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Abstract

Virtual Reality in Lower Secondary Education

By

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Master of Arts in Educational Technology

This study examined whether applying Virtual Reality (VR) technologies in instruction can increase meaningful learning and intrinsic motivation among middle school students. This research investigated VR in education with a multidisciplinary focus, but the topic of the lesson used in this project primarily targeted the education content standards in the content area of science. This study hypothesized that students will experience a higher sense of meaningful learning and intrinsic motivation when using interactive and immersive Virtual Reality for learning compared to the traditional classroom situation. The study included eleven (N=11) middle school students who participated in one control lesson and one experimental lesson. An Intrinsic Motivation Inventory (IMI) survey was used to measure intrinsic motivation and
supplemented with a conceptual interview. Results showed that students were more intrinsically motivated to participate in the learning activity when they used immersive VR in the lesson.

*Keywords:* Virtual Reality, middle school, intrinsic motivation, meaningful learning, immersion, education, educational technology
Introduction

About a hundred years ago, Dewey (1916) wrote: “an ounce of experience is better than a ton of theory simply because it is only in experience that any theory has vital and verifiable significance” (p.169). Our world has changed since then, but these words still hold value. The relationship between teaching and learning is a balance of theory bound to practice. There is much theory in school, but relevant practice is not always accessible for middle school students. Experience-based education is more common in higher education, through for example internships, cooperative education, studio arts, laboratory study, or field projects, but practice and experience in middle school often require extra resources such as instruments, transportation, or adult supervision (Kolb, 2014). I believe VR can provide younger learners with experiences in immersive and interactive virtual environments that they never before could access - from their own classrooms. Experiences in VR environments can support a learner’s mastery of knowledge and create a more meaningful learning situation where students can interact with and manipulate objects, which again can lead to more interest and motivation to learn.

The promise of twenty-first-century education is that digital technologies will transform traditional learning (van Laar, 2017). We have for the past few decades witnessed rapid development and integration of digital technologies for communication, collaborative knowledge construction, reading, and multimedia learning in the education system (Silber-Varod et al., 2019). Information and Communications Technologies (ICT) such as computers, Chromebooks, tablets, internet, and software programs have been embraced as a trusted pedagogical learning tool in most developed countries’ classrooms. However, large amounts of resources and capital
have been invested in educational technology that might not be as efficient as hoped for (Bulman & Fairlie, 2016; U.S. Department of Education, 2017). The SAMR model is a tool that can be used to evaluate the degree of technology integration and its transformative power in the K-12 classroom (Hamilton et al., 2016).

**Illustration 1**

*The Substitution, Augmentation, Modification, Redefinition (SAMR) model.*

![Image retrieved from: Schrock, 2020.](Image retrieved from: Schrock, 2020.)

Research has shown that the current use of ICTs most often are used in the enhancement level with substitution and augmentation (Barzilai et al., 2015; Juniu, 2006; OECD, 2015; Silber-Varod et al., 2019). It is for example most commonly used to read digital books instead of
regular books, search for information, or teachers use it to present information through direct class instruction (International Association for the Evaluation of Educational Achievement, 2019). VR has the potential to transform a lesson and bring new instructional methods to the classroom through immersion, interaction, and user involvement in virtual simulations of concrete or abstract objects and situations. It can redesign educational practices and create new ways for schools to educate their students in an autonomy-supportive way. Students can learn by doing in a virtual world and experience environments they never before could access in school. Research studies have indicated there are positive benefits for students from using immersive VR technology compared to conventional education methods (Freina & Ott, 2015; James et al., 2002; Jang, et al., 2017; Jensen & Konradsen, 2018; Makransky et al., 2019; Meijer & den Broek, 2010; Nicholson et al., 2006; Slater & Sanchez-Vives, 2016; Uskov et al., 2020). However, these are studies from higher education and more research is still needed for how effective VR can be if used in middle school.

**Virtual Reality**

The concept of 3D images has been around since 1838, and the concept of head-mounted display VR (HMD, used in this study) was invented in the 1960s. The first commercial VR tools appeared in the late 1980s, but the technology has not been widely accessible to the general public until recent years. Since 2015, when companies like Samsung, Oculus, Facebook, Google, and Microsoft took a great interest in it, VR technology has developed significantly and become affordable and easy to use (Barnard, 2019; Cipresso et al., 2018; Heim, 2017). For example, an Oculus Quest, the headset used in this research project, costs $299 (Oculus Quest: All-in-one Vr Headset, n.d.). Apple has supposedly been working on VR and AR technologies for years and is
rumored to have over a thousand engineers working on a headset with resolution so high that the user will have trouble differentiating the virtual world from the real world (Gurman, 2020). Facebook, owner of Oculus, believes strongly in the future of VR and AR and has about ten thousand employees working on VR and AR products (Heath & Olson, 2021; Zibreg, 2021). Although leisure and entertainment are the biggest sector of interest for VR developers right now, educational institutions will also benefit from better access to virtual technologies (Martín-Gutiérrez et al., 2017). A recent study among university students, for example, saw that the participants who learned in HMD VR reported higher levels of enjoyment, intrinsic motivation, higher levels of self-efficacy, and better transfer of the learned material (Makransky et al., 2019).

Today, VR has progressed to be a useful tool in many industries, such as aerospace, entertainment, real estate, and neuroscience (Ferrari et al., 2018; Mania, et al., 2010; Minderer & Harvey, 2016). In education for medical caregivers and the field of medicine, VR is considered a cost-effective and efficient tool that has been used in medical education since the 1990s, both as a tool for patient treatment and doctor training (Li et al., 2017; Satava & Jones, 1998). VR has been used as an alternative to drugs in helping patients control and reduce pain, anxiety, and to improve balance and mobility rehabilitation (Gold et al., 2006; Hoffman et al., 2011; Levin et al., 2012; Levin et al., 2015; Schneider & Hood, 2007; Wright et al., 2005). It is also successfully used in many aspects of surgery training and to show medical students the patient experience from a patient perspective (Gugliucci, 2018; Li et al., 2017).

VR was introduced to K-12 and higher education in the 1990s, but had little success due to practical and economical limitations and concerns. Instead, desktop-based PCs became the
leading technology in education (Merchant et al., 2014; Nicholson et al., 2006). There has been a lot of research on VR in education, but the larger body of research has taken place in higher education. Combined with more appropriate content and affordability, VR technology has now been placed on the agenda for K-12 educational technology again (Dahl et al., 2020).

With the recent innovation of a modern, cheaper, and more sophisticated setup, HMD VR shows educational potential among younger students as it can motivate and engage the user (Queiroz et al., 2018). VR technology differs from other digital technology in that it has a stronger sense of sensory immersion (Heim, 2017). It allows students to experience and interact with virtual environments of concrete and abstract concepts they never could access before. It can give students educational experiences that cannot be replicated in a textbook or on a desktop computer. The interactive and immersive technology can increase students' perception of meaningful education and intrinsic motivation by cognitive means of mental associations and facilitate a more comprehensive understanding of the learning content (Freina & Ott, 2015). A multisensory immersion can leave a more significant impression with the learner, making the content more interesting and accessible for transfer into new learning situations (Kátai et al., 2008; Makransky et al., 2019).

The immersive and interactive features of VR seems well suited to make learning exciting, interactive, and memorable. It aligns with educational learning theories such as constructivism and situated learning theory which positions that learning is individually constructed in a reciprocal interaction with the environment (Jensen & Konradsen, 2018; Schott & Marshall, 2018). More research is, however, still needed for the use of VR in education among middle school students (Jensen & Konradsen, 2018; Queiroz et al., 2018).
Motivation

I have met many students who lacked the motivation to perform well in traditional education. Many of them seemed to dismiss the school’s interests, values, or goals. Some clearly expressed their dissatisfaction with school, and some liked going to school for other reasons than academics and content learning, such as meeting their friends and peers. Among some of these students, I recognized how their low interest in school often originated in a lack of a meaningful connection between the student and the learning content. The students did not see why the skills they were supposed to learn in school was relevant to them. According to Gee (2004), much of today’s processes in schools involve instruction and practicing of skills outside any contexts in which they are used, but people learn best when they can tie the words and structures to experiences they have had. When students do not perceive what they learn in school as meaningful and purposeful, they often lack a feeling of ownership to it (Damasio, 2010). This may lead them to put in less effort thinking their actions do not matter, and they will not achieve their full learning potential (Gee, 2013; Maslow 1971). Extrinsic motivators can become necessary to motivate students to “get through the curriculum.” But research has shown that when students work for a grade, a prize, or a reward, it can further undermine their inner motivation to learn (Ryan & Deci, 2000).

An important part of a teacher’s job and the school's mission is to make the content they teach relevant for the student’s current and future life. Schools and teachers arrange field trips for students to have real-world experiences and hands-on activities, so they can connect the theory they have learned in the classroom with practice. But a field trip requires lots of time, logistics, planning, and organization. A field trip’s reach is also limited in time, space, and resources. A
teacher cannot take their students further than to a local area, and a big part of the school day will be spent traveling. VR on the other hand, brings the environment to the student, instead of the student to the environment. If a class has a set of VR headsets, the students can go anywhere in the known universe within seconds. Students can study penguins or glaciers in Antarctica, they can study the sun or the planets in our solar system, they can walk among lions and elephants on the African Savannah, or they can swim among fish and sharks in the ocean. They can also visit historical eras or events, like ancient Olympia in Greece, or see how ruins looked like before they were ruins (Joseph, 2020; Matchar, 2017).

**Meaningful Learning**

The core mission of education today is to develop students' knowledge, skills, and attitudes. Schools also hold a responsibility to facilitate opportunities for students to be creative, committed, inquisitive, and to give them challenges that promote formation and the desire to learn (Utdanningsdirektoratet, 2020). Many topics and problems addressed in school today do not arise from students' own wondering and inquiry, but are presented to them because it is the curriculum (Bereiter, 2002). Standards and curriculum are necessary for purposes like accountability, guidance, and equal education, but combined with expectations to perform well on tests and presentations, they can take away the joy and curiosity for learning away. Many students do not have a clear and compelling goal for learning in a formal classroom or caring about the learning material other than how to best remember the curriculum for their next test.

Dewey (1916) argued that reality must be experienced and students must be equipped with agencies for doing so. He claimed that traditional schooling de-contextualized the curriculum and deviated from educational conditions in the out-of-school environment, and
replaced the social environment with a bookish, pseudo-intellectual spirit. When learning is
treated as a separate business from the environment, and cognition is separated from the context,
intellectual learning can contradict its aim (Dewey, 1916; Lave & Wenger, 1991). Today, we
have higher expectations for schools than for a hundred years ago, and current educational
practices are built on evidence-based cognitive science theories (Bransford et al., 2000). It is
therefore interesting that these matters are still debated today.

Some modern scholars have criticized traditional educational practices for being outdated
and built on the written words’ premises. The knowledge is to be found in a textbook, and much
of the time in school is devoted to listening and reading language, learning information, facts,
and formulas from books or lectures (Gee, 2013; Skaftun, 2019). The American scholar Gee
(2013) accused today’s schools of having become skill-and-drill test-prep academies, where
students are treated like a “memory bank” without meaningful responses to their actions or
meaningful goals beyond grades and graduation. Wegerif (2016) claimed that traditional
schooling is built around a monologic representation of reality, which is presented in the books
selected for the school’s core curriculum, and students are further being tested to make sure they
can reproduce these representations correctly.

Applying VR in education cannot solve these alleged problems by itself, but it can
possibly make the curriculum content more meaningful for students. By placing them in a virtual
environment, a situation, where the curriculum content is relevant, they might get a feeling of
ownership to it or give rise to internal wondering and motivation to learn about the topic.
The purpose of this research project is to investigate whether implementing VR in instruction can achieve this. Therefore, my hypothesis for this research project is: “students will experience a higher sense of meaningful learning and intrinsic motivation when using interactive and immersive Virtual Reality technology for learning, compared to the traditional classroom situation.”

To learn is hard work, and I believe the basis for good learning starts with a will to learn; motivation. People must be interested in what they are going to learn and find the knowledge about it valuable enough to put in an effort; it must be meaningful. For something to be worth investing time and work, it must affect the learner’s life; it needs a social context. I aimed to investigate whether learning in VR can be more motivating than traditional learning methods and provide a better context for the subject content to be more meaningful for the learner’s life. Therefore, the research question for this project was “can VR improve students’ motivation to learn compared to traditional learning methods?”

This study aimed to investigate the educational features of modern VR technology and whether it can add value to middle school students' learning experiences and increase their autonomy and intrinsic motivation, compared to traditional schooling. With traditional schooling, I refer to a classroom situation where one teacher instructs 20-30 students and uses books or technology tools such as electronic blackboards, PCs, tablets, smartphones, or ICTs.

Six female and five male (N=11) middle school students participated in this study. I conducted one lesson using VR and one traditional lesson with traditional technologies and instruction methods. Because of the COVID-19 pandemic, this research project had to be conducted online and over Zoom. Therefore, as the traditional learning method in this study, I
used a popular and commonly used digital and web-based learning tool called Nearpod. To measure intrinsic motivation I used an intrinsic motivation survey and interviewed the participants after both lessons. The research data indicated that using VR technologies in instruction improved intrinsic motivation to learn. In the experimental lesson, the participants showed a higher interest in the lesson and the subject.

The conclusion of this research project is that students experienced a higher sense of meaningful learning and intrinsic motivation when using immersive technology for learning.
Literature Review

The purpose of this research project was to examine motivational features of VR in education and the relationship between learning and experiences in VR. It aimed to investigate conditions for learning and whether VR can contribute to richer and more meaningful learning experiences that increased intrinsic motivation for middle school students.

Although VR shows promising educational potential for learning and motivation among middle school students, it must first of all be grounded in established learning theory and approached by solid pedagogy. The literature reviewed will therefore first explain the technical features of VR, the type of VR used in this project, and the basic principles of VR. Then it will describe the processes of learning from a constructivist point of view and review how and why VR can be applied and used for the benefit of the learner based on the constructivist principles and modern neuroscience. Further on two motivation theories about self-efficacy and self-determination will be described, and VR will be investigated in the light of these. Finally, the literature reviewed will discuss the importance of the teacher and some potential limitations and pitfalls for using VR as a medium for learning.

Virtual Reality

VR technology is based on three basic principles; immersion, interaction, and user involvement. It is a technology that “talks” to the user, and it is designed to feel natural, immediate, and real. This is achieved through multisensory representations of 3D images, audio, and accurate movement transferring. VR can provide first-person experiences through simulations in real-time interactions through multiple senses, offering environments that exceed the classroom’s usual limitations. Instead of transporting or placing the user in a location, like,
for example a field trip does, VR brings objects and people from other places into the user's environment (Dahl et al., 2020; Lombard & Ditton, 1997).

**Head-mounted Display VR**

There are different types of VR technologies, such as desktop VR, which is done on a flat computer monitor, or CAVE, which creates a virtual environment with the help of projectors in a cube-shaped room. The HMD and CAVE VR have sensory immersive features, while desktop VR is less immersive (Srivastava et al., 2019). There is no clear consensus on what type of technology the research literature refers to when discussing VR. Therefore, it is important to clarify that VR in this research project refers to the HMD type. A pair of goggles cover the user’s natural field of view with a virtual view and translates the user’s movements into the virtual environment.

**The VR Hardware**

VR devices come with input or output features. Input devices are those that allow the user to communicate with the virtual environment through, for example, a joystick, a keyboard, a mouse, or hand tracking. The output devices allow the user to experience everything in the virtual environment (Cipresso et al., 2018). VR is a computer-generated experience, and for that experience to be successful, it is important to use a headset with a high display resolution and low latency and one that is comfortable to wear.

The VR system used in this research project was the Oculus Quest from Facebook (Oculus Quest: All-in-one Vr Headset, n.d.). Oculus Quest is a wireless headset that does not require a PC to run, but it also has PC compatibility for those applications that are built to run on a PC. The headset has about 2-3 hours of battery time, measures 7.5 x 4 x 5.2 inches, and weighs
1.1 pounds. It offers 1832 x 1920 pixels per eye, which is almost 4K resolution. It is easy to transport and can be used sitting down or standing up in a safe environment (Heaney, 2020; Oculus Quest: All-in-one Vr Headset, n.d.; Oculus Quest Features, n.d).

The Oculus Quest system has both an input and an output device. The headset has built-in sensors that interpret the user’s communication with the device into the virtual environment. The controllers or the hand tracking system transports the user’s hands and gestures right into the game, and the scoop-shaped controller. The headset itself is an output of sensory stimuli; it offers the user a 360-degree view, positional audio built into the headset, and it has outside cameras to track the user's head and hand movements and translate their position into the virtual environment (Oculus Quest Features, n.d.). The handheld controllers give an authentic feeling of actually grabbing an object and offer some degree of tactile feedback as they vibrate when used. Some applications and the Oculus home environment have developed a hand tracking system where the headset’s cameras capture the user’s hand movements and the controllers do not need to be used at all. However, the hand tracking feature is only available in some applications, and the two handheld controllers must still be used in many applications (Heaney, 2020; Oculus Hand Tracking, n.d.).
Immersion

What separates a VR experience from a traditional technology experience? Books, TVs, PCs, or other ICTs can also provide rich experiences, and they have traditionally been used in school to offer students richer multimodal experiences than just verbal instructions from the teacher (Mayer, 2002; 2003). The distinguishing and fundamental feature of VR is the level of immersion and the sense of presence in the virtual environment. Immersion is the perception and authentic feeling of being Psychically present in a virtual world and is the most important feature that separates HMD VR from desktop VR (Freina & Ott, 2015; Messinis et al., 2010; Srivastava et al., 2019). Students seem to enjoy learning in HMD VR more than desktop VR precisely because of the immersion and feeling of presence (Uskov et al., 2020).
**Sensory Immersion.** Eagleman (2015a) stated that reality is an illusion. If people could perceive reality as it actually was, it would be silent, colorless, odorless, tasteless, and energyless matter. All perceptions of experience take place inside our brain, where all information about the outside world comes through and is interpreted by the sensory organs. Experiences of reality are simply electrochemical signals to brain neurons. The sensory immersion from the input and output features of a VR system like the Oculus Quest replicate the real world’s sensory stimuli and can create an authentic illusion and experience of being present in an environment and a situation.

