 Strongly agree
I am good at using virtual reality technology.	○	○	○	○	○
I am afraid of making mistakes on virtual reality devices that I am unable to fix.	○	○	○	○	○
Using virtual reality technology makes me feel insecure.	○	○	○	○	○
I plan to avoid using virtual reality technology as much as possible.	○	○	○	○	○
I enjoy using virtual reality technology.	○	○	○	○	○
I am willing to try hard in order to learn something about virtual reality technology.	○	○	○	○	○
I have confidence in my abilities to learn to use virtual reality devices.	○	○	○	○	○

2. Tell us about your thoughts towards the use of virtual reality devices for studying.

	1 Strongly disagree	2 Somewhat disagree	3 Neither agree or disagree	4 Somewhat agree	2 Strongly agree
I would like to use virtual reality devices more when working at school.	○	○	○	○	○
I am more excited working at school when I get to use virtual reality devices.	○	○	○	○	○
I am willing to try harder at school when I get to use virtual reality devices.	○	○	○	○	○

Appendix H. A screenshot that displays the structure of the shared document for the chat-like interview.

JL:

Interviewee:

<u>About the method</u>

JL:

I:

<u>Instructions</u>

JL:

I:

<u>The interview</u>

JL:

I:

JL:

I:

JL:

I:

JL:

I:

JL:

I:

Appendix I. An overview of the data acquisition phases and methods.

Phase 1			Phase 2		Phase 3	
Students' pre-surveys	Teachers' pre-surveys	SRI	E-log an online questionnaire	Teachers as observers	Students' post-survey	Teachers' online interviews
Access and usage rate of digital technologies	Basic information Educational philosophy	Students' spatial reasoning abilities:	The usability of the VR system: Comfortability of the device	Teachers observed:	Role play with open-ended questions and self-assessment of:	An innovative Google Drive interview:
Digital technology self-efficacy beliefs and interest	Important in environmental studies	Mental rotation	1-5 scale and open-ended questions User friendliness of the program	The successes and challenges of the implementation process		Overall impression of the project
Preconception and prior use of virtual reality	Typical environmental studies lessons of the 5th and 6th graders	Spatial orientation	1-5 scale and open-ended questions Credibility of the Google Earth VR:		Field trip project	Implementation of the VR system and the course of the project
Familiarity with the Google Earth VR and basic programs		Spatial visualization	Likert-5 statements and open-ended follow-up questions	The students' reactions to the VR system	Concept of VR	
Typical environmental studies lessons	Typical environmental studies periods of the 5th and 6th graders		Emotional response to the use of the VR system:		Learning outcomes and affects of VR	Changes in spatial, temporal and social dimensions
Prior use of maps and confidence in map reading skills	Expectations for the virtual field trip project		Enjoyment and boredom related Likert-5 statements and open-ended questions regarding the learning activity		Fantasy educational VR world	General observations
Preconceptions of the project's continent					Self-efficacy beliefs and interest in engaging with VR enhanced learning activities: Likert-5 statements	An assessment of the challenges and possibilities of the current VR system and VR technology in general
Prior knowledge of planetary phenomenon						

Appendix J. The basic form that was sent to the students' parents, informing them of the upcoming study and asking for their consent.

VR-TOIMINTA JA TUTKIMUS OSANA VISIOT-HANKETTA

Hyvä huoltaja,

Ryhmä A osallistuu Innokas-verkoston VISIOT-hankkeeseen, jossa kehitetään ja tutkitaan virtuaalitodellisuuden käyttöä oppimisen ja opettamisen tukena. Hanketta rahoittaa Opetushallitus ja se on osa hallituksen Uusi peruskoulu-ohjelmaa. Hankkeeseen osallistuu Innokas-verkoston kouluja eri puolilta Suomea.

Hankkeen aikana kehitetään muun muassa Vive- ja muiden silmikkonäyttöjen käyttöä opetuksessa. Allekirjoittamalla tämän asiakirjan voitte ilmaista suostumuksenne lapsenne osallistumisesta 1) virtuaalilasien käyttöön ja 2) lasten virtuaalilasien käyttöön liittyviä kokemuksia kartoittavaan tutkimukseen. Tutkimus toteutetaan kyselynä, johon oppilaat vastaavat virtuaalilasien käytön jälkeen. Osallistuminen tutkimukseen on luottamuksellista, eikä henkilötietoja käytetä tutkimusraportissa. Aineistoa käytetään vain tutkimustarkoituksiin.