Although vision is the most dominant sense for people without disabilities, learning is a process that involves the whole body (Eagleman, 2015a). Hansen (2017) wrote a book about how to best improve and train cognitive functions such as memory or attention. The answer is not to practice crossword puzzles, sudoku, or other “brain exercises”, it is to move. He claimed that our ancient brains were created to learn new things when they were in activity. When our ancestors moved around, they often discovered new things and were exposed to new impulses and environments, and it was important to be focused and remember the impressions from when they were moving. From a physiological point of view, sitting still signals to the brain that you are not experiencing anything new. This was first demonstrated in a study in 1963 when 10 pairs of kittens were exposed to the same environment of visual stimuli, but one kitten was actively moving while the other was transported in a gondola. The researchers found that only the kitten that was using its body developed normal vision, showing that self-produced movement is important for the developmental processes (Held & Hein, 1963). The sensory signals coming into our brain can only be made sense of by training, which requires cross-referencing the signals
with information from our actions and sensory consequences. This is how our brain can interpret what the visual data actually means. This is for example why human babies reach out to grab objects in front of them, it is not just to feel the surfaces and textures, it is also a part of cognitive development and visual training (Eagleman, 2015a). This falls in with the constructivist perspectives described further below; social constructivist learning theory emphasized that information is derived and processed from the environment, cognitive learning theory that learners either assimilate or accommodate information from the environment, and sociocultural learning theory that valued the interaction between the learner and the environment. Although the VR simulation is not real, the sensory stimuli and immersion brought by the technology are so convincing that it can deceive our human brain to perceive the virtual environment as real and the user’s movements in the virtual environment are perceived as real movements (Lenggenhager et al., 2007).

All human cognitive processes start with sensory inputs from the environment that cause different modality cortices in the brain to process and translate the inputs into meaning. It is the capacity to “transform perception into recognition, word-forms into meaning, scenes and events into experiences, and spatial locations into targets for exploration” (Mesulam, 1998, p. 1). The human consciousness encodes sensory neural inputs into subjective versions of the world, so they are meaningful experiences rather than surface properties of events (Bandura, 2001). As emphasized by Vygotsky and sociocultural learning theory, the mind and the environment are deeply connected to individual sensemaking (Edwards, 2017). Consciousness is what allows people to find meaning in their life, reflect, and develop a self-identity (Bandura, 2001). Historically, when humans developed a language, we became aware of consciousness. It is
having a language that allows people to create abstract representations of concepts, and with that, transfer knowledge with symbolic communication (Bandura, 2001; Damasio, 2010; Mesulam, 1998). People normally experience their conscious self within their own physical body, but studies have shown that presence in VR can deceive the body’s self-consciousness and self-localization (Lenggenhager et al., 2007). VR creates an illusion of a virtual body that for the user feels like is their own body.

Neuroscientific science has seen that more neurons in the brain are activated when more senses are exposed to stimuli. All the sensory organs function as an interpreter of sensory impressions, and the brain is organized to process information from different senses in order to have a complete understanding of reality (Kátai et al., 2008). All cognitive processes begin with analogous associations of similar sensory inputs; we use all our senses to understand and learn (Mesulam, 1998).
Illustration 3

_All cognitive processes begin with sensory inputs._

Ponticorvo et al. (2018) claimed that the digital revolution has led to less interaction with the physical world, and especially for children, educational materials have changed from physical to digital ones. However, modern technology also has the chance to recover this. Results from their study among primary school students indicated that multisensory materials are effective for learning. The researchers found that in a story told by either multisensory materials, digital with touch-screen, or a traditional book, children remembered the story better when using the multisensory materials (Ponticorvo et al., 2018).
Digital multisensory technologies, including VR, mainly rely on sight, hearing, and touch. Smell and taste are difficult for technology to develop, which is a limitation compared to real-world experiences (Ponticorvo et al., 2018). The main difference of a VR experience compared to traditional technologies is that VR offers a more persuasive perception of sensory immersion and interaction with more than two senses; it has 360 degrees 3D view, positional audio, and kinaesthetic communication. A system that can perceive the whole body, by, for example, looking around or under an object, will have a higher level of interaction for the user than if they are just looking at a screen, where they easily can see the rest of the world just by turning their head (Slater, 2018).

**Presence in a VR Environment.** VR allows for a higher level of interaction with the environment than books and other ICTs do. This has shown to positively relate to a higher sense of presence and better learning outcomes (Jensen & Konradsen, 2018). The illusion of spatial presence has cognitive benefits as the multisensory representations can enhance the learners’ understanding of scientific models and expand their perceptual visualization (Kátai et al., 2008; Loftin et al., 1998). Instead of reading in a book or watching a screen, students can directly experience and physically explore earlier inaccessible world phenomena. This first-hand experience provides the learner with an environmental context and can help them understand and remember the concept better. They can, for example, visit different historical periods, explore the solar system, or investigate situations that would be dangerous or ethically problematic, like firefighting, rescue situations, or surgery (Freina & Ott, 2015). Students are given access to an experience where they can observe and interact with a spatial environment that they can assimilate or accommodate to existing schemas (see cognitive learning theory described below).
Conscious Presence. Sensory immersion in VR tricks the senses into experiencing kinesthetic sensations. However, the conscious mind is not fooled (Bereiter, 2002). Slater (2018) pointed out that the whole point of presence in VR is the illusion of being there. It is not a cognitive but a perceptual illusion. Slater and Wilbur (1997) distinguished between immersion and presence in a virtual environment. They defined immersion as a state that technology can deliver to the human senses, while presence referred to a state of consciousness of being in the virtual environment. Immersion is a state that can give rise to presence (Kim et al., 2017). Other media and technologies than VR can engage people to be immersed, like TV shows, movies, video games, board games, or even a good storyteller (Green et al., 2004). However, VR experiences deceive the human senses to feel a presence, and it places the user in the virtual environment. TVs and PCs bring the environment to the user through a screen. VR gives the user a feeling of “being there,” while other media like TV and PCs gives the user a feeling of “it is here” (Lombard & Ditton, 1997).

This feeling of presence is more convincing in VR than in other technologies, but it is not yet as good as in real life. It is noteworthy for the future that the CEO of Facebook, Zuckerberg, recently stated that one of his and the company’s main goals for future VR development is to create more realistic digital avatars and a headset that can translate the user’s facial expressions and make realistic eye contact with other avatars (Heath & Olson, 2021). Almost a fifth of Facebook’s workforce, about 10 000 people, are reportedly working on further developing the company’s VR and AR products (Zibreg, 2021).
User Involvement and Interaction

VR is a technology that has the potential to fulfill the pedagogical ideals many scholars and ideologies have emphasized, but that has been impossible to fully achieve in the traditional classroom situation. Field trips or hands-on experiments in school have historically demanded resources that do not always exist in schools, such as time, qualified instructors, availability, or financial means. Abstract or unreachable concepts like space, organs, or the Mesozoic era can never truly, or rarely, be experienced by students in the traditional classroom.

One organizational example of how VR technologies are used to place the user in a learning situation is the Dutch-based company WarpVR. Using powerful 360 cameras, they produce real-world first-person educational training simulations for companies all over the world, such as the airplane company KLM, the broadcasting company BBC, or training simulations for the Dutch police (Warp vr - virtual reality software for training, n.d.). For example, in one of the simulations, which is about safety awareness on an oil platform, the user takes the role of a novice employee who interacts with their supervisor, then they follow and learn from a more experienced employee, and experiences an accident where the safety awareness was low (Warp VR, 2020). Another example from the educational sector is an ongoing research project in Norway, where a VR application is being produced to teach K-12 students first aid (Dahl et al., 2020).

Roleplay and Storytelling. The role of play is important for young learners’ development, and both Piaget and Vygotsky (see learning theories described below) believed in the link between play and the development of social cognition (Eagleman, 2015a; Granic et al., 2014). Most learning involves playing a character or a role in some way. For example, in a
science classroom students think and act like a scientist, while in an English classroom they think and act like linguistics. Playing games and characters is a way for students to try new identities or roles, which can be a powerful motivator for learning (Gee, 2003).

Storytelling brings emotions into learning, improves engagement, and ensures better memory. People who are immersed in a medium and are enjoying themselves usually experience the positive consequence that they have fun, and they will likely seek the experience over again in the future. Green et al. (2004) discussed why people enjoy media and suggested transportation into a story world as one key element. They called the phenomena of being fully engaged in a story “transportation into a narrative world” (Green et al., 2004, p. 312). It has been argued that stories are the most natural way of thought, and both children and adults are naturally drawn into narrative stories. People do not store information as computers do; they remember information in a context, situation, or story (Gee, 2013). This is valid for many types of mediums. Green (2004) reported in a study about transportation into narrative worlds that transportation was positively correlated with perceived realism and that pre-existing knowledge impacted the participation level of transportation.

The realistic and immersive feature of VR brings it into the educational discussion. Students can do more than take a virtual field trip; they can experience the environment from their own or from someone or something else’s perspective. They can travel anywhere in their VR headset, as long as there is software built for it. They can go to geographical places, historical places, abstract places, or unavailable places. They can, for example, be a tree, an octopus, a blood cell, or an atom and learn in an interactive and immersive way that books or ICTs only can achieve to some degree. One example where VR has been used for educational
roleplay, is in education for medical caregivers where VR was used to prepare medical students’ interaction with patients. Through VR simulations, the students could experience a health care situation from the patient’s perspective (Gugliucci, 2018; Li et al., 2017).

**Fun.** Gamification is the idea of applying elements from games in a serious situation to enhance engagement and motivation (Chou, 2017). Integrating computer games with education is also called edutainment. Since games can be an instance of VR, it is reasonable to assume that students will become motivated by the idea of playing a game or test out VR (Huang et al., 2010).

The novelty of multisensory VR technology can promote a learner’s motivation (Huang et al., 2010). The “novelty effect” is an interest in new technology. Research has shown that the perceived reward of using new technology can have a direct positive effect on attitudes towards usage (Wells et al., 2010). Parong and Mayer (2018) found that even if students' interests are motivated by the idea of VR as new and exciting technology, it is more enjoyable and motivating compared to traditional PowerPoint presentations while still promoting meaningful education. The presence of multisensory details created by the VR environment can lead to greater transportation and enjoyment for the user. Green et al. (2004) hypothesized that rich details in media allow individuals to form more vivid mental images, and perhaps these details allowed users to feel that they are closer to or more knowledgeable about the story.

**Theories of Learning**

Learning theories are a set of principles that offer to explain phenomena of learning. There is no universally accepted definition of what learning is, but Schunk’s (2012) definition captures some broad criteria most educational professionals consider to be central for learning:
“Learning is an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience” (p. 3). We cannot directly observe learning, but when people become capable of doing something different, they have learned something. People can learn without demonstrating it at the time because learning can develop over some time. People are genetically predisposed to a certain behavior, but the environment significantly affects how it can be developed.

VR technology is not educational in itself, but it can simulate an authentic environment, a situation, or a social interaction where students can actively participate and construct knowledge. Cognitive processes do not happen solely in a learner’s mind but in a reciprocal relation between a person and a situation (Greeno, 1989). The main features of VR are immersion, interaction, and user involvement, all of which are processes linked to user-centered activity where learners can interact with objects and events in the artificial world (Huang et al., 2010). VR can be a tool that guides and exposes students to social and spatial environments, powerful artifacts, or experiences. An important premise in the learning theory constructivism is that knowledge is actively constructed, not passively absorbed. Knowledge is individually constructed in meaningful social or physical contexts. A teacher can not just deliver information to a group of students, the students must be actively involved in their own learning process and be given access to actively work with the content and explore their interests (Schunk, 2012).

**Constructivism**

Constructivism is a learner-centered theory of how people learn. It is based on the idea that learning is a process of individual interpretations of experiences where the learner is engaged and actively constructing their own learning and knowledge. Prior experience and
beliefs will influence or modify how individuals learn and interpret a new situation (Applefield et al., 2001; Schunk, 2012). Knowledge is not an absolute truth. It is subjective and constructed within every person to explain, organize, and give meaning to actions and experiences in their lives (Brown et al., 1989; McLeod, 2019; Schunk, 2012; Simpson, 2002; Matthews, 1993).

There is no consistent constructivist theory but a range of perspectives where the role of environment, situation, or internal cognition has been weighted differently (Phillips, 1995; Schunk, 2012). Here, we will describe some of the perspectives; cognitive learning theory, social constructivism, and sociocultural learning theory, and discuss how VR pedagogically can support and enhance a meaningful learning situation.

**Cognitive Learning Theory.** Originating from the Swiss psychologist Piaget in the 1920s, cognitive learning theory focuses on internal and individual construction of knowledge. Children are viewed as learners who process and organize ideas and aspects of the world in cognitive structures (Applefield et al., 2001; Bransford et al., 2000; Moshman, 1982). Existing mental structures, schemas, moderate how new ideas and knowledge are interpreted. For Piaget, development was interpreted as an ongoing dialectic process where the individual either assimilates new experiences consistent with existing schemas or changes schemas to fit their experience (McVee et al., 2005; Piaget, 1964).

Piaget developed the theory of cognitive development, which suggested that children go through four stages of mental development: the sensorimotor stage, the preoperational stage, the concrete operational stage, and the formal operational stage. Children are in their sensorimotor stage at the beginning of their life, and understanding is rooted in the presence. An object only exists if the child can see or sense it. Children in their preoperational stage begin to develop a
language and can create symbolic representations of thoughts and mental structures. In the concrete operational stage, children are able to operate on objects and begin to show abstract thinking. In the last and most advanced stage of mental development, the formal operational stage, children are able to think about hypothetical situations and abstract properties based on logic rather than concrete objects (Piaget, 1964; Schunk, 2012).

Although there have been new contributions to the science of cognitive development, and development in children are today viewed as more dynamic than going through the four stages, Piaget’s theory creates a good understanding of the foundation on how children mature, develop, and construct knowledge (Schunk, 2012).

**Spatial Schemas.** Piaget’s theory of cognitive development emphasized experience as one of four main factors for the development of knowledge in children, together with maturation, social transmission, and self-regulation. Piaget (1964, p. 178) wrote: “experience of objects, of physical reality, is obviously a basic factor in the development of cognitive structures.” He further described two types of experience; physical experience and logical-mathematical experience. Physical experience happened when a person acted upon objects and drew knowledge abstracted from the objects themselves. Logical-mathematical experience drew knowledge from the actions affected on the objects. This is an experience not from the objects themselves but from actions of the subject. Concrete materials support children when they learn about new or abstract concepts (Piaget, 1964). For example, when a child learns about numbers and amounts, they count concrete objects in the beginning, like their fingers or toes, before they discover the conceptual idea of numbers. The theory of cognitive development has been challenged, and newer research indicates that also younger children and toddlers have a stronger
spatial cognition than what was originally argued by Piaget. Both biological and environmental processes change children's spatial ability through maturation of the brain and experience with physical environments and objects (Vasilyeva & Lourenco, 2012).

In line with Piaget's theory that children rely more heavily on concrete objects than adults, modern research studies have shown that mental representations and manipulations of objects improved when supported by manual manipulations. The effect was particularly strong among children but also found among adults (Funk et al., 2005; Horst et al., 2010; Wiedenbauer & Jansen-Osmann, 2008). Interactable and immersive VR technology can be especially suitable to study spatial representation and spatial navigation because of the sense of spatial presence in the environment and the capacity to manipulate objects (Slater & Sanchez-Vives, 2016).

The development from a novice to an expert in a field of subject involves the ability to de-contextualized knowledge from concrete objects. The expert uses mental representations and processes to think about hypothetical situations and abstract properties based on logic rather than concrete objects (Piaget, 1964; Schunk, 2012). It is generally theorized that these mental representations are products of spatial thinking (Meijer & van den Broek, 2010). According to Peissig and Tarr (2007), “object identification is a primary end state of visual processing and a critical precursor to interacting with and reasoning about the world” (p. 76). How objects are recognized is both a perceptual and a cognitive process. Spatial processing is a complex cognitive operation of sensing and integrating multisensory information from the environment and mentally constructed representations (Cona & Scarpazza, 2019). The skill of spatial visualization involves the ability to mentally transform spatial information (Uttal et al., 2013).
**Spatial Schemas in STEM.** In the spatially demanding fields of science, technology, engineering, and mathematics (STEM), spatial ability has traditionally been described as correlative to performance and a predictive of who will pursue a career in the STEM fields (Wai et al., 2009).

Spatial skills can be developed and improved through training (Sorby & Baartmans, 2000). One example of this is a course that was developed and used to help middle school students’ spatial cognition. The students who participated in the spatial training activities showed significantly higher gains in spatial skills than the students who did not participate in the same training activities. Spatial skills training seemed to be especially beneficial for middle school girls, who went on to enroll in more math and science courses than other girls in a similar comparison group (Sorby, 2009). Sorby (2009) suggested that “the optimal age for girls to participate in spatial skills training is likely in or around middle school. High school interventions may be too late for most girls who have firmly established their poor self-efficacy beliefs about mathematics and science” (p. 314).

The research literature is split between whether virtual 3D models are a benefit or a disadvantage for low visualizers. The field of medicine has a great body of research and studies from anatomy training in VR have found different outcomes related to virtual 3D models and low spatial visualizers. One study about e-learning instructional designs of brain anatomy found that viewing a virtual 3D brain model from multiple angles led to less learning, especially for those with poor spatial ability (Levinson et al., 2007). Another study of ear anatomy learning found that computer-generated 3-D models were beneficial for learning (Nicholson et al., 2006). It has been hypothesized that the multiple views of multimedia graphics can be more difficult to
comprehend for low visualizers, but the reasons for the different research results may be found in the type of technology used and the level of immersion and interaction (Levinson et al., 2007). Studies that compared passively viewing 3D models with direct manipulation of virtual structures in a 3D environment have found better results among the manipulation group than the viewing group. Direct manipulation of the virtual environment was found to particularly support participants with low spatial ability (James et al., 2002; Jang et al., 2017; Meijer & den Broek, 2010). A meta-analysis of studies with different HMD VR inputs has found that devices with hand tracking were more immersive and had a higher simulator fidelity than devices with joystick or pointing device (Jensen & Konradsen, 2018).

**Social Constructivism.** This perspective emphasizes the importance of the environment more than the cognitive learning theory. Social constructivism highlights that learning is socially situated, and knowledge is constructed through interaction with others or the environment (Lave & Wenger, 1991; Simpson, 2002). The assumption is that that knowledge is found in reality and is derived from the environment. Social constructivism focuses on the importance of the environment and considers the external world to have a strong influence on learning, such as experiences, teaching, and exposure to models (Moshman, 1982; Schunk, 2012).

How people process the information they receive through the environment is considered by the information processing theory. This theory focuses on the internal processes between people and the environment; how information is encoded, related to knowledge, and stored in memory (Macik, 2018; Schunk, 2012). New information from experiences is actively selected, organized, and connected to existing knowledge to make sense of them. Knowledge is viewed as mental representations, and memories are bound to spatial schemas (Mayer, 1996).
**Conceptual Knowledge.** The processing of information and construction of mental representations is not just a visual process (Meijer & den Broek, 2010). Real-life spatial cognition normally happens in an environmental context, and semantic and spatial knowledge is naturally intertwined (Uttal & Cohen, 2012). Uttal and Cohen (2012) conducted a large-scale meta-analysis of research on spatial thinking in STEM education and reported that spatial ability plays an important role among novices. However, at a higher level of expertise and mastery within a field, spatial cognition did not seem to predict performance in the same way consistently. Uttal and Cohen (2012) suggested that experts in the STEM fields have developed mental models of domain-specific knowledge, and therefore use different mental processes to make judgments about meaningful representations rather than their general spatial ability. They argued that “expertise in STEM reasoning is best characterized as a complex interplay between spatial and semantic knowledge” (p. 162). At a higher educational level than middle school, where more VR systems have been developed for education, advanced medical surgery training serves as a good example of how VR can facilitate concrete training materials. For example, novice medical students can access complex operations that are rarely accessible to novices through VR-based simulations. Through virtual systems with advanced haptic sensation, they can practice and refine their skills before proceeding to do a procedure on a real patient (Wu et al., 2014). A study by Heil et al. (1998) found that mental representations of models were replaced by retrieval of stored memories the more specific stimuli and training their participants’ had been introduced to. Their conclusion was that practice speeds up performance. Compared to professionals who have gained specific education in a STEM field, middle schoolers are novices;
they have less experience and less semantic knowledge and therefore rely more on their spatial abilities.

**Sociocultural Learning Theory.** The perhaps most impactful constructivist perspective in modern education is the sociocultural, or dialectical, perspective. Knowledge is constructed in a continuous interaction between the learner and the environment, and neither one is predominant over the other. Learning happens in a reciprocal relation between the individual and the environment, new knowledge is constructed in the interaction between them (Moshman, 1982).

One of the most influential contributors to the sociocultural perspective, Vygotsky, emphasized that mind, individual sensemaking, and culture were connected (Edwards, 2017). A socially meaningful activity has an important influence on the human consciousness (Schunk, 2012). He argued that knowledge cannot simply be transmitted, it must undergo a fundamental development from the child’s existing level of ability and knowledge (Fosnot & Perry, 2005). Vygotsky’s theory of the zone of proximal development referred to the connection between the learner and the environment. The zone of proximal development is the distance between what a learner can do independently and what they can do with help from a more knowledgeable other, tools, or powerful artifacts. These can assist the learner to increasingly raise their level of competence into successively more advanced levels. What a student can do with assistance one day, they can do alone the next day. This zone is different from child to child and reflects the learner’s potential to understand a concept (Bransford et al., 2000; Brown, 1994).

**Previous Experience.** Eagleman (2015b) captured the importance of pre-existing knowledge and previous experiences when he wrote: “you don’t perceive objects as they are, you
perceive them as you are” (p. 34). Every situation or object has a specific and unique meaning to people depending on their history of experiences. For example, a flag is just a piece of fabric for those who have no relation to or knowledge of what a flag is and what it symbolizes. When people learn something new, they construct the new knowledge around what they already know; the new information is assimilated or accommodated into existing schemas. What people already know is influenced by the culture and society they grew up in and the real-life references they have experienced from their socialization process (Gee, 2014).

Students are novices who come to school with different backgrounds. They have a range of prior experiences, knowledge, skills, and beliefs. If students' existing beliefs and knowledge are ignored, the teacher’s intention can be misinterpreted. K-12 students, children, and adolescents have less experience and fewer schemas than adults do, and they are introduced to many abstract concepts that they have no real-life references to (Bransford et al., 2000). Younger learners simply do not have a broad spectrum of existing mental structures to moderate how new ideas and knowledge are interpreted. They have smaller vocabularies, which can make it more difficult for them to express complex or subtle ideas or for teachers to explain abstract and complex concepts (Bransford et al., 2000; Gersmehl & Gersmehl, 2007).

VR can facilitate a context where learning is embedded and create a learning environment that all the students in the classroom have access to. The sense of presence and interaction allows the VR user to be an actor rather than a spectator in an authentic spatial environment and learning situation. The user’s actions will have consequences, and they will experience them. Examples of this are the previously mentioned simulations from WarpVR where the user takes a first-person role in a VR environment where they have to interact with
other persons and make decisions, or the ongoing research project in Norway where students can learn first aid in VR (Dahl et al., 2020; Warp VR, 2020).

**Memory.** The psychologist Willingham (2009, 2011) claimed that the human brain is not designed for thinking, but rather designed to save people from having to think. Although thinking and reasoning are some of the most distinguishing human features, most of the brain mass is devoted to avoiding thinking by creating habits and chunking information. For example, speaking and hearing a native language is effortless for most non-disabled people, but if they try speaking a second language they are less trained in, it requires a lot more thinking and concentration. The human brain is biased to use memory over thinking to guide their actions. It requires less effort to recognize shapes and patterns stored in memory than to continuously make new interpretations.

In the Vygotskian learning theory, meaning was determined by an active consciousness, and consciousness was considered the ability to perceive meaningfully, not the ability to remember all the ontological answers in the universe (Edwards, 2017; Hua & Matthews, 2005). People can make the mistake of picturing human memory to work as computer memory does: storing information exactly how it is being interpreted. We can store almost limitless numbers of experiences in our heads, but we do not store them as computers store information; we edit them to remember only what is important and relevant to us in that situation. Human memory is designed to help us make sense of the world, see connections, patterns, and recall effective strategies to accomplish our goals (Gee, 2013).

When learning happens, new connections between brain neurons are created. To explain these neuron connections, Hansen (2017) described memories as mental paths. A path quickly
grows back unless it is frequently used. A unique or intense experience will leave a mark so strong that it creates a mental imprint that lasts a lifetime. Less unique or very emotional experiences will not leave a strong path and will easily be forgotten. The main difference between VR and other technologies is the sensory perception and authentic feeling of being psychically present in a virtual world, which are the fundamental feature of VR (Freina & Ott, 2015; Srivastava et al., 2019). Memories are neural representations that have been created in a specific context, and memories registered by several senses will be registered in several interrelated memory networks. A memory that has been created and stored through several senses becomes more powerful and accessible than a memory stored in only one sensory area (Hung, 2003).

**Motivation Theory**

Motivation is a major component for successful learning because it is the core drive of exploration, engagement, persistence, and effort (Ryan & Deci, 2000; Makransky et al., 2019; Schunk & DiBenedetto, 2020). Humans are naturally goal-driven, and agency and attribution are important components in motivation (Bransford et al., 2000; Demetci et al., 2016). People are motivated to achieve goals under conditions that are meaningful to them and that they care about. When people lack motivation, they often do not familiarize themselves with the goal or care about the results (Gee, 2013). Although people want to perceive themselves as agents and control events that affect their lives, they do not actually live their lives in individual autonomy. Rather they are part of an interplay between personal agency and impact from the environment (Bandura, 1997; 2001; Schunk, 2012). It is important for a student’s motivation that the learning situation takes place in a meaningful context (Greeno, 1989). As described earlier in this review,
VR has features that potentially can facilitate a more meaningful learning situation and provide realistic spatial simulations of real-life situations to support and scaffold children’s development and learning in a way that other ICTs and books cannot do.

Students in school quickly learn the values and actions that are appreciated and not appreciated in class. When students are expected to simply follow the school’s and the teacher’s instructional agenda, it can alienate them from their own inner motivation (Reeve, 2006). Dewey (1916) claimed that there is an artificiality attached to much learned in school. Students do not consciously think of the learning content as unreal, but it does often not possess a value for them in their ordinary life for other purposes than succeeding in lessons, assessments, and external requirements. Dewey asked the question: is the student learning new knowledge to solve the student’s own problem or to solve the teacher’s or the textbook’s problem? If the latter is the case, students will only be motivated to learn if they are driven by extrinsic motivators (Ryan & Deci, 2000). Extrinsic motivation (described further below) like rewards or punishment flourish in the school system today, such as grades, deadlines, extra credit, attendance, honor students, expectations from significant caregivers and peers, GPAs, or ice cream parties. However, research on rewards has shown that tangible rewards, pressure, and imposed goals do not have an effect, and extrinsic motivation actually undermines students’ intrinsic motivation (Deci, Koestner & Ryan, 2001; Ryan & Deci, 2000).

**Self-Efficacy**

According to Bandura (1989), there is no mechanism behind human agency stronger than perceived self-efficacy. And “those who have a strong sense of efficacy generally set a higher standard for themselves” (p. 1180). Perceived self-efficacy is the belief in one's own capabilities
to execute and organize the course of actions required to achieve a goal. Efficacy beliefs influence people's actions, thoughts, feelings, and motivation (Bandura, 1997). The level of self-efficacy can regulate the level of motivation. Unless people believe they can reach their desired goal, they will not put in the necessary engagement and effort to resolve difficulties and set-backs. Whatever the benefits of success might be, people who lack self-efficacy in a field will not consider their success or goals as possible to achieve (Bandura et al., 2001).

A middle-school student is neither a completely autonomous agent nor controlled solely by environmental influences, and the classroom setting can support or undermine their motivation (Bandura, 1989; Reeve, 2006). Teachers in autonomy-supportive classrooms facilitate congruence between students’ self-determined motivation and daily classroom activities (Reeve, 2006).

With modern VR technologies, teachers can design learning activities and virtual learning environments that can address the learners’ needs and contribute with motivational factors (Shu et al., 2018). Integrating VR technologies is not an educational goal in itself nor sufficient to enhance student learning outcomes alone, but when a student can utilize the technology as a reciprocal interactive environment rather than just receiving information from it, their self-efficacy can improve (Hamilton et al., 2016). Research projects have seen positive tendencies of improved self-efficacy among university students when meaningful and immersive VR technology has been used intentionally and actively (Nissim & Weissblueth, 2017; Shu et al., 2018; Xu et al. 2011). For example, Xu et al. (2011) reported that undergraduate students’ self-efficacy improved when they actively engaged in digital storytelling writing in a virtual-reality learning environment. Also Shu et al. (2018) discovered that university students'
self-efficacy was substantially greater when they learned earthquake preparedness in a VR environment. They did, however, not discover any difference between desktop VR and head-mounted display VR.

**Self Determination Theory**

Self-determination theory (SDT) is a psychological framework about conditions that foster or undermine students' positive performance and motivation in a classroom situation (Gagné, 2014; Reeve, 2006). SDT has defined three essential inherent conditions for optimal growth and motivation among students: the need for competence, relatedness, and autonomy. Thwarting these three basic needs have been found to hinder or undermine autonomous motivation (Ryan & Deci, 2000).

**Autonomous Motivation.** There is an important distinction between autonomous motivation and controlled motivation. Autonomous motivation referred to motivation that comes from within the self, from personal interest, and enjoyment. Controlled motivation referred to doing something in order to get a reward or avoid punishment (The brainwaves video anthology, 2017). Much of the student activity we see in school today is driven by controlled motivation; many students do their school work as they work to get a good grade, not because they find the content of study especially interesting or enjoyable.

**Intrinsic and Extrinsic Motivation.** SDT furthermore described two types of autonomous motivation, intrinsic and extrinsic. Intrinsic motivation occurred when people found interest and joy in the activity itself. Extrinsic motivation originated from outside factors. Those who are driven by intrinsic motivation have more interest, excitement, and confidence in their
activities, which again manifests in increased performance, persistence, and creativity (Ryan & Deci, 2000).

Childhood socialization and education are a combination of intrinsic and extrinsic motivation. Learning is hard work, and people will only be intrinsically motivated when the activity has an intrinsic interest for them. Because most students do not find intrinsic interest or joy in every subject or lesson in school, extrinsic motivators are important and necessary in education. And if a student perceives these extrinsic motivational factors as meaningful, they can be internalized and integrated, and further create intrinsically motivated commitments (Ryan & Deci, 2000). However, the more students are externally regulated, the less interest, value, and effort they seem to show toward achievement in school. If a student's participation in school has too many extrinsic regulators and not much intrinsic value or motivation, students tend to disown responsibility for the negative outcomes, blaming others such as the teacher (Ryan & Deci, 2000). Therefore, it is important to present the learning content in a meaningful way to the student. Even if the learning environment is virtual, artificial, and created by extrinsic motivation, it can create intrinsically motivated commitments. The more students “own” the learning content and they can relate to it, the more intrinsically committed they may be (Damasio, 2010).

Makransky et al. (2019) conducted a study among three groups of university engineering students where they used immersive HMD VR, desktop VR, and no VR. Students who used immersive VR reported the highest level of enjoyment, followed by the desktop VR group who reported to enjoy their lesson significantly more than the students who learned the same lesson without VR technology. The students who used VR reported significantly higher intrinsic
motivation compared to students who learned from text booklets. The immersive VR group also reported higher levels of self-efficacy. The study did however not discover any difference between the students in the retention test, but the immersive VR participants scored significantly higher on behavioral transfer than the display VR and text participants did. This indicated that the Immersive VR participants had better learning outcomes and could more easily transfer the learned material to solve new problems.

**Technological Pedagogical Content Knowledge**

Research has shown that the teacher is the most important facilitator of learning processes in the classroom. While the VR experience might lead to discoveries and ‘aha’ reactions, will learning processes that lead to generalized knowledge and meaningful connections require a conscious mind (Hua & Matthews, 2005). VR can be a learning tool for teachers and students that can possibly improve students’ self-efficacy and intrinsic interest in the learning content. However, experiences with learning content do not cause learning by themselves, but it is the cognitive thought processes by the learner that causes learning and meaning (Dewey, 1916; Mayer, 2003). Education happens in a sociocultural context, and the students need guidance from their teacher while learning: they need anchor points to be able to make sense of their experiences (Gollub, 2002; Hsieh & Tsai, 2018).

Students can observe and learn in a virtual or real environment, but passively receiving knowledge is easy to facilitate with traditional teaching methods (Chang et al., 2020). Looking back to the SAMR model, if VR were to transform education, the teacher who instructs with VR needs not just pedagogical content knowledge but also technological pedagogical content knowledge. They must know how to utilize the technology properly in order for it to be a useful
tool for student agency in learning and education. As VR fairly recently became available to the general public, most teachers or students have little or no experience using VR. VR must be integrated with the pedagogy, and teachers and students must receive training in how to use VR properly. That might also redefine the traditional teacher and student role, where teachers for example must deviate from a direct-instruction approach to a hands-off approach (COSN, 2020).

**Limitations**

*The VR Application*

A good learning experience in VR highly depends on a good VR application. Teachers and students mainly have to rely on the content and premade applications. Most educational virtual environments have been designed and created by groups which have members from both educational, technological, and scientific backgrounds (Mikropoulos & Natsis, 2011). Teachers do not have the same freedom to choose VR applications as they have to choose other modes, for example books, because there simply are not that many applications available today.

An application can be well-made, but there are also many limitations in today's application pool for VR. Most of the educational virtual environments are constructed for science, technology, and mathematics. Also history and culture are popular topics, but there are fewer applications built for the social science subjects (Mikropoulos & Natsis, 2011). There are not many applications built for K-12 education, although there is a growing interest in the field, such as the mentioned first-aid training project by Dahl et al. (2020).

In a meta-analysis of twenty-one VR studies that accounted for motion sickness, Jensen and Konradsen (2018) reported eight of the studies had participants who experienced physical discomfort or cybersickness, but the symptoms reported varied from very rare to almost every
participant. Combined with the researcher’s own experience and level of motion sickness from different VR games and applications, Jensen and Konradsen’s (2018) analysis showed that how an application is made plays a big role on the level of motion sickness for the user.

It is also important to keep the novelty effect in mind. There is a chance that when utilizing Virtual Reality in the instruction, the tool itself, and not the content it provides, can have an impact on the students in the experimental lesson motivation. Mikropoulos and Natsis (2011) concluded that “carefully designed learning activities are more important than an exotic interface that contributes to intuitive interaction” (p. 774).

**User Characteristic**

User characteristics such as learning styles, gender, and age play an important role in learning with VR as it does with other learning tools. For example, in a meta-analysis of VR studies, Mikropoulos and Natsis (2011) found that some studies reported boys performed better than girls in VR, others reported the opposite, and other studies again found no difference between gender. It is unclear what the reason for these different results is. Spatial ability, prior computer knowledge, attitudes, and abilities also affected the participants’ results or feeling of presence in the studies reviewed by Mikropoulos and Natsis (2011). For example, the previously mentioned study by Levinson et al. (2007) found that multiple views of a 3D brain model led to less learning, especially for those with poor spatial ability (Levinson et al., 2007).

In a study investigating correlations between user experience in immersive VR environments and personality traits, Janssen et al (2016) found indications that the user experience in a virtual learning environment depended on individual traits. Students with more anxious or reserved characteristics had a more negative experience in the virtual learning
environment, which again influenced the feeling of immersion and sense of presence. More open-minded and social students judged themselves with a higher competence in solving tasks, they were able handle technological problems better, and they had an overall more positive experience.

Summary

Learning is a personal process but it happens in an authentic context and is embedded in activity, context, and culture. Using VR technology does not automatically cause learning among students, but can be used as a medium to access virtual simulations in which learning may take place (Jensen & Konradsen, 2018). HMD VR is today affordable and accessible and it can give students access to experiences they never before could access.

Learning is a multisensory process (Eagleman, 2015a; Kátai et al., 2008; Mesulam, 1998). Memories and knowledge that have been created and stored through several senses in a specific context become more accessible than a memory stored in only one sensory area (Hung, 2003). The VR hardware has input and output features that deceive the user’s self-consciousness and self-localization (Lenggenhager et al., 2007). It tricks the user’s senses into experiencing the virtual environment and facilitates an illusion of being there (Slater, 2018).

If students are solely driven by extrinsic motivators, such as punishment or rewards, it can undermine intrinsic motivation and interest in the subject content (Deci, Koestner & Ryan, 2001; Ryan & Deci, 2000). Agency and attribution are important components behind human motivation (Bransford et al., 2000; Demetci et al., 2016). For a student's motivation to learn subject content that might not possess a value for them in their ordinary life it is important that the learning situation takes place in a meaningful context (Greeno, 1989). VR can facilitate this
context by placing the student in a contextual environment where they can perceive and interact with the virtual objects and environment. Physical experience and concrete materials support children when they learn about new or abstract concepts (Piaget, 1964). Although VR experiences and VR objects are not real, they feel real to the user. In contrast to the traditional classroom situation where a teacher and a class have limited resources and access to experiences, VR can give access to any experience or object - as long as there is a VR application built for it.
Methodology

This study was a qualitative study that investigated if students experienced a higher sense of meaningful learning and intrinsic motivation when using interactive and immersive Virtual Reality technology for learning compared to traditional learning methods. Two lessons about the solar system were created and conducted with 13-14-year-old participants (N=11). Both lessons were adapted to be completely online because of the COVID-19 pandemic. The first lesson served as a control lesson where a traditional and widely used digital presentation tool, Nearpod, was used. The second lesson was the experimental lesson where the participants used VR goggles and handheld remotes from Oculus Quest. To measure intrinsic motivation, the Intrinsic Motivation Inventory (IMI) was sent to the participants right after the lessons (Appendix A). The participants were further interviewed to assess their subjective experience of the lessons (Appendix C). Zoom was used to instruct the participants in how to complete both lessons, the survey, and the interview. The collected data, the survey, interview, and an assignment at the end of both lessons, were subject for analysis and conclusion for whether Virtual Reality contributed to a more meaningful learning experience and increased student intrinsic motivation.

Participants

Six female and five male (N=11) middle school students aged 13-14 years old in the US East Coast area participated in this study. Participants younger than 13 years old were not allowed into the study as this is the lower age limit set by Oculus Quest (Oculus Quest Legal Documents, n.d.). Participants with pre-existing medical conditions that might be triggered or disturbed by the VR technology were not allowed to participate in this study. All the participants completed both lessons with the following IMI survey and interview.
Three of the participants knew each other (but participated at different times), two lived in the same household (participated at different times), and two participated at the same time. The participants had mixed experiences with VR before this study. Five of them had never used VR before, while six had an Oculus Quest in their household and had used VR before. They used their own Oculus Quest in the study.