Ystävällisin terveisin,

Tiina Korhonen ja Laura Salo,
tiina.korhonen@helsinki.fi ja laura.salo@helsinki.fi

Palauta alla oleva lomake opettajalle xxyy mennessä

1. Annan suostumukseni lapseni osallistumisesta VR (Vive ja muut silmikkonäytöt)- toimintaan:

Kyllä________ Ei_________

2. Annan suostumukseni lapseni osallistumisesta VR-käyttöön liittyvään tutkimukseen:

Kyllä________ Ei__________

Paikka ja aika ___________________________________

Oppilaan nimi ___________________________________

____
Vanhemman allekirjoitus

____
Nimen selvennys

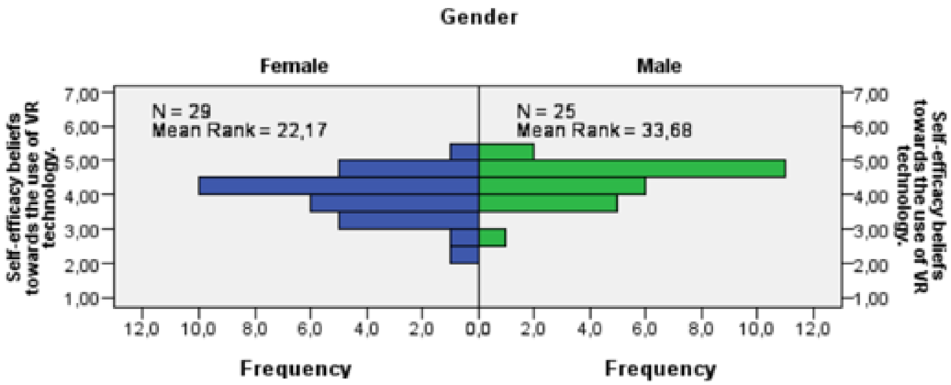
Appendix K. Mann Whitney U-test on IBM SPSS Statistics software revealed a significant difference between the two genders self-efficacy beliefs.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Self-efficacy beliefs towards the use of VR technology. is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	7,000	Reject the null hypothesis.
2	The distribution of Interest towards continuing to use VR technology for studying. is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	271,000	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Independent-Samples Mann-Whitney U Test



Total N	54
Mann-Whitney U	517,000
Wilcoxon W	842,000
Test Statistic	517,000

Standard Error	57,471
Standardized Test Statistic	2,688
Asymptotic Sig. (2-sided test)	,007

Appendix L. Comparison of the student groups' means with the Kruskal-Wallis test in IBM SPSS Statistics software yielded no statistically significant results.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Self-efficacy beliefs towards the use of VR technology. is the same across categories of Grade.	Independent-Samples Kruskal-Wallis Test	909.000	Retain the null hypothesis.
2	The distribution of Interest towards continuing to use VR technology for studying. is the same across categories of Grade.	Independent-Samples Kruskal-Wallis Test	153.000	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Appendix M. Mann Whitney U-test on IBM SPSS Statistics software revealed a significant difference between the user-friendliness assessments of the rural 5th graders and the urban 5th graders.

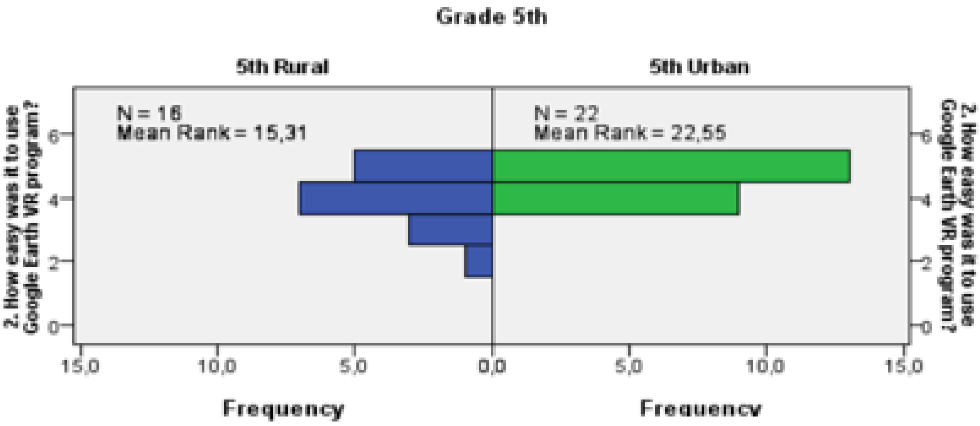
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of 2. How easy was it to use Google Earth VR program? is the same across categories of Grade 5th.	Independent-Samples Mann-Whitney U Test	48,000[1]	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

Independent-Samples Mann-Whitney U Test



Total N	38
Mann-Whitney U	109,000
Wilcoxon W	245,000
Test Statistic	109,000

Standard Error	30,612
Standardized Test Statistic	-2,189
Asymptotic Sig. (2-sided test)	,029
Exact Sig. (2-sided test)	,048