Because of the COVID-19 pandemic, all research activities were done from home over Zoom.

**Instruments and Materials**

**Nearpod Lesson**

Nearpod is a free website application that is designed to help educators develop interactive presentations and lessons. This study modified an “introduction to the solar system” Nearpod lesson created by Classroom Complete Press (The Solar System - Introduction, n.d.). This lesson’s learning objectives were to explore the various parts of the solar system, read about the planets and what they are made of, and discover the roles and importance of planets, moons, and asteroids.

The lesson consisted of a 36 pages long multimodal, self-paced, and interactive slide show presentation made for 5th-8th grades (see Appendix E). The presentation was sectioned into a “before you read,” a “reading passage,” and an “after your read” section and aimed to follow modern pedagogical lesson planning principles. The “before reading” section presented the learning objectives and attempted to activate previous knowledge with a “fill in the blank” quiz and “name the planet” drawing assignment. The “reading” section explained important vocabulary to facilitate better reading comprehension. The same words were highlighted in the
reading passage. Images and a video were also included to illustrate and support the text. The “after you read” passage was an assessment section where the student had to take a stand on some false/true statements about key ideas from what they just read and recognize important words. The students were given instant feedback as the next slide revealed the correct answer.

**VR Application: Star Chart**

For the experimental lesson (see Appendix F), an application called Star Chart was used. The user can navigate in the solar system and explore planets, moons, stars, and see an accurate real-time simulation of the night sky (Star Chart on Oculus Quest, n.d.). The reason for choosing this application is that it was hypothesized it would allow for a redefined way of teaching the students about space. When I researched VR applications to use for this study, this application did not provoke motion sickness and felt like a well-made application. The Star Chart application used on Oculus Quest can facilitate an illusion of perceived physical presence in space. It allows for multiple views of the objects, such as planets and moons. It also has multiple subject characteristics, as it includes mathematical terms like diameters, time, and space. It also connects to historical references like Neil Armstrong and Buzz Aldrin. It refers to science, social studies, and religion with representations of constellations of stars, planets, and their material.
Illustration 4

Examples from Star Chart.

Image retrieved from: Star Chart, n.d.
Intrinsic Motivation Inventory Survey

The Intrinsic Motivation Inventory (IMI) was used to determine the participants’ subjective experience of intrinsic motivation in the lesson. The IMI has been developed by SDT
scholars and has been used in several experiments related to intrinsic motivation (Intrinsic Motivation Inventory, n.d; Ryan, 1982). Studies have found strong support for the validity of the IMI (McAuley et al., 1989).

This study used a 22 item version of the IMI (Appendix A) that addressed the four subscales interest/enjoyment, perceived choice, perceived competence, and pressure/tension. The interest/enjoyment subscale is considered the self-report measure of intrinsic motivation, while perceived choice and perceived competence are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation. Pressure tension is theorized to be a negative predictor of intrinsic motivation. A higher score indicated more of the concept described in the subscale name: a higher score on interest/enjoyment meant the participants felt more interest/enjoyment; a higher score on perceived competence meant the participants felt more competence; a higher score on perceived choice meant the participants felt more choice. (Intrinsic Motivation Inventory, n.d.).

The IMI was digitized and sent as a digital survey using www.surveymonkey.com (Appendix B). The participants’ reported scores from 1 to 7, where 1 = not true at all, 4 = somewhat true, and 7 = very true. Seven of the questions were related to the subscale interest/enjoyment, while five questions were related to each of the three other subscales: perceived competence, perceived choice, and perceived tension.

**Interview**

An interview protocol (Appendix C) was created to learn more about the participants' subjective experience of the lessons, the subject (science/space), and the tools used (Nearpod/VR). Although the IMI questionnaire measured the participants’ intrinsic motivation,
an additional interview allowed them to explain how or if they felt immersed or present in the
two lessons, what they thought about them, and to share and explain their thoughts about VR in
education. The interview was audio-recorded and later transcribed (Appendix I).

The interview for the control lesson consisted of twelve questions, while the interview for
the experimental lesson consisted of thirteen questions. In some cases, a follow-up question was
asked (see Appendix I). Most of the questions were the same for the two interviews; control
lesson interview questions 1, 7, 8, 10, 12 were the same as experimental lesson interview
questions 1, 6, 7, 9, 10. Control lesson interview questions 2, 3, 4, 9, 11 were the same as
experimental lesson interview questions 3, 4, 5, 8, 11 but were related to the tool used. For
example, Q3/4: “What do you think about using Nearpod in this lesson?”; “What do you think
about using VR in this lesson?”. Control lesson interview questions 5, 6, and experimental
interview questions 2, 12 were unique for that interview.

Assignment

At the end of both lessons, the participants were given an open-ended assignment and
asked to write 1-3 facts on what they found interesting about the solar system (Appendix E;
Appendix F). This was used to compare if there was any difference in the participants' takeaways
from the lessons.

Procedure

The Lessons

The participants took part in two or three online sessions from their homes over Zoom.
Each session lasted for approximately 30-40 minutes, and the lessons about 15-30 minutes. How
much time the participants used on each lesson was noted. All of the participants completed all
the sessions and lessons in one Zoom meeting.

**Intro Lesson.** For those who did not have VR experience, the first session was a Zoom
meeting with an introduction to VR and instructions for how to safely set up, customize, and use
the VR technology (Appendix D). The participants did an intro tutorial created by Oculus on
using the controllers and navigating in the environment. The subjects could also play simple
games like Beat Saber to become comfortable moving around and using the technology.

**Control Lesson.** The second session was the control lesson, where Nearpod was used
(Appendix D). The participants were given a link to the Nearpod presentation, and they worked
at their own pace until they were done. The researcher and the participant were connected on
Zoom throughout the whole session. After the lesson, the participants did the assignment, then
they received a new link to the IMI survey and participated in the interview.

**Experimental Lesson.** The third session was the experimental lesson where VR
technology was used (Appendix F). The researcher and the participant were connected on Zoom
through the whole session and could talk to each other also when the participant was using the
VR headset and Star Chart. The participant was given instructions over Zoom on how to find the
right application, but they followed a tutorial in Star Chart for navigating in the app. They then
watched an immersive simulation of a guided tour in the solar system. They used the rest of the
lesson to investigate objects in the solar system on their own initiative. After the lesson, the
participants did the assignment, then they received a new link to the IMI survey, and participated
in the interview at the end.
As Oculus warned about in their own legal documents (Oculus Quest Legal Documents, n.d.), none of the participants used the VR technology for more than 30 minutes at a time. If any of the participants felt uncomfortable or sick, they were instructed to immediately stop the lessons.

**Data Analysis Method**

The results from the IMI survey (Appendix G), both the total results and the subscales, were analyzed. Results from the control and the experimental lesson were compared and contrasted. Individual and gender differences were also examined.

The interviews (Appendix I) were used to interpret whether the participant’s experience with and opinion about VR in education were in line or not with the hypothesis. For example students discussing their motivation, what about the lesson they liked the most, and if VR technologies changed their perception of the topic, subject, or lesson. Or if they had any negative outcomes or experiences with the use of VR technology. The participant's response was also interpreted in the light of their result on the IMI survey.

The assignment (Appendix J) was used to evaluate if students in the experimental lesson expressed their learning outcomes or takeaway differently from the control lesson.

Time spent on the lessons (Appendix K) was also subject for examination and assessed if there were any differences between the control and the experimental lesson.
Results

This chapter demonstrates findings and results that address the hypothesis in this research project: “students will experience a higher sense of meaningful learning and intrinsic motivation when using interactive and immersive Virtual Reality technology for learning, compared to the traditional classroom situation.” The research question addressed was: “can VR improve students’ motivation to learn compared to traditional learning methods?” Six female and five male students (N=11) aged 13 and 14 years participated.

Table 1

Participant Characteristics (N=11).

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age</th>
<th>Nearpod Experience?</th>
<th>VR Experience?</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Female</td>
<td>14</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>F2</td>
<td>Female</td>
<td>14</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>F3</td>
<td>Female</td>
<td>13</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>F4</td>
<td>Female</td>
<td>13</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>F5</td>
<td>Female</td>
<td>13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>F6</td>
<td>Female</td>
<td>13</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>M1</td>
<td>Male</td>
<td>13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>M2</td>
<td>Male</td>
<td>14</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>M3</td>
<td>Male</td>
<td>14</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>M4</td>
<td>Male</td>
<td>13</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>M5</td>
<td>Male</td>
<td>13</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Student Performance

At the end of both lessons, before the participants did the survey and the interview, they were given the open-ended assignment to write down 1-3 sentences that they found interesting about the solar system (Appendix J). There was not a large difference between the answers from the control lesson and the experimental lesson. All the participants did the assignment and wrote down 1-3 facts about something they found to be interesting about the solar system. For example, participant F2 wrote down relevant facts they found to be interesting in the two lessons (Table 2).

All the answers from the assignment after the control lesson were related to facts the participants had read in the lesson, while some of the answers from the assignment after the experimental lesson referred to something the participant had observed, such as for example participant F5 (Table 2). Some of the answers from the assignment after the experimental lesson were also related to the immersive and interactable features of VR, such as for example participant M4’s and M5’s answers (Table 2). Based on M5’s answer in the assignment, the experimental lesson seemed to have raised more awareness and metacognition about the learning content and the learning tool for this student. Participant M5’s results in the survey (Table 3) and the interview (Appendix I) also revealed that they liked and enjoyed the experimental lesson more than they liked the control lesson.
<table>
<thead>
<tr>
<th>Write 1-3 facts that you find interesting about the solar system.</th>
<th>Example quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Lesson</td>
<td>Experimental Lesson</td>
</tr>
<tr>
<td>Participant</td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td>&quot;I find the asteroid belt interesting. The fact that it is made from bits of planets is really cool. I also think that what Saturn's rings are made out of is interesting&quot;</td>
</tr>
<tr>
<td>F5</td>
<td>&quot;I didn't know that there are other dwarf planets in our solar system. I thought it was just Pluto. I also it didn't know that venus and earth were sort of like sisters in a way&quot;</td>
</tr>
<tr>
<td>F5</td>
<td>&quot;A planet can be made from helium&quot;</td>
</tr>
<tr>
<td>M4</td>
<td>&quot;Sometimes you can see venus I think it was during the day. one of the planets was flipped over on its side&quot;</td>
</tr>
<tr>
<td>M4</td>
<td>&quot;I found it interesting that I was able to go up close to the different planets and see them from different points of view&quot;</td>
</tr>
<tr>
<td>M5</td>
<td>&quot;I think something that was very interesting was that I was able to see all of the planets in 3D which really helped me become engaged with the lesson. Also I liked the different features in the lesson like being able to increase the size, and be able to move around the solar system&quot;</td>
</tr>
<tr>
<td>M5</td>
<td></td>
</tr>
</tbody>
</table>
The assignment answers also revealed that the participants had pre-existing knowledge about the solar system and the specific planets. One participant, for example, answered after the control lesson that: “Pluto is not a planet anymore.” The text from the control lesson read: “in 2006, Pluto lost its planetary status.” This indicates that the participant already knew what a planet is and probably had heard about the planet Pluto since they reported this as an interesting fact. The “before you read” passage in the control lesson started with a drawing assignment where the students were asked to draw a line from the name to the correct image of the planet. Only three out of the eleven participants mixed up one or two planets, they were otherwise able to name the planets correctly based on their location from the sun and an image of the planet. This confirms that the participant already had knowledge about how the planets look like and the order of the planets.

Working Time on Learning Task

The experimental lesson facilitated a freer learning situation than the control lesson, but there were structures the participants had to follow in the experimental lesson as well. In the experimental lesson, the participants had to watch the eight minute long “Orrery Tour” video and they had to do the tutorial on how to navigate in the virtual solar system (for a detailed lesson plan see Appendix E for control lesson and Appendix F for experimental lesson).

The participants spent an average time of 12.36 (SD = 2.76) minutes working on the control lesson and an average time of 19.73 (SD = 4.05) minutes working on the experimental lesson, including the eight minute long “Orrery Tour” video. At the end of the experimental lesson, the participants could spend some time of their own choice to investigate the virtual environment, which is the reason for the bigger difference between the time spent in the
experimental lesson and the control lesson. They spent an average time of 7.37 minutes more working in the experimental lesson than they did in the control lesson. One participant ended the experimental lesson after 14 minutes. This was a first-time user who had already spent about 30 minutes in VR in the intro lesson setting up and adjusting the VR headset before they participated in the control and experimental lesson, and they reported some motion sickness in the experimental lesson. It is therefore reasonable that this participant ended the experimental lesson earlier than the other participants because they were tired.

**Intrinsic Motivation Inventory Survey**

Immediately after the participants completed the lessons, they were sent a link to the digitized IMI survey. They were allowed to ask for help or clarification if they did not understand a question. The survey for the control lesson and the experimental lesson were identical measuring self-reported scores of intrinsic motivation for both lessons. The participants spent an average time of 2 minutes and 34 seconds to complete the survey after the control lesson and an average time of 2 minutes and 5 seconds to complete the survey after the experimental lesson (Appendix H). It is reasonable that the participants finished the survey faster the second time because they had already done the survey one time and were more familiar with the questions.

The IMI consisted of 22 questions correlated to four subscales, where the minimum score was 1, and the maximum score was 7 in each subscale. A higher score indicated more of the concept described in the subscale name. The interest/enjoyment subscale was considered the self-reported measure of intrinsic motivation, while perceived choice and perceived competence are theorized to be positive predictors of both self-reported and behavioral measures of intrinsic
motivation. A higher score on pressure/tension meant the person felt more pressure and tension, and a high score is theorized to be a negative predictor of intrinsic motivation (Intrinsic Motivation Inventory, n.d.).

**Mean Score**

The mean score from the eleven participants was calculated for every subscale for both lessons (Table 3). The mean score difference was the difference in mean score between the experimental lesson and the control lesson. To test for significance, a t-Test Paired Two Sample for Means was conducted (Table 4). The mean score in every subscale was in favor of the experimental lesson with a total mean score difference was significant with 3.33 points (p<.01) in favor of the experimental lesson (Figure 1).

**Figure 1**

*Mean Subscale Scores From IMI Survey After Control Lesson and Experimental Lesson (VR).*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Control Lesson</th>
<th>Experimental Lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest/Enjoyment</td>
<td>4.45</td>
<td>6.22</td>
</tr>
<tr>
<td>Perceived Competence</td>
<td>5.11</td>
<td>5.67</td>
</tr>
<tr>
<td>Perceived Choice</td>
<td>5.07</td>
<td>5.76</td>
</tr>
<tr>
<td>Pressure/Tension</td>
<td>2.38</td>
<td>2.07</td>
</tr>
</tbody>
</table>
The participants’ self-reported mean score was higher in the subscales interest/enjoyment, perceived competence, and perceived choice and lower in the subscale pressure tension after the experimental lesson than after the control lesson. This data indicates that the participants were more intrinsically motivated during the experimental lesson than the control lesson. A t-test were conducted for the four subscales and the total mean, finding only the pressure/tension subscale not significant (p>.05) (Table 4).

All the reported subscale scores were in positive favor of the experimental VR lesson, and combined was the total reported score significant (p<.01) and 3.33 points higher in the experimental lesson than in the control lesson. Especially high was the mean score for the main intrinsic motivation predictor, interest/enjoyment. In this subscale, the participants reported an average score of 1.77 (p<.01) points higher in the experimental lesson than the control lesson. The 1.77 points higher score in the 7 points scale makes up 25.23% of the total score of interest/enjoyment subscale. The positive predictors of self-report and behavioral measures of intrinsic motivation; perceived choice and perceived competence, were also higher for the lesson when VR was used. The participants reported 0.56 (p<.01) points higher scores in the perceived competence subscale and 0.69 (p<.02) points higher scores in the perceived choice subscale for the experimental lesson.

The negative predictor for intrinsic motivation, pressure/tension, was also in a small favor of VR. The experimental lesson’s mean score was 0.31 (p>.05) points lower than the control lesson. Although still in favor of the experimental lesson, the pressure/tension subscale was the lowest mean score difference in favor of the experimental lesson. Four of the participants reported less pressure/tension during the control lesson, and one participant reported the same
score in both lessons. The control lesson was designed in a format that is familiar to most students (Appendix E), and nine of the eleven participants reported in the interview to have used Nearpod in school before (Table 1). It is reasonable to believe that they felt more comfortable in a situation that was more familiar to them. In this case, using VR or using it for education was less familiar to the participants than Nearpod, which makes it realistic that the pressure/tension subscale was in favor for some participants in the control lesson.

Table 3

*Individual Scores From IMI Survey After Control Lesson and Experimental Lesson (VR).*

*Score range is 1-7. A low score is positive in subscale pressure/tension.*

*CL = Control Lesson, EL = Experiential Lesson.*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Interest/enjoyment</th>
<th>Perceived competence</th>
<th>Perceived choice</th>
<th>Pressure/tension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CL</td>
<td>EL</td>
<td>CL</td>
<td>EL</td>
</tr>
<tr>
<td>F1</td>
<td>4.71</td>
<td>6.43</td>
<td>6.40</td>
<td>6.40</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.53)</td>
<td>(0.55)</td>
<td>(0.55)</td>
</tr>
<tr>
<td>F2</td>
<td>3.14</td>
<td>6.14</td>
<td>4.20</td>
<td>5.40</td>
</tr>
<tr>
<td></td>
<td>(0.90)</td>
<td>(0.69)</td>
<td>(0.45)</td>
<td>(0.55)</td>
</tr>
<tr>
<td>F3</td>
<td>6.29</td>
<td>7.00</td>
<td>7.00</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>F4</td>
<td>4.71</td>
<td>6.57</td>
<td>5.80</td>
<td>5.80</td>
</tr>
<tr>
<td></td>
<td>(0.95)</td>
<td>(0.53)</td>
<td>(0.45)</td>
<td>(0.84)</td>
</tr>
<tr>
<td>F5</td>
<td>5.71</td>
<td>6.14</td>
<td>4.80</td>
<td>5.80</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.69)</td>
<td>(0.45)</td>
<td>(0.45)</td>
</tr>
<tr>
<td></td>
<td>F6</td>
<td>M1</td>
<td>M2</td>
<td>M3</td>
</tr>
<tr>
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<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>3.43</td>
<td>5.29</td>
<td>3.57</td>
<td>6.86</td>
</tr>
<tr>
<td>(0.79)</td>
<td>(0.49)</td>
<td>(0.53)</td>
<td>(0.38)</td>
<td>(1.27)</td>
</tr>
<tr>
<td></td>
<td>5.57</td>
<td>6.14</td>
<td>5.71</td>
<td>7.00</td>
</tr>
<tr>
<td>(1.90)</td>
<td>(0.38)</td>
<td>(1.11)</td>
<td>(0.00)</td>
<td>(0.79)</td>
</tr>
<tr>
<td></td>
<td>3.20</td>
<td>5.80</td>
<td>5.40</td>
<td>6.00</td>
</tr>
<tr>
<td>(0.84)</td>
<td>(1.30)</td>
<td>(1.67)</td>
<td>(0.71)</td>
<td>(0.45)</td>
</tr>
<tr>
<td></td>
<td>4.40</td>
<td>5.20</td>
<td>6.00</td>
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<tr>
<td>(0.55)</td>
<td>(0.45)</td>
<td>(0.71)</td>
<td>(0.45)</td>
<td>(0.45)</td>
</tr>
<tr>
<td></td>
<td>2.40</td>
<td>5.80</td>
<td>6.00</td>
<td>7.00</td>
</tr>
<tr>
<td>(2.61)</td>
<td>(0.45)</td>
<td>(0.71)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td></td>
<td>2.80</td>
<td>6.00</td>
<td>6.20</td>
<td>7.00</td>
</tr>
<tr>
<td>(2.68)</td>
<td>(0.00)</td>
<td>(1.79)</td>
<td>(1.30)</td>
<td>(1.79)</td>
</tr>
<tr>
<td></td>
<td>4.80</td>
<td>2.20</td>
<td>1.80</td>
<td>2.00</td>
</tr>
<tr>
<td>(1.79)</td>
<td>(0.84)</td>
<td>(1.30)</td>
<td>(1.41)</td>
<td>(0.45)</td>
</tr>
<tr>
<td></td>
<td>5.00</td>
<td>1.80</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(2.35)</td>
<td>(0.45)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(1.10)</td>
</tr>
</tbody>
</table>

**Difference in Mean Scores**

EL - CL

**Mean**

1.77
0.56
0.69
-0.31
Table 4

*T-tests Comparing IMI Survey Mean Difference from Control Lesson to Experimental Lesson.*

*CL = Control Lesson, EL = Experiential Lesson.*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Mean Score CL</th>
<th>Mean Score EL</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interes/enjoyment</td>
<td>4.45</td>
<td>6.22</td>
<td>0.0004*</td>
</tr>
<tr>
<td></td>
<td>(1.62)</td>
<td>(0.91)</td>
<td></td>
</tr>
<tr>
<td>Perceived competence</td>
<td>5.11</td>
<td>5.67</td>
<td>0.0094*</td>
</tr>
<tr>
<td></td>
<td>(1.41)</td>
<td>(1.03)</td>
<td></td>
</tr>
<tr>
<td>Perceived choice</td>
<td>5.07</td>
<td>5.76</td>
<td>0.0191*</td>
</tr>
<tr>
<td></td>
<td>(1.73)</td>
<td>(1.57)</td>
<td></td>
</tr>
<tr>
<td>Pressure/tension</td>
<td>2.38</td>
<td>2.07</td>
<td>0.2060**</td>
</tr>
<tr>
<td></td>
<td>(1.51)</td>
<td>(1.55)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.25</td>
<td>23.58</td>
<td>0.0027*</td>
</tr>
<tr>
<td></td>
<td>(0.42)</td>
<td>(0.32)</td>
<td></td>
</tr>
</tbody>
</table>

Note: The pressure/tension subscale was reversed in the total calculation (8 - score) in order for all the numbers to have the same value.

*CL-EL difference is significant

**CL-EL difference is not significant

User Characteristics

Every participant’s total score from the IMI survey was in favor of the experimental lesson over the control lesson (Table 3). However, there were some differences among the participants for how much higher they scored the VR experimental lesson than the control lesson. Some participants also favored the control lesson in one or two subscales. There were
five first-time users of HMD VR in this research project, and their self-reported score in the interest/enjoyment subscale may indicate there was a novelty effect from using the VR headset for the first time (Table 6).

**Irregular Participants.** Four participants reported a higher difference of total mean scores (all the subscales combined) between the experimental and the control lesson than the total mean score for all the participants. The average difference for all the participants was 3.33 points higher in favor of the experimental lesson. Participant M5’s self-reported score was 11.83 points higher (lower for the pressure tension subscale) for the experimental lesson than the control lesson. Their interest/enjoyment subscale difference was especially large, with 4.43 points higher for the experimental lesson (average was 1.77). Participant M5 also expressed a negative attitude towards the control lesson in the interview. Also, participants F2, M2, and F6 had a total mean score difference between the experimental and control lessons of 5.40, 3.74, and 3.54. The median number of all the participants’ difference scores between experimental and control lessons was 2, suggesting that these four participants, especially participant M5, strongly contributed to a higher mean score for the experimental lesson. Four participants, F4, F5, F6, and M4, reported higher pressure/tension scores from the experimental lesson than the control lesson. Participant F3 reported the same score for both the lessons in the pressure/tension subscale.

**Gender Analysis.** Six females and five males participated in this study (Table 5). There was not observed any major difference between female and male participants’ mean scores. However, there were some minor differences; the female participants reported higher average scores in the subscale interest/enjoyment and perceived competence, while the male participants reported higher average scores in the perceived choice subscale and lower average scores in the
pressure/tension subscale. The largest difference was found in the subscale perceived choice, where the male participants reported a 0.87 points higher score than the female participants in the experimental lesson. The second-largest difference was found in the pressure/tension subscale, where the male participants reported a 0.72 points lower score than the female participants after the experimental lesson. Because of the low sample size, these differences are most likely due to individual variance rather than gender variance. The standard deviation is higher among the female participants in the perceived choice subscale and the pressure/tension subscale (Table 5) than for all the participants together (Table 3) and for the male participants (Table 5), indicating that there is a larger difference in between the female participants than between the female and the male participants in these subscales.

Table 5

*Gender Mean Subscale Scores From IMI Survey After Control Lesson and Experimental Lesson (VR). Subscales scores are reported individually for the CL and EL. Score range is 1-7. A low score is positive in subscale pressure/tension. CL = Control Lesson, EL = Experiential Lesson.*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Interest/enjoyment</th>
<th>Perceived competence</th>
<th>Perceived choice</th>
<th>Pressure/tension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CL</td>
<td>EL</td>
<td>CL</td>
<td>EL</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Mean</td>
<td>4.67</td>
<td>4.20</td>
<td>6.31</td>
<td>6.11</td>
</tr>
<tr>
<td></td>
<td>(1.30)</td>
<td>(1.91)</td>
<td>(0.96)</td>
<td>(0.82)</td>
</tr>
<tr>
<td></td>
<td>5.23</td>
<td>4.96</td>
<td>5.80</td>
<td>5.52</td>
</tr>
<tr>
<td></td>
<td>(1.38)</td>
<td>(1.43)</td>
<td>(0.95)</td>
<td>(1.10)</td>
</tr>
<tr>
<td></td>
<td>4.97</td>
<td>5.20</td>
<td>5.37</td>
<td>6.24</td>
</tr>
<tr>
<td></td>
<td>(1.83)</td>
<td>(1.57)</td>
<td>(1.87)</td>
<td>(0.91)</td>
</tr>
<tr>
<td></td>
<td>2.50</td>
<td>2.24</td>
<td>2.40</td>
<td>1.68</td>
</tr>
<tr>
<td></td>
<td>(1.65)</td>
<td>(1.28)</td>
<td>(1.83)</td>
<td>(1.06)</td>
</tr>
</tbody>
</table>
**First Time HMD VR Users.** The participants F2, F3, F4, F6, and M5 had never used HMD VR before participating in this research project (Table 6), while participant F1, F5, M1, M2, M3, and M4 had a VR headset in their homes and were used to the technology.

The mean score for the subscale pressure/tension in the experimental lesson was higher for the first-time users, 2.28 vs 1.90 for the experienced VR users, indicating that first time users felt more pressure or tension because this was their first time using HMD VR. The first time users reported a mean score difference in the subscale pressure/tension in that was larger than the experienced users; 0.64 vs. 0.03. The experienced VR users reported close to the same level of pressure tension in both lessons. As it was their first time using HMD VR, this can be why participants F4 and F6 reported higher pressure/tension scores in the experimental lesson. For example, participants F6, F2, and M4 reported in their interviews that they experienced a low degree of physical discomfort, such as feeling a little tired or having a small headache, after using the VR headset in the experimental lesson. Participant F6 reported a high pressure/tension score (5) for the experimental lesson, but they also reported a high score for the control lesson (4.8).

First-time HMD VR users reported a slightly higher score in the interest/enjoyment subscale than the experienced VR users in the experimental lesson score with 6.29 points vs. 6.17 points (Table 6). In the subscale interest/enjoyment, the first-time users also reported a greater mean score difference between the control lesson and the experimental lesson than the experienced VR users, 2.43 vs. 1.21, which may indicate a novelty effect for first-time users. As this is a small pool of numbers, the result can be vulnerable to big outliers. Participant M5’s
scores contributed strongly in favor of the experimental lesson (see Table 3). However, even if M5 is excluded from the mean score for first-time VR users under the subscale interest/enjoyment, the first-time VR users still reported a higher score than the experienced VR users with a mean score difference of 1.93.

**Table 6**

*Mean Score from IMI Survey for First Time HMD VR Users and Experienced HMD VR Users. Subscales scores are reported individually and combined as the total mean score difference for the whole CL and EL.*

*Score range is 1-7. A low score is positive in subscale pressure/tension.*

*CL = Control Lesson, EL = Experiential Lesson.*

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CL</td>
</tr>
<tr>
<td>Interest/enjoyment</td>
<td>3.86(1.74)</td>
</tr>
<tr>
<td>Perceived competence</td>
<td>4.80(1.52)</td>
</tr>
<tr>
<td>Perceived choice</td>
<td>4.28(1.89)</td>
</tr>
<tr>
<td>Pressure/tension</td>
<td>2.92(1.76)</td>
</tr>
</tbody>
</table>

| First-Time VR Users       | 3.86(1.74)  | 6.29(1.03)  |
|                          | 4.80(1.52)  | 5.60(1.06)  |
|                          | 4.28(1.89)  | 5.12(1.95)  |
|                          | 2.92(1.76)  | 2.28(1.86)  |

| Experienced VR Users      | 4.95(1.33)  | 6.17(0.78)  |
|                          | 5.37(1.25)  | 5.73(1.00)  |
|                          | 5.73(1.24)  | 6.30(0.86)  |
|                          | 1.93(1.06)  | 1.90(1.24)  |

| Difference First-Time VR Users EL** - CL* | 2.43 0.80 0.84 -0.64 2.71 |
| Difference Experience VR Users EL** - CL* | 1.21 0.37 0.57 -0.03 3.40 |
Participants Reaction to the Lessons

The interview attempted to comprehensively understand what the participants thought about the control lesson and the experimental lesson (Appendix C, H). While the IMI survey was a predictor for intrinsic motivation, the interview gave a better understanding of the participants’ experiences of the lessons. Topics discussed in the interview were the participants' experience with the tool they used in the lesson (Nearpod/VR), level of immersion, the participants’ opinion about the lesson, and their attitudes towards the subject science.

The participants participated in the experimental lesson and interview after the control lesson and interview, and many of them compared the two lessons in their second interview.

The Subject Science

Most of the participants liked the subject of science and thought it was fun. Two participants said they did not like science, but one of them referred to the home-school situation brought by the COVID-19 pandemic. The home school lessons for this participant was described as little enjoyable because it consisted of reading articles and answering questions from the reading.

On the question about how they usually like to learn in science, the participants reported that their preferred way of learning was not to read about the content but to explore it physically through experiments or watch videos (Table 7).
Table 7

Example Quotes From The Interview Question About How the Participants Normally Like to Learn In Science.

<table>
<thead>
<tr>
<th>How do you normally like to learn in this subject?</th>
<th>Example quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I don’t like reading. I don’t know, videos are kind of interesting.”</td>
<td></td>
</tr>
<tr>
<td>“I like visual and tactile stuff, like videos or physically doing something”</td>
<td></td>
</tr>
<tr>
<td>“Hands-on approach for sure.”</td>
<td></td>
</tr>
<tr>
<td>“I am a visual learner; I like to see things and touch things that I am learning about. Rather than reading about and looking at.”</td>
<td></td>
</tr>
<tr>
<td>“Experiments”</td>
<td></td>
</tr>
<tr>
<td>“I usually just read out of the textbook but I like to watch videos.”</td>
<td></td>
</tr>
</tbody>
</table>

The Lessons

The Control Lesson. Overall the participants expressed liking the control lesson and thought it was a simple lesson with an interesting topic (see Table 8 for examples). They called it “pretty good,” “easy,” “straight forward,” and similar to what they usually do in school. One participant did not like the lesson. They said, “It gave information but not in the greatest way.” This corresponded with a low score from the control lesson in the IMI survey from this participant.
Most of the participants liked the video or the activities, such as the drawing assignment or the question assignment. One participant summed the lesson up to be “very mediocre” because it was an average and normal lesson that did not stand out to them.

**The Experimental Lesson.** The interview answers reflected the IMI survey results. All the participants expressed liking the experimental lesson more than the control lesson. They used expressions like “really fun,” “enjoyed it more,” “more interesting,” “I was actually there,” “more interactive.”

The participants’ answer in interview question 6, “What did you enjoy most about this lesson?” demonstrated the interactive and immersive feature of the experimental lesson (Table 8). Although the participants appreciated the interactive elements in the control lesson when asked the same question, they either commented on one section of the lesson they liked, like the video or one assignment, or said they liked it all. When the participants were asked what they liked most about the experimental lesson, they talked about something they experienced or did, such as something they saw, clicked on, picked up, grabbed, moved, or explored. Participant M2 explicitly said that the physics in the lesson was what they enjoyed the most, and they wanted more of it:

I got to pick up the sun. I like the hands-on bit of it. I like that you can grab stuff and use physics in it. I would like more physics, I wish I could grab it and throw it around, but I guess that is not how the solar system works. I like that you could pick up things and hold it. I picked up everything I could find.
Table 8

*Example Quotes From The Interview Question About What the Participants Liked the Most in the Control Lesson and the Experimental Lesson.*

<table>
<thead>
<tr>
<th>What did you enjoy the most in this lesson?</th>
<th>Example quote</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Lesson</strong></td>
<td>“I would say the illustrations, the videos and the pictures.”</td>
</tr>
<tr>
<td></td>
<td>“I liked the activities and the questions. I like this because that is fun. And that it was very simple and straight forward.”</td>
</tr>
<tr>
<td></td>
<td>“I liked the layout of it I thought it was a good layout”</td>
</tr>
<tr>
<td></td>
<td>“Not really, I like all Nearpods.”</td>
</tr>
<tr>
<td></td>
<td>“I’d say I enjoyed the part where it was easy to take all the information in. Like I was able to understand it very well. Probably when I read the stuff and it was pretty straight forward.”</td>
</tr>
<tr>
<td><strong>Experimental Lesson</strong></td>
<td>“Being able to see all the planets and then being able to click on one and then learn about that planet.”</td>
</tr>
<tr>
<td></td>
<td>“That after the video, I could go around and choose what I wanted to look at – I thought that was really cool.”</td>
</tr>
<tr>
<td></td>
<td>“That it was very interactable, like I felt like I was being there, I could pick up the planets and read about them. It was really cool.”</td>
</tr>
<tr>
<td></td>
<td>“I enjoyed how you could move at the pace you wanted and look and explore different things that you wanted to see.”</td>
</tr>
</tbody>
</table>
“I liked that you could speed up time and see where each planet would be in this year or where it would be like two weeks from now, or where it was a year ago. That was really cool.”

**Tool**

**Nearpod.** Two of the participants had never used Nearpod before, the other nine participants had used it before in school. Most of the participants were positive to Nearpod in this lesson and for use in school. They expressed positive attitudes towards it and several of them liked the self-paced and interactive aspect of the tool. One participant said “I like how it just not is about reading and it gives you other things to do while you are reading to make sure you actually understand what you just read.”

**VR.** Five participants used HMD VR for the first time in this research project. Three of the first-time users said they felt “a little bit” motion sick when using the VR headset for the lesson. None of the other participants felt motion sick or unwell during the lesson.

**Immersion**

The participants expressed liking the experimental lesson more than the control lesson and enjoyed the immersive and interactive features of VR. They reported becoming more curious about the lesson’s topic and wanted to learn more about it after the experimental lesson.

On the question of how immersed or present the participant felt, most of the participants in the control lesson said they did not feel present. Some said they were pretty present, but they could have interpreted the question as “how focused were you”? For example, one answer was, “I felt like I was present, I zoned out a little bit”.

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For the experimental lesson, the participants found the lesson to be immersive and interactive. One participant pointed out the difference between the sensory immersion and the conscious presence: “I would say that it felt pretty real. I kind of felt like I was there, but I knew I was not there, but I kind of felt that I was. I really liked it.” This was also emphasized by another participant, who clarified one limitation of the VR environment by saying: “First of all, it is the logical part – how am I breathing in space?”

**Interview Summary**

Based on the participants' answers in the interviews, it appeared that the experimental lesson was more meaningful than the control lesson. When the participants talked about the lessons, they referred to the experimental lesson as something they had done and experienced. In contrast, they referred to the control lesson as an assignment with sections. One participant said about the experimental lesson: “it is not a science textbook. It stays in my mind longer whenever I'm in VR.”

There is a chance the novelty effect played a part, especially among the first-time VR users. However, as explained by one first-time user who believed students in school would be more excited for class if they could use VR: “I think the most exciting part would be how they actually get to be in the solar system or wherever, and actually get to do things manually and be in control.” It is not the VR technology itself that motivates, but the environment and content it can provide.

**Results Summary**

The survey and the interview addressed the research question “can VR improve students’ motivation to learn compared to traditional learning methods?” Results from the intrinsic
motivation survey (Appendix G) confirmed the research question of whether using VR can improve students’ motivation to learn compared to traditional learning methods. The participants reported higher scores of intrinsic motivation in favor of the experimental lesson with 3.33 points on the 7 point scale (Table 3). Every participant’s self-reported mean score of the intrinsic motivation survey favored the experimental lesson, although there were differences among the eleven participants for how much higher scores they reported in favor of the experimental lesson (Table 3, Table 5, Table 6).

Results from the interview (Appendix I) addressed the hypothesis, where all of the participants expressed that they liked and enjoyed the experimental lesson better than the control lesson because of the immersive and interactive features of VR. The interview results indicated that the participants experienced the content in a more meaningful way than in the control lesson. They expressed more positive attitudes to the use of VR in the experimental lesson, and they emphasized the experience of “being there” and the higher level of interaction with the objects as the distinguishing difference from the control lesson.

The interview results and the survey results complemented each other and both were in favor of the experimental lesson. The participants who reported low mean scores or subscale scores for the lessons in the survey also expressed less positive attitudes in the interview related to that matter. For example, one participant who reported high pressure/tension scores in the experimental lesson, also reported in the interview being a first-time user and experiencing some physical discomfort. These results concur because it is natural for a student to feel more tense in a novel situation where they use a tool they have no previous experience with.
Discussion

This study examined whether applying VR technologies in instruction can increase intrinsic motivation among middle school students. The background for this study was to investigate VR as a pedagogical tool that can create a meaningful and motivational learning situation for middle school students. A large portion of this paper has been dedicated to reviewing learning theory and discussing how VR can facilitate a meaningful learning environment. I believe intrinsic motivation to learn grows from an authentic and meaningful learning situation. Using VR is an instructional approach that places students in an environment where they can address, explore, and experience a problem or content that is relevant to them and the situation they are in.

Background

Digital technologies have in the past few decades quickly entered into the education system. They have been referred to as a “revolution” (Kunnskapsdepartementet, 2017, p. 3) and, according to the U.S. Department of Education (2017), a “powerful tool for transforming learning” (p. 3) that can “accelerate, amplify, and expand the impact of powerful principles of learning” (p. 12). However, large-scale research studies have shown that the ICTs used in school today might not have been as efficient as hoped for (Bulman & Fairlie, 2016; International Association for the Evaluation of Educational Achievement, 2019; OECD, 2015; U.S. Department of Education, 2017). It has most often been used as substitution or augmentation for teaching methods without technology (see Illustration 1 SAMR Model). VR has the potential to redefine education as students can access previously inaccessible experiences and learning situations in VR.
The concept of VR has been around for a long time, but it is not until recent years that the technology has developed to be affordable and accessible. Many of the large technology companies, such as Microsoft, Apple, and Facebook, are making big bets on the future of AR and VR as the technology quickly improves (Gurman, 2020; Heath & Olson, 2021; Zibreg, 2021).

The field of medicine already considers VR to be a cost-effective educational tool, and I believe it has the same potential in primary and secondary education (Li et al., 2017; Satava & Jones, 1998). There is a large research base on VR in higher education, and the time has come to investigate VR’s potential in transforming and redefining education for younger students. Using VR, middle school students can be given agency and attribution to act in the virtual environment and interact with virtual objects or other VR players. Younger students are also still developing cognitively, and experience with situations and objects is one of the main factors of cognitive development among children (Lave & Wenger, 1991; Piaget, 1964). Dewey (1916) argued over a hundred years ago that reality must be experienced and students must be equipped with agencies for doing so. Based on the pedagogy of constructivism and situated learning, I have argued that the immersive and interactive features of VR can facilitate learning environments supporting cognitive processes which the traditional classroom situation or the traditional learning technologies cannot do.

Learning happens in a meaningful context, and knowledge is constructed as subjective interpretations of individual experiences, not as objective facts. Knowledge cannot simply be transmitted, it must undergo a fundamental development from the child’s existing level of ability and knowledge (Fosnot & Perry, 2005; Piaget, 1964). New knowledge is interpreted in the light
of what one already knows (Gee, 2014). Students in primary and secondary education often have limited experience with the many concepts they learn about in school (Bransford et al., 2000). Therefore, it is important for a student’s motivation that the learning situation takes place in a meaningful context (Greeno, 1989). Immersive and interactive VR technology can facilitate an authentic learning environment of concrete or abstract objects or situations, where students can actively participate and construct knowledge.

The main difference between VR technology and traditional technology is the perceptual illusion of feeling present in the virtual environment (Slater, 2018). This is achieved by advanced input and output features from the VR hardware. The difference between an experience in VR and an experience in the real world is that the virtual environment can be anything or anywhere. In contrast to the real world, VR can create a situation for the concept the student learns about in school that they cannot access in the real world. This can be historical experiences such as seeing a ruin before it becomes a ruin, it can be a social language experience such as meeting with a virtual avatar that speaks another language, or it can be a scientific experience that would be unethical or inaccessible in the real world such as dissecting organs or exploring the solar system. However, a good VR experience depends on a well-built application. Some VR users can experience discomfort or motion sickness when using VR which can make the VR experience unenjoyable (Jensen and Konradsen, 2018).

**Methods Used to Address the Research Question**

The research question addressed in this study was: “can VR improve students’ motivation to learn compared to traditional learning methods?” 11 middle school students aged 13 and 14 participated in the study. In this group, there were six female students and five male students.
Five of the participants had never tried HMD VR before, while six of them had previous experience with VR. All the students participated in one control lesson where the online learning tool Nearpod was used and one experimental lesson where VR was used as a learning tool. To measure motivation, the IMI survey and conceptual interviews were conducted after both lessons.

The IMI survey was a questionnaire developed by experienced motivation scholars and had been used in several studies related to intrinsic motivation (Intrinsic Motivation Inventory, n.d; McAuley et al., 1989; Ryan, 1982). The 22 question IMI survey measured four subscales; interest/enjoyment, perceived choice, perceived competence, and pressure/tension, in which the participants reported scores with points from one to seven. High scores in the three first subscales were indicators of intrinsic motivation, while low scores were a positive predictor in the pressure/tension subscale.

An additional conceptual interview allowed the participants to explain their experience and perception of the control lesson and the experimental lesson.

**Findings and Implications**

The purpose of this study was to investigate the potential of VR in education and whether it could positively contribute to motivating students’ interest in learning through meaningful learning in virtual immersive and interactive environments. The study results confirmed the research hypothesis that students experienced a higher sense of meaningful learning and intrinsic motivation when using immersive and interactive Virtual Reality technology for learning compared to the traditional classroom situation. Based on the self-reported scores from the IMI survey, the experimental lesson was shown to be more motivating. This result was supported in
the interview as the participants expressed liking and enjoying the experimental lesson more because of the immersive and interactive features of VR. Many of them liked it because it felt like they were “really there”. The participants talked about the control lesson as an assignment and they discussed some of the technical features of the Nearpod website, while they talked about the experimental lesson more holistically as something they did and experienced. They talked less about the technology and more about the experience.

**Intrinsic Motivation**

The experimental lesson received better self-reported scores from the participants in all the IMI survey subscales (Appendix G), with a total mean score difference of 3.33 points in favor of the experimental lesson. Particularly high was the difference in self-reported scores between the two lessons in the “interest/enjoyment” subscale with a 1.77 (25.23%) higher points score on the seven point scale in favor of the experimental lesson. This means that the participants found the experimental lesson to be more motivating than the control lesson. These results were supported in the interview. The participants found the control lesson to be straightforward and similar to something they usually do in school. For the experimental lesson, they expressed liking and enjoying this lesson more for reasons such as they felt like they were present in the solar system. They were more involved and could interact with many of the objects like the sun or the planets. In other words, the lesson that was more intrinsically motivating was the one where the participants were situated in a virtual 3D environment that felt real and authentic, which was caused by the main features of VR: immersion, interaction, and user involvement.
Immersion, Interaction, and User Involvement

Immersion. The participant clearly expressed being immersed in the experimental lesson. Some of the participants called for more immersion, interaction, and user involvement; they wanted to be able to pick up more objects and to take an even closer look at the planets. One participant pointed at the immersive sensory scarcity of VR when they asked the question “how am I breathing in space?” This comment exemplifies a curiosity and reasoning that was not observed in the control lesson. It also is an example of a student who felt a deceived bodily self-consciousness, but the information they perceived did not make sense in relation to existing knowledge. They connected this experience and feeling of being in space with previously learned knowledge and existing schemas about space. They could have reasoned that because they were in space, and they had previously learned that there is no oxygen in space, “how am I breathing in space?” The same participant also suggested that it would be cool if they could fly in a spaceship instead of just floating over the planets. This showed a student who consciously perceived the information from the virtual environment and processed it to be meaningful or not, based on what they already knew. The information they perceived did not make sense in relation to existing knowledge, because this participant probably knew that astronauts flew in spaceships and used oxygen masks when they were in space.

Interaction in the Spatial Environment. Object recognition is both a perceptual and a cognitive process (Cona & Scarpazza, 2019). The ability to interact with the objects in the spatial environment in the experimental lesson was appreciated by the participants. The ability to pick up planets or the sun, move around in the 3D virtual environment, zoom out/in, and go back/forward in time was emphasized by all the participants as something they liked being able
to do, and contributing factors to why they found this lesson to be more fun and motivating than the control lesson.

This study did not account for whether the participants were low or high spatial visualizers. However, none of the participants expressed being overwhelmed or having difficulties comprehending the virtual 3D environment. Previous research literature has been split over whether 3D models are beneficial or not for low visualizers. This study can contribute to that debate by stating that the 3D models and the 3D environment did not seem to be difficult to comprehend; it rather seemed to interest the participants to explore the 3D objects further. One participant also stated that“I was able to see all of the planets in 3D which really helped me become engaged with the lesson.” The virtual environment and objects in the experimental lesson could be moved and picked up, but they could not be manipulated in the sense of being taken apart or restructured in any way. Some of the participants wanted to be able to do more manipulation of the virtual objects and called for more intractable features.

Uttal and Cohen (2012) suggested that expertise in STEM fields is characterized by an interplay between spatial and semantic knowledge. As confirmed in the assignments and the “before you read” passage in the control lesson, the participants in this study had a great deal of pre-existing knowledge about the solar system. They already knew about the planets and were able to identify them. When students have developed mental models of domain-specific knowledge they use this in their judgments about meaningful representations rather than their general spatial abilities (Uttal & Cohen, 2012).

User Involvement. Taking on roles or playing a character can be a powerful motivator for learning (Gee, 2003). How the immersive virtual environment facilitated role-play was
explicitly explained by one participant stating that “it felt like I was an astronaut looking from above.” This role play, or identification with a character, was artificially staged by VR but came authentically as a result of spatial presence in the virtual environment.

Green et al. (2004) suggested that transportation into a narrative world was an essential element of why people enjoy media. The participants' choice of words when they talked about the control lesson and the experimental lesson, where they talked about the control lesson as an assignment they did while they talked about the experimental lesson as an experience they had, suggests that the participants were more immersed into the experimental lesson. None of the participants expressed feeling transported into the control lessons, while for the experimental lesson, they associated the feeling of being in space with those who actually go to space: the astronauts.

**Self-Efficacy**

Although self-efficacy was not measured directly in this study, perceived choice and perceived competence were two subscales in the IMI survey which was theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation. The results from the two subscales were both in favor of the VR lesson.

When students perceive high self-efficacy, they tend to put in greater effort and persist longer (Bandura et al., 2001; Schunk, 2012). The fact that the participants spent more voluntary time on the learning task in the experimental lesson than they did in the control lesson supports the assumption that they perceived higher self-efficacy. The participants spent an average time of 7.37 minutes more in the experimental lesson (19.73 minutes) than they did in the control lesson (12.36 minutes). In the interview, the participants expressed positive attitudes towards the
freedom they were given in the virtual environment, such as they could move where they wanted to or pick up the planets they wanted to.

It can be argued that the participants did not have a choice of when to end the control lesson. This is true, but that is also how the school works in real life: students come to class and are expected to work with a particular topic for a specific amount of time. The Self-determination theory framework defined three inherent conditions for optimal growth and motivation among students: the need for competence, relatedness, and autonomy. Not fulfilling these three basic needs has been found to hinder or undermine autonomous motivation (Ryan & Deci, 2000). The participants explicitly expressed in the interview that they appreciated the agency and autonomy of choosing their own activities in the lesson. Instead of being told what to learn, they chose what to learn, and they chose to spend more time learning in the experimental lesson. As emphasized by the SDT framework, the more students are externally regulated, the less intrinsic motivation they seem to show towards the learning content (Ryan & Deci, 2000). The experimental lesson pointed towards the opposite; they were less externally regulated and more intrinsically motivated.

One participant, a first-time user who reported some motion sickness and for that reason probably enjoyed the lesson less, ended the experimental lesson after 14 minutes. This indicates that the other participants who spent more time learning in the experimental lesson did this because they enjoyed it, and it was their choice to do it. Self-efficacy is a strong factor in motivation and effort (Bandura, 1989). Students who feel efficacious in a learning situation usually put in greater effort and persistence than those who doubt their capabilities (Bandura et al., 2001; Schunk, 2012).
The Control Lesson

The control lesson aimed to imitate a traditional classroom situation. With the current situation with the COVID-19 pandemic, this research project had to be conducted online, and it became impossible to imitate the traditional classroom situation where one teacher instructs 20-30 students. However, I believe the control lesson still served its purpose as a traditional lesson. The participants stated in the interview that they had done similar types of lessons in school or that this lesson reminded them of school work. Their interview answers and the survey results indicated that the control lesson was a good lesson that could be used in a traditional classroom situation.

The overall impression of the control lesson was that it was an average and “pretty good” lesson. The control lesson followed traditional lesson planning principles with a “before you read,” a “reading passage,” and an “after your read” section, in which the pedagogical goal is to activate prior knowledge, learn new knowledge, and use newly learned knowledge. It was confirmed by the participants that the control lesson was similar to the lessons they usually did in school.

Although the experimental lesson gained higher scores than the control lesson in the IMI survey, the control lesson still got good scores (Table 3). The IMI survey score ranged from 1-7 and the middle score in the survey was 4. The participant’s mean scores were higher than 4 in the three subscales interest/enjoyment (M = 4.45, SD = 1.62), perceived competence (M = 5.11, SD = 1.41), and perceived choice (M = 5.07, SD = 1.73), and lower in the subscale pressure/tension (M = 2.38, SD = 1.51).
Limitations of the Study

Participants. The number of participants in this study was low. This was a small study of volunteer participants, who participated in their free time out of school. They were recruited to the study through a flyer or a friend and were not reimbursed economically for their participation. That gives reason to believe that this group of students, and their legal guardians, already came into this study with positive attitudes towards the VR technology, and they participated out of an interest in the study and the technology. Six of the participants had their own Oculus Quest headset and were already using the technology. This does not mean that their results or experience in this research project was wrong, but this group of participants may not represent the average middle school student’s attitudes towards VR technology.

The Study Setup. Because of the ongoing COVID-19 pandemic, this research study was conducted one-on-one over Zoom. Although both the lessons required little teacher instruction and could have been done with a large group of students, it was not an authentic traditional classroom situation.

Both lessons were on the same subject, the solar system, but they were not identical. There was some variance in the content and the specific facts the students were taught. The subject of the VR lesson might have been more interesting for some participants. To measure solely the motivational effect of the VR technology the two lessons should have used the same application.

Novelty Effect. It is important to keep the novelty effect in mind when investigating new technology for motivational purposes. There is a chance that when utilizing VR in the instruction, the tool itself, and not the content it provides, can have an impact on the student’s
attitudes in the experimental lesson motivation. The first-time HMD VR users reported higher scores in the IMI survey’s subscale interest/enjoyment, which can indicate there was a novelty effect among them.

Conclusion

The data and interviews from this study showed that students found learning in VR more intrinsically motivating and meaningful than learning with traditional technologies. The hypothesis was confirmed showing students experienced a higher sense of meaningful learning and intrinsic motivation when using interactive and immersive VR technology for learning, compared to the traditional classroom situation.

The VR technology facilitated sensory immersion, a feeling of spatial presence, and interaction with the virtual objects. The experience of being present in the virtual environment created a perception of agency and autonomy. The immersive virtual learning environment raised more curiosity and the participants' indicated that the experimental lesson actively engaged more existing schemas. When the learner could take an active role in their own education, and the cognition was situated in a context which they found to be meaningful, the intrinsic commitment to the content became stronger.

Based on the findings in this study, I would recommend immersive VR to be implemented as a tool for learning in education for younger students (>13). VR has the potential to concretize concepts and verify theories and can expand the classroom lesson into a holistic exploration of concepts where students can get direct experience with earlier inaccessible ideas and situations.
However, as for now, VR is a tool for exploration, discovery, subject specific explanations, and a rise of subject curiosity. The VR technology still needs to develop further for it to be a fully appropriate exclusive working tool.

**Further Research**

This study indicated that learning in VR environments is more intrinsically motivating and meaningful than learning in traditional classroom situations or with traditional learning technologies. However, this study did not measure memory or learning outcome from the immersive learning situation in VR compared to the control lesson, or what this meant for future retention. My recommendation for further research of VR in education for younger students is to investigate the implications of the increased motivation and enjoyment. Does learning in VR generate a greater learning outcome and how does it affect memory over time compared to a traditional learning situation?

Although this study aimed for a multidisciplinary focus, it concentrated on the subject of science. A second suggestion for further research would be to investigate if the findings in this study hold value in lessons related to other subjects.
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Appendices

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Appendix A: Intrinsic Motivation Inventory Questionnaire

The following is a 22 item version of the scale that has been used in some lab studies on intrinsic motivation. It has four subscales: interest/enjoyment, perceived choice, perceived competence, and pressure/tension. The interest/enjoyment subscale is considered the self-report measure of intrinsic motivation; perceived choice and perceived competence are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation. Pressure tension is theorized to be a negative predictor of intrinsic motivation. Scoring information is presented after the questionnaire itself.

TASK EVALUATION QUESTIONNAIRE

For each of the following statements, please indicate how true it is for you, using the following scale:

1  2  3  4  5  6  7
not at all somewhat very
true     true     true

1. While I was working on the task I was thinking about how much I enjoyed it.

2. I did not feel at all nervous about doing the task.

3. I felt that it was my choice to do the task.
4. I think I am pretty good at this task.

5. I found the task very interesting.

6. I felt tense while doing the task.

7. I think I did pretty well at this activity, compared to other students.

8. Doing the task was fun.

9. I felt relaxed while doing the task.

10. I enjoyed doing the task very much.

11. I didn’t really have a choice about doing the task.

12. I am satisfied with my performance at this task.

13. I was anxious while doing the task.

14. I thought the task was very boring.

15. I felt like I was doing what I wanted to do while I was working on the task.

16. I felt pretty skilled at this task.

17. I thought the task was very interesting.

18. I felt pressured while doing the task.

19. I felt like I had to do the task.

20. I would describe the task as very enjoyable.

21. I did the task because I had no choice.
22. After working at this task for awhile, I felt pretty competent.

Scoring information. Begin by reverse scoring items # 2, 9, 11, 14, 19, 21. In other words, subtract the item response from 8, and use the result as the item score for that item. This way, a higher score will indicate more of the concept described in the subscale name. Thus, a higher score on pressure/tension means the person felt more pressured and tense; a higher score on perceived competence means the person felt more competent; and so on. Then calculate subscale scores by averaging the items scores for the items on each subscale. They are as follows. The (R) after an item number is just a reminder that the item score is the reverse of the participant’s response on that item.

Interest/enjoyment: 1, 5, 8, 10, 14(R), 17, 20

Perceived competence: 4, 7, 12, 16, 22

Perceived choice: 3, 11(R), 15, 19(R), 21(R)

Pressure/tension: 2(R), 6, 9(R), 13, 18

The subscale scores can then be used as dependent variables, predictors, or mediators, depending on the research questions being addressed.
Appendix B: Digitized Survey

Survey VR Lesson

For each of the following statements, please indicate how true it is for you. 1 is not true at all, 4 is somewhat true, and 7 is very true.

1. I could

2. While I was working on the lesson I was thinking about how much I enjoyed it.

3. I did not feel at all nervous about doing the task.

4. I felt that it was my choice to do the task.

5. I think I am pretty good at this task.

6. I found the task very interesting.

7. I felt tense while doing the task.

8. I didn’t really have a choice about doing the task.

9. I am satisfied with my performance at this task.

10. I was anxious while doing the task.

11. I thought the task was very boring.

12. I did not like what I wanted to do while I was working on the task.

13. I thought the task was very interesting.

14. I felt pressured while doing the task.

15. I would describe the task as very enjoyable.

16. I did the task because I had no choice.

17. After working on this task for a while, I felt pretty competent.
Appendix C: Interview protocol

Lesson 1 Nearpod

Question 1: What do you think about this lesson?

Nearpod

Question 2: Was this your first time using Nearpod?

Question 3: What do you think about using Nearpod in this lesson?

Question 4: What do you think about using Nearpod in education?

Lesson

Question 5: What do you normally think about this subject?

Question 6: How do you normally like to learn in this subject (science)?

Question 7: What did you enjoy the most in this lesson?

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual environment?

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?

Lesson 2 VR

Question 1: What do you think about this lesson?

VR

Question 2: Did you feel sick or unwell during the lesson?

Question 3: Was this your first time using VR?

Question 4: What do you think about using VR in this lesson?

Question 5: What do you think about using VR in education?
Lesson

Question 6: What did you enjoy the most in this lesson?

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual environment?

Question 10: How real did the overall experience feel?

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

Question 12: Would you describe the VR experience as different than a TV or PC experience? Please explain.

Question 13: Is there anything else you want to add about this lesson, VR, or education?
Appendix D: Intro Lesson

Lesson Plan for Intro Lesson (1)
Prepared by Caroline Roland

OVERVIEW & PURPOSE

The purpose of this lesson is to go over the security statements with the student and guide them to customize the headset and set up the VR technology.

OBJECTIVES

1. Recognize and accept the content of the minor assent.
2. Be familiar with the health and safety warnings, and know what to do if student experiences discomfort or serious health issues.
3. Know how to handle and treat the VR technology.
4. Know how to start up and navigate in the VR environment.

MATERIALS NEEDED

1. Oculus Quest Health and Safety Warnings:
2. Pre-Existing Medical Conditions Screening Tool
3. Occulus Quest headset and remotes.
4. A computer with Zoom.

ACTIVITY

1. Introduction to the research project.
   - The purpose of the project.
   - What is required from the participant?
     - Important that they are always allowed to stop their participation in the research project at any time.
   - Discuss the content of the minor assent, and make sure the student understands the content of it.
   - Information about data collection.
• Questions?

2. **Health and safety warnings**
   
   - Use the Pre-Existing Medical Conditions Screening Tool.
   
   - Emphasize the age requirements and the possible experience of discomfort or severe medical conditions. Explain to the student what might happen, and talk about if they have had any positive or negative experiences with VR before. Explain to the student that they can experience the feeling of being boat sick or car sick while using or after using VR, or experience more serious health conditions like severe dizziness, seizures, eye or muscle twitching, or blackouts.
   
   - Explain for the student what we will do if they experience any discomfort or severe medical conditions and what precautions we will take.
     - Make sure there is an adult present before we use the VR technology. The researcher will have the parents’/legal guardians’ phone number to call in case of any adverse medical events.
     - Immediately stop the lesson if the student feels any discomfort or feels sick.
     - We can also pause the lesson at any time if the student needs a break.
     - There will be no consequences for the student if we have to stop or cancel the lesson.
   
   - Explain how to use and set up the VR technology safely and what not to do.
     - Treat the technology with care, keep it in the box when not in use, keep away from pets, and do not expose the lenses to direct sunlight.
     - Set up a safe play space environment.
       - Only for indoor use.
       - 6,5 x 6,5 feet object free play area.
       - Start the VR while sitting down.
   
   - We will make sure that there is someone else at home that the researcher has emergency contact information to in case of an adverse event, and who will monitor the student while they are using the headset and controllers. If the student feels ill, we will immediately stop the lesson. If the student shows any signs of severe medical illness or loses consciousness, we will immediately call the emergency contact and ask for assistance to check on the student.

3. **Customize the technology**

The researcher will be virtually present (via Zoom) throughout the whole lesson and
guide the student in how to start the VR headset and where to find the right activities. The researcher and the student can communicate throughout the whole lesson if the student has any questions or technical problems, or the researcher wants to check in to see how the student is doing.

- Adjust the headset.
- Start the headset.
- Set the inter-pupillary distance for the lenses.
- Connect to WiFi.
- Set up the guardian system boundary.
- Do the Oculus system's tutorials.

4. **Test out some games in the VR environment.**
   - To practice using the controllers and become familiar with the feeling of being in a virtual world, the student can test out some games that the researcher already has installed in the VR technology.
     - Beat Saber. [https://beatsaber.com/](https://beatsaber.com/)
     - Pro Put Mini Golf. [https://www.proputt.com/](https://www.proputt.com/)

5. **Questions?**
Appendix E: Control Lesson

Lesson Plan for Control Lesson (2)
Prepared by Caroline Roland

OVERVIEW & PURPOSE
The student will explore our solar system and the galaxy not using VR. The purpose of this lesson is to give students a holistic impression and understanding of the solar system. This lesson aims to teach students in a similar way as they are being taught in a regular classroom situation.

EDUCATION STANDARDS
This lesson is not created to fit an educational standard but to complement the experimental lesson with VR as a similar lesson without VR. However, the lesson can be used in instructions related to the California State Standards listed below and the Common Core connections as mentioned in the Science Identifier.

Science:

1. **MS-ESS1-1 (Science (CA NGSS))**
   Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

2. **MS-ESS1-2 (Science (CA NGSS))**
   Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

3. **MS-ESS1-3 (Science (CA NGSS))**
   Analyze and interpret data to determine the scale properties of objects in the solar system.

4. **MS-PS2-4 (Science (CA NGSS))**
   Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
OBJECTIVES

1. Explore the various parts of the solar system.
2. Read about the planets and what they are made of.
3. Discover the roles and importance of planets, moons, and asteroids.

MATERIALS NEEDED

1. A computer with Zoom.
2. Nearpod Lesson: https://share.nearpod.com/x2q7rnddZab

ACTIVITY

30 minutes

The researcher will be virtually present (via Zoom) throughout the whole lesson and guide the student in how to start the Nearpod lesson. The researcher and the student can communicate throughout the whole lesson if the student has any questions or technical problems, or the researcher wants to check in to see how the student is doing.

The lesson is a multimodal and interactive slide show presentation made for 5th-8th grades that supports many modern pedagogical lesson planning principles.

1. It includes:
   a. A before reading section that presents the learning objectives and attempts to activate previous knowledge with a “fill in the blank” quiz and “name the planet” assignment.
   b. A reading passage that explains relevant vocabulary to facilitate better reading comprehension and then highlights these words in the reading passage. Images and a video illustrates and reinforces the content in the text.
   c. An after reading section that has an assessment section where the students have to answer some false/true statements about key ideas from what they just read and recognize important words. The students are given instant feedback as the next slide reveals the right answer.

2. Assignment after the lesson:
   a. Write 1-3 facts that you find interesting about the solar system.
THE PRESENTATION:
Learning Objectives

Students will:
1. Explore the various parts of the solar system
2. Read about the planets and what they are made of
3. Discover the roles and importance of planets, moons and asteroids

Before You Read

Quiz

Select the correct word that completes the phrase.

- moons
- sun
- asteroids
- planets

- moons
- sun
- asteroids
- planets
Select the correct word that completes the phrase.

- moons
- sun
- asteroids
- planets

Select the correct word that completes the phrase.

- comets
- sun
- solar system
- asteroids

Connect the names with the planets

Earth, Mars, Saturn, Neptune, Venus, Mercury, Uranus, Jupiter

Draw It

Vocabulary

- Orbits: The curved path of an object around the Sun
- Rocky Planets: Planets made of rock, such as Mercury, Venus, Earth and Mars
- Rings: Elliptical particles made of dust, water and ice that orbit a planet
- Gas Planets: Planets made of gas, such as Jupiter, Saturn, Uranus and Neptune
- Hydrogen: A colorless, flammable, odorless gas that combined with oxygen creates water
- Helium: A motionless gas used as a substitute for flammable gases
Did you know that people once believed that Earth was the center of the solar system? They thought that all of the planets and the Sun revolved around us! Now we know that our solar system has eight planets that travel around the Sun. The planets travel in circular paths called **orbits**.

The planets are divided into inner planets and outer planets. The first four planets, Mercury, Venus, Earth and Mars, are the inner planets. Then, Jupiter, Saturn, Uranus and Neptune make up the outer planets. In 2006, Pluto lost its planetary status.

The inner and outer planets have a row of asteroids in between them. It is called an **asteroid belt**. Asteroids are pieces of space rock that orbit around the Sun. Scientists think that asteroids are like “space trash”, leftover garbage from when the planets were first formed.

The eight planets in our solar system are made of either rocky materials or gases. Mercury, Venus, Earth and Mars are the **rocky planets**. They are smaller than planets made of gas. They are also heavier and move more slowly. They have no **rings** around them, and have very few moons. The former planet, Pluto, is also rocky, has no rings and has very few moons as well.

Jupiter, Saturn, Uranus and Neptune are the **gas planets**. They are made of gases called **hydrogen** and **helium**. These big planets are often called the “Gas Giants”. They are lighter than the rocky planets and move faster. Most of these planets have many moons. Did you know that Jupiter has sixty-three moons? All of the gas planets also have rings around them, but Saturn’s rings are most well known. You have probably seen pictures of the rings around Saturn before. These rings are made of ice chunks and rock.
Which statements are True and which statements are False? Underline the correct answer

TRUE / FALSE  A) Planets that are made of gases tend to move more slowly than the smaller, rocky planets.

TRUE / FALSE  B) Mercury, Venus, Earth and Mars are known as inner planets because they have rocks inside them.

TRUE / FALSE  C) The gas planets can have rings and often have many moons.

Circle the words that are NOT part of the solar system

moon, satellite, planet, comet  moon, satellite, planet, comet

asteroid, quasar, sun, asteroid, quasar, sun
Draw It

Which statements are True and which statements are False? Underline the correct answer

TRUE / FALSE  D) Moons are part of the solar system because they orbit around the Sun.
TRUE / FALSE  E) Asteroids are known as “space trash” because they are left over from when the planets were formed.
TRUE / FALSE  F) The farther a planet is from the Sun, the more difficult it is to visit it.

Which statements are True and which statements are False? Underline the correct answer

TRUE / FALSE  G) The rings around Venus are made of ice and rock.
TRUE / FALSE  H) The inner planets have few moons around them.
TRUE / FALSE  I) The Earth is the center of the solar system.

TRUE / FALSE  J) The rings around Venus are made of ice and rock.
TRUE / FALSE  K) The inner planets have few moons around them.
TRUE / FALSE  L) The Earth is the center of the solar system.
Circle the items below that planets can be made of.

- helium
- dust
- fireballs
- rock
- oxygen
- ice
- hydrogen

Open Ended Question

Write 1-3 facts that you find interesting about the solar system.

Thank You!
Appendix F: Experimental Lesson

Lesson Plan for Experimental Lesson (3)
Prepared by Caroline Roland

OVERVIEW & PURPOSE

The student will explore our solar system and galaxy using VR. The purpose of this lesson is to give students a holistic impression and understanding of the solar system. After providing the students with a holistic image of how our solar system looks, this lesson aims to support students’ agency in exploring the pieces of the holistic image they find interesting.

EDUCATION STANDARDS

This lesson is not created to fit an educational standard but to utilize VR as an educational tool. However, the lesson can be used in instructions related to the California State Standards listed below and the Common Core connections as mentioned in the Science identifier.

Science:

1. MS-ESS1-1 (Science (CA NGSS))
   Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

2. MS-ESS1-2 (Science (CA NGSS))
   Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

3. MS-ESS1-3 (Science (CA NGSS))
   Analyze and interpret data to determine the scale properties of objects in the solar system.

4. MS-PS2-4 (Science (CA NGSS))
   Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
OBJECTIVES

1. Explore the various parts of the solar system.
2. Navigate around the solar system and get an impression of planets and what they are made of.
3. Discover the roles and importance of planets, moons, and asteroids.

MATERIALS NEEDED

1. Oculus Quest.
2. The “Star Chart” application.
3. A computer with Zoom.

ACTIVITY

30 minutes of total VR time

Before we start the lesson, we will repeat and make sure the student remember the Health and Safety warnings from the intro lesson:

Health and safety warnings

- Emphasize the age requirements and the possible experience of discomfort or severe medical conditions.
- Explain how to use and set up the VR technology safely and what not to do.
  - Treat the technology with care, keep it in the box when not in use, keep away from pets, and do not expose the lenses to direct sunlight.
  - Set up a safe play space environment.
    - Only for indoor use.
    - 6,5 x 6,5 feet object free play area.
    - Start the VR while sitting down.

In addition, we will make sure that there is an adult present to monitor the student in case of an adverse event. We will closely monitor the student while they use the VR technology via Zoom. If the student feels ill, we will immediately stop the lesson.

The researcher will be virtually present (via Zoom) throughout the whole lesson and guide the student in how to start Start Chart and where to find the right activities. The researcher and the student can also communicate throughout the whole lesson if the
student has any questions or technical problems or the researcher wants to check in to see how the student is doing.

**Note.** For those who are not familiar with the VR environment or the Star Chart application, we recommend watching the YouTube videos linked to in steps 2 and 3 below. They give an impression of what the student will experience. However, unlike watching a video, the player can make their own choices of where to go (within the boundaries of the solar system) and what to see.

**Instruction of activities:**

1. Start the app “Star Chart.”
2. Do the “Orrery” tutorial. This is a tutorial that teaches the student how to navigate and move around in the applications environment. For example, how to move to the moon. The student explores while being taught how to move around.

   Example: [from the Orrery tutorial](#)

   Take a break if the student needs one.

3. Watch the 8-minute long “Orrery Tour” in VR. The students will watch this in an immersive 360° environment, but the example video will provide an overview of the content they are presented with.

   Example: [Star Chart Orrery Tour](#)

4. For the remaining time of the lesson, the student can navigate around in the virtual solar system as they learned in the tutorial. The purpose here is to investigate what they want to learn more about. The student can for example:
   - Closer investigate phenomena they saw in the tutorial or tour, for example
     - One of the planets.
     - The sun.
     - Planets’ moon(s).
     - Asteroids
   - They can fast-forward/rewind time to see changes over time.

5. **Assignment after the lesson:**
   a. Write 1-3 facts that you find interesting about the solar system.
Examples from Star Chart:

Screenshot from the start menu and the tutorial:
## Appendix G: Survey Results

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# Appendix H: Time Spent on Survey

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Appendix I: Interview Transcripts

Participant F1

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?
- It was fairly simple and general what I had to do. I had already learnt some of the stuff in the slides in the past. I learned that the asteroid belt is called space trash, which was new. It was fun, kind of simple.

Nearpod

Question 2: Was this your first time using Nearpod?
-No

Question 3: What do you think about using Nearpod in this lesson?
-I think it was pretty good, a nice way of doing it. But one think I like to do is looking at the questions before I read so I know what I am looking for.

Question 4: What do you think about using Nearpod in education?
-Yes I do.

Lesson

Question 5: What do you normally think about this subject (science)?
-I think it is kind of cool to learn about how things work.

Question 6: How do you normally like to learn in this subject (science)?
-I like visual and tactile stuff, like videos or physically doing something.

Question 7: What did you enjoy the most in this lesson?
-Ehm... I would say the illustrations, the videos and the pictures.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?
-A little bit, not like a ton, but a little.
Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?

01: No, not really.

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/virtual Environment?

-Not really.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?

-Ehm, maybe. Yeah, probably not in a regular day though.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?

-No.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?

- I thought it was a lot more interesting and fun than the Nearpod, because I was actually there. And I could choose what planet I wanted to learn about, I could just click on a planet and learn the facts about it.

VR

Question 2: Did you feel sick or unwell?

-No, not really.

Question 3: Was this your first time using VR?

-No

Question 4: What do you think about using VR in this lesson?

01: I think it was fun, and cooler to watch and do.

Question 5: What do you think about using VR in education?
I think it would be fun. I think doing it a lot would be kind of hard, like my eyes would hurt. But I think it would be really fun to do some lessons in VR.

**Lesson**

**Question 6:** What did you enjoy the most in this lesson?
- Being able to see all the planets and then being able to click on one and then learn about that planet.

**Question 7:** Did you become more curious about space, planets, and the galaxy after this lesson?
- A little bit yeah.

**Question 8:** Is there anything you especially didn’t like about using VR in the lesson?
- No

**Presence/ experience**

**Question 9:** To what extent did you experience a sense of being ‘really there’ in space/virtual environment?
- More present. Because it was 3D.

**Question 10:** How real did the overall experience feel?
- It felt pretty real.

**Question 11:** Do you think you can use what you learned in VR in the real world, or in your lessons in school?
- Yeah maybe a little bit I mean yeah.

**Question 12:** Would you describe the VR experience as different than a TV or PC experience?
Please explain.
- I think it a lot different. It is a lot bigger, and you are there.

**Question 13:** Is there anything else you want to add about this lesson, VR, or education?

No
Participant F2

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?
-I thought it was pretty good.

Question 2: Was this your first time using Nearpod?
-I have used it a few times in science class.

Question 3: What do you think about using Nearpod in this lesson?
-I like how it just not about reading and it gives you other things to do while you are reading to make sure you actually understand what you just read.

Question 4: What do you think about using Nearpod in education?
-I like it I think it is pretty good.

Lesson

Question 5: What do you normally think about this subject (science)?
-I think science is really cool and there is some thing that is a little boring, but that is ok.

Question 6: How do you normally like to learn in this subject (science)?
-I am a visual learner; I like to see things and touch things that I am learning about. Rather than reading about and looking at.

Question 7: What did you enjoy the most in this lesson?
-I think I liked the part where I learned about the asteroid belt, I found that to be really cool. And I got to look at it [the video]. I haven’t really thought about the asteroid belt and that it and I thought it was pretty cool.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?
-It defiantly did.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?
-I thought it was good.

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?

-I felt like I was present, I zoned out a little bit.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?

-I defiantly think I could keep a conversation going with it.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?

-I really liked the part where you could draw with the pencil and connect the planets.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?

-I really enjoyed it. I thought it was really fun.

Question 2: Did you feel sick or unwell during the lesson?

-No. A little bit.

Question 3: Was this your first time using VR?

-Yes. I was really cool and not that hard to use.

Question 4: What do you think about using VR in this lesson?

-I thought it was really cool because you could see where the planets were in the solar system and move around with them. I thought it was really good.

Question 5: What do you think about using VR in education?

-I think they should defiantly do it. Because I feel like I was more into the lesson and I learned more than if I was just reading a text about the topic.

Lesson
Question 6: What did you enjoy the most in this lesson?
-That after the video, I could go around and choose what I wanted to look at – I thought that was really cool.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?
-Yes absolutely.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?
-No.

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?
-I would say that it felt I pretty real. I kind of felt like I was there, but I knew I was not there, but I kind of felt that I was. I really liked it.

-Question 10: How real did the overall experience feel?
-It felt pretty real.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?
-Yeah, I think I could.

Question 12: Would you describe the VR experience as different than a TV or PC experience? Please explain.
-Yes, I think it is different because it is right in your face. Like a TV is more distant, you're not right in it, you're just watching it from a distance.

Question 13: Is there anything else you want to add about this lesson, VR, or education?
-I want to do it in school. I was excited to use the Oculus and use it to learn about it.
Participant F3

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?

-I thought it was pretty good.

Nearpod

Question 2: Was this your first time using Nearpod?

-No, actually I have used it a couple of times in math and once in ELA.

Question 3: What do you think about using Nearpod in this lesson?

-I think it is pretty good. I like Nearpod honestly, so it felt good to know that I knew what I was doing.

Question 4: What do you think about using Nearpod in education?

-I think it is a good source. I honestly like it, I’m not sure about other people but its pretty good. There are other ones like Peardeck but those aren’t nearly as interactive as Nearpod so.

Lesson

Question 5: What do you normally think about this subject (science)?

-I think it is cool I like science a lot.

Question 6: How do you normally like to learn in this subject (science)?

-Not really, I like online learning. Doing it through Nearpod, we don’t use it in Nearpod but I think it would be cool to use it on Nearpod or in VR.

Question 7: What did you enjoy the most in this lesson?

-Not really, I like all Nearpods.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?

-Yeah.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?

-I liked it.
Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment? How present did you feel?
-I am a very creative person, so it kind of felt like I was reading from a textbook, so I thought that was pretty cool, but that probably just me.

Do you like reading from a textbook?
-Yeah.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?
-Yepp.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?
-No.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?
-This was really fun.

Did you like it?
-Yes I felt like I was actually in the solar system.

Question 2: Did you feel sick or unwell during the lesson?
-No.

VR

Question 3: Was this your first time using VR?
-Yes.

Question 4: What do you think about using VR in this lesson?
-It is really good. I felt like I was actually there, and it is more interactable then the Nearpod.

Question 5: What do you think about using VR in education?
-I think it would be pretty cool because you could be there, because if you put it in classroom setting, you could actually be in the classroom. [Referring to home/online schooling as s/he is currently doing because of covid-19]

Lesson

Question 6: What did you enjoy the most in this lesson?

-That it was very interactable, like I felt like I was being there, I could pick up the planets and read about them. It was really cool.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

-Defiantly yes.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

-No

Presence/ experience.

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?

-Very present. I was very cool, it felt like I was an astronaut looking from above.

Question 10: How real did the overall experience feel?

-Very good.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-Yep, definitely.

Question 12: Would you describe the VR experience as different than a TV or PC experience? Please explain.
-Probably the most different about it is that it is a 3D view. So you can like pick up the planets and turn them around and like look all around you like you are in a huge dome. Whereas being on a computer or something like that, is that it is more 2D and you cannot do as much there, you can't really be there.

Question 13: Is there anything else you want to add about this lesson, VR, or education?
-No.

Participant F4

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?
- I liked it, it was more interactive than what I usually do in school.

Nearpod

Question 2: Was this your first time using Nearpod?
- Yes.

Question 3: What do you think about using Nearpod in this lesson?
- I thought it was good because it was more engaging than a regular slides presentation.

Question 4: What do you think about using Nearpod in education?
- I think it would be good because getting engaged more helps.

Lesson

Question 5: What do you normally think about this subject (science)?
- I like science.

Question 6: How do you normally like to learn in this subject (science)?
- I usually just read out of the textbook but I like to watch videos.

Question 7: What did you enjoy the most in this lesson?
- I really liked the when we had to say which planet were witch, drawing the lines between them.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?
Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?
-No

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment? How present did you feel?
-I felt pretty present.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?
-I don’t know, I guess.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?
-No.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?
-I really enjoyed it.

Question 2: Did you feel sick or unwell during the lesson?
-No.

VR

Question 3: Was this your first time using VR?
-No.

Question 4: What do you think about using VR in this lesson?
-I really enjoyed it, I liked how it was interactive and that you could do what you wanted.

Question 5: What do you think about using VR in education?
-I think it’s really fun and that you get more out of the experience.
Lesson

Question 6: What did you enjoy the most in this lesson?

-I enjoyed how you could move at the pace you wanted and look and explore different things that you wanted to see.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

-Yes.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

Presence/experience

-Not really no.

Question 9: To what extent did you experience a sense of being ‘really there’ in space/virtual environment?

-I felt really present with that.

Question 10: How real did the overall experience feel?

-I knew that I wasn’t real obviously but it felt and looked pretty cool.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-I don’t really think so.

Question 12: Would you describe the VR experience as different than a TV or PC experience?

Please explain.

-It is different. I think that you really get into it with VR and enjoy it more because you feel more involved.

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-No.
Participant F5

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?
-I thought that it was a good topic because I kind of like taking about the solar system. I like the solar system.

Nearpod

Question 2: Was this your first time using Nearpod?
-No, we use it all the time in school.

Question 3: What do you think about using Nearpod in this lesson?
-I think it was a good choice to do. I liked it.

Question 4: What do you think about using Nearpod in education?
-I think it can be used as a good tool of learning for kids in all ages they can all follow along and participate. It is good.

Lesson

Question 5: What do you normally think about this subject?
-I kind of like science. I think it is a good subject.

Question 6: How do you normally like to learn in this subject (science)?
-Not really. I like to watch movies and do good experiments I think.

Question 7: What did you enjoy the most in this lesson?
-I really liked, I kind of liked all of it.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?
-Ehm kind of.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?
-No, I felt kind of positive over all.
Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?

-I feel like I was pretty present.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?

-I think if I was in the right situation or in the right job.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?

-No.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?

-I thought it was, I found it interesting because I learned a few things I did not know and also really fun because I really liked using VR. It is just so cool I love it.

Is there a special reason for why you like VR?

-It feels really real and it is superfun to do at the same time.

Question 2: Did you feel sick or unwell during the lesson?

-Not with this game, there is a few games where I move around and I start to get motion sickness, but not with this game.

VR

Question 3: Was this your first time using VR?

-I have been playing it a lot before.

Question 4: What do you think about using VR in this lesson?

-I don’t know how to describe it.

Do you think VR add something different to the lesson about space?
-Yes I think it makes it more, you are actually there and you can actually see the stuff.

Question 5: What do you think about using VR in education?
- I think that would be nice. That would be cool and a lot of fun.

Do you think you could learn more, or would it just be more fun?
- I think on one hand it would be really fun and on one hand you could actually learn more because if you just read about something in a book, that is all you know. But if you are in VR I feel you could learn more.

Lesson

Question 6: What did you enjoy the most in this lesson?
- I liked that you could speed up time and see where each planet would be in this year or where it would be like two weeks from now, or where it was a year ago. That was really cool.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?
- Yes. I really did.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?
- Not really no. I liked pretty much everything about it.

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual environment?
- I felt like I was really there, and I can’t describe it, it was just really amazing.

Question 10: How real did the overall experience feel?
- I feel like 45% of me felt like I am really in space now, while the other 55% knew that I was here. But it felt really real.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?
- I would say the same as last time, if you were in the right position or job then yes I think I could.
Question 12: Would you describe the VR experience as different than a TV or PC experience?

Please explain.

-It’s very real because it is on your face and you have to speakers that works like if you hear something on the side it actually sounds like it is coming from over there. It is just amazing, I love it.

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-No not really.

Participant F6

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?

-It was like good, it liked taught me about stuff, but it was not like fun, I felt like I was doing schoolwork. Like when I am in school and I have to pay attention to it.

Nearpod

Question 2: Was this your first time using Nearpod?

-Yes.

Question 3: What do you think about using Nearpod in this lesson?

-It was better then some of the things I use because I could go at my own pace, there was no rush on the questions.

Question 4: What do you think about using Nearpod in education? Would you like it if your school used it?

-Maybe.

Lesson

Question 5: What do you normally think about this subject?
I really like my science classes, they are really fun because we get to do a lot of experiments and it not just always worksheets and documents and work that makes you feel stressful, it is more simple.

Question 6: How do you normally like to learn in this subject (science)?
-I like not having to be on a computer, and do group activates, and not just the teacher saying “ok we are going to do documents and you are going to answer a bunch of questions and the you have to write a paper about it”. I like when we are having an activity but we still learn from it.

Question 7: What did you enjoy the most in this lesson?
-I liked the true and false questions because it did not just make you answer a question, it showed you the correct answer after on the next slide, and I liked that because then you know what you got wrong and right.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?
-Yeah.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?
-Probably that it was it like work. It felt like you had to answer questions and that sometimes get like..
Some of questions when I read them... Because I like when people read out load to me and when things are said to me because when I read it sometimes it doesn’t make sense.

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?
-Probably from a scale from 1-10, probably a 7.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?
-Yeah some of the things.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?
Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?

- I thought it was more fun, it wasn’t like I had to type a bunch of things and it was more intriguing to learn about thing, like I wanted to learn about it.

Question 2: Did you feel sick or unwell during the lesson?

- I had a headache for a little while. But that was all really.

VR

Question 3: Was this your first time using VR?

- Yes.

Question 4: What do you think about using VR in this lesson?

- I thought it was really cool. I would use it again.

Question 5: What do you think about using VR in education?

- I thing that would be really cool and fun to learn like that.

Lesson

Question 6: What did you enjoy the most in this lesson?

- That you could like control what you looked at and you could go back in time and just choose what you do.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

- Yes.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

- Probably just the headache, but that was probably just because it was my first time.

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual
Environment?

-It was pretty believable. Because it was right in front of you, and you could look behind you and you would not see the chair. I thought it looked real.

Question 10: How real did the overall experience feel?

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-Yes.

Question 12: Would you describe the VR experience as different than a TV or PC experience?

Please explain.

-Probably that the computer... This is more realistic but on a computer is just pictures and sometimes it is blurry. And in VR you can adjust the eyesight [the lenses]. And it was kind of cool that you can move things around and that you can, you can do that on a computer but not as much as you can with Virtual reality.

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-No.

Participant M1

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?

-I thought it was kind of interesting. I learned a few things I didn’t know before.

Nearpod

Question 2: Was this your first time using Nearpod?

-No, I have used it in school.

Question 3: What do you think about using Nearpod in this lesson?
-I thought it was more interesting than just someone talking, because it was kind of interactive.

Question 4: What do you think about using Nearpod in education?

-I would use it, I like it.

Lesson

Question 5: What do you normally think about this subject (science)?

-I like it, I think it is pretty interesting. Because there is a lot you don’t know.

Question 6: How do you normally like to learn in this subject (science)?

-I don’t like reading. I don’t know, videos are kind of interesting.

Question 7: What did you enjoy the most in this lesson?

-I liked the activities and the questions. I like this because that is fun. And that it was very simple and straightforward.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?

-A little bit.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?

Presence/ experience

-Not really. There was a long space without questions in the middle of the lesson, and then there was a bunch of questions at the end.

Question 10: To what extent did you experience a sense of being ‘really there’ in space/virtual environment?

-Not really, because the video was kind of laggy. I think it was because I was on zoom too.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?

-Probably not, but it is interesting to know.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?
Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?

-It was a lot more interesting from the last time.

Question 2: Did you feel sick or unwell during the lesson?

-No, when you take it [the headset] off it’s kind of wow, but no I feel fine.

VR

Question 3: Was this your first time using VR?

-No.

Question 4: What do you think about using VR in this lesson?

-I was more involved. I thought it was cool to see the planets scale, scale-ish, to see the distances. I could really see how far away Pluto were away from the sun. Instead of seeing it in a picture.

Question 5: What do you think about using VR in education?

-It would be pretty cool. I don’t know how 30 kids could do it in a class period. But it would be cool.

Lesson

Question 6: What did you enjoy the most in this lesson?

-The video was really cool. Seeing the distances, I thought that was kind of cool. The distances, seeing how far it takes for me to get there. And just like random facts about each planet.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

-Probably a little more than the last one.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

-Really not anything. The part in the end, where I was speeding up time was probably the least interesting part, but it was not interesting. It was just a little confusing about what you could do.

Presence/ experience
Question 9: To what extent did you experience a sense of being ‘really there’ in space/virtual environment?

-Oh yeah! Especially with Mars and Jupiter when came really close, that was really cool.

Question 10: How real did the overall experience feel?

-One out of ten scale I would give it a 7. For it to be a 10, it should have been a real video. If it was a real video that would be really cool, but we would have to make it to Pluto first. That would be cool, and maybe if you could fly in a fake spaceship, instead of just floating over the planets.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-I don’t think I would tell anyone about that, but I have learned some cool things I didn’t know before.

Question 12: Would you describe the VR experience as different than a TV or PC experience? Please explain.

-Yes absolutely. One of the coolest things was that you could turn around in a circle and look around you. See the planets go over your head. Being able to look around and go closer to what you want to see.

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-I don’t think so.

Participant M2

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?

-I thought it was pretty easy and a straightforward lesson. After every slide I could just check my answers.

Nearpod

Question 2: Was this your first time using Nearpod?

-No
Question 3: What do you think about using Nearpod in this lesson?

-I feel Nearpod works for most lessons, so I see no reason this would not.

Question 4: What do you think about using Nearpod in education?

-I like the part where you get to draw.

Lesson

Question 5: What do you normally think about this subject?

-I like science. I think it is difficult, I don’t have the best grade in it, but I like science.

Question 6: How do you normally like to learn in this subject (science)?

-Experiments.

Question 7: What did you enjoy the most in this lesson?

-I thought it was... On terms of enjoyable, it was mediocre. It was not enjoyable like “oh man I want to do this again”, it was just a lesson.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?

-I learned that asteroids are space trash, I guess. But I don’t think I want to go to the moon after this though. I didn’t learn too much about it.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?

-I don’t dislike Nearpod, it is just very mediocre. I don’t stand out to me.

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?

-No. I circled what was in space, like the asteroids and sun, I didn’t do anything in space.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?
-If someone asks me what planets are outside the asteroid belt, I can tell them Uranus, Jupiter, and Neptune.

**Question 12:** Is there anything else you want to add about this lesson, Nearpod, or education?

*Very mediocre.*

**Lesson 2 Experimental Lesson VR**

**Question 1:** What do you think about this lesson?

-I thought it was more freedom to do what you wanted. Like I could stick the sun inside my face. And I could completely skip the tutorial. But I was able to figure it all out.

**Question 2:** Did you feel sick or unwell during the lesson?

-No, I don’t get motion sick.

**VR**

**Question 3:** Was this your first time using VR?

-No

**Question 4:** What do you think about using VR in this lesson?

-I feel for space it is very useful. Maybe a different app that would go more in depth. In this one, all I could do in this app was to grab the sun and put it in my face. I mean, I could look at the diameter and look at how many planets that orbit it. Or the same for Jupiter, Uranus or Earth or something, which is all good, But I feel it would be more engaging if you could get a more closer look, or see what stuff inhabits it was made of. The moon IO that I am pretty sure orbit Saturn, looked like it was dipped it in water for a year and that it was made out of metal. It was completely rusted.

**Question 5:** What do you think about using VR in education?

-I do feel that it would be a good use of VR headset, because it could be a lot more immersive. I know there are VR games where you are on the space station, I think that would be very cool. I feel that VR is a way more immersive experience.
Question 6: What did you enjoy the most in this lesson?

-I got to pick up the sun. I like the hands-on bit of it. I like that you can grab stuff and use physics in it. I would like more physics, I wish I could grab it and throw (shovel) it around, but I guess that is not how the solar system works. I like that you could pick up things and hold it. I picked up everything I could find.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

-Yes.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

-No

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual environment?

-First of all, it is the logical part – how am I breathing in space? Which is kind of, you know... Also the thing that kind of made me feel like I was not there was the giant earfs going around the earth. It's a feeling of like other wordily, you're not really there. Like other VR games like beat saber, there is no way you are in a neon looking room hitting blocks.

Question 10: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-I do, I can tell my science teacher “hey look at me, I know what the moon IO is and why it looks like rust”.

Question 10: How real did the overall experience feel?

Question 11: Would you describe the VR experience as different than a TV or PC experience?

Please explain.

-Defiantly yes, it is not a science text book. It stays in my mind longer whenever I’m in VR.

Question 12: Is there anything else you want to add about this lesson, VR, or education?

-It is not mediocre.
Participant M3

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?
-I thought the lesson was very interesting. I liked the part where you talked about the asteroid belt and what all the planets had together, their shared similarities. But I felt it would be easy to look up on google what was going on and check the answers.

Nearpod

Question 2: Was this your first time using Nearpod?
-No

Question 3: What do you think about using Nearpod in this lesson?
-I think most lessons run on Nearpod really well. But I know a bunch of students who think it is a pain to log on the lesson and run through all the steps, so they don’t enjoy it as much.

Question 4: What do you think about using Nearpod in education?
-Said in Q3.

Lesson

Question 5: What do you normally think about this subject?
-Science for me is overall a good subject, I really enjoy it and I have fun while learning.

Question 6: How do you normally like to learn in this subject (science)?
-Hands-on approach for sure.

Question 7: What did you enjoy the most in this lesson?
-I liked the layout of it I thought it was a good layout.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?
-I think I would like to learn more about why the inner planets don’t have grids/rings compared to the outer planets.
Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?
-I have no issue with any of it.

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?
-No, not all.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?
-I think it interesting. I think I can use it if someone asks when was Pluto declassified as a planet, and a few other things.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?
-No.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?
-I defiantly liked this lesson a lot better. I liked how it went around each to planet and you could see where it all was and what order the planets came in. It talked about Pluto, compared the planets, you could walk around, and I enjoyed it all.

Question 2: Did you feel sick or unwell during the lesson?
-No, I don’t get motion sick.

VR

Question 3: Was this your first time using VR?
-No

Question 4: What do you think about using VR in this lesson?
-I found it to be well made, I liked. It was interesting I could look. I could figure out stuff pretty well. I think I would like to get a closer look at it, but I feel I got a good experience without it.

Question 5: What do you think about using VR in education?
- I think that it is more immersive and it would defiantly better. But my only issue with this is that I think space would be an issue.

Question 6: What did you enjoy the most in this lesson?
- I enjoyed the fact that it gave me several objects that were not planets. Not including Pluto either, when I looked in the asteroids belt I could find Sirius and a few of the dwarf planets and asteroids in there. That was interesting to me.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?
- Yes

Question 8: Is there anything you especially didn’t like about using VR in the lesson?
- No

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual environment?
- I found it immersive, and it felt like I was there. But I know of course, I was not. It is sad.

Question 10: How real did the overall experience feel?

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?
- I do, it would be cool to just pop in the science classroom and just say “hey, we named an asteroid in the asteroid belt”.

Question 12: Would you describe the VR experience as different than a TV or PC experience?
Please explain.
Defiantly yes. It’s way more immersive, you get a feel of it.

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-I think it is immersive.

Participant M4

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?

-The lesson was pretty basic, it's like something you do every day in school everyday. Which is you read something and then you answer questions. Or you watch a video and answer some questions.

Nearpod

Question 2: Was this your first time using Nearpod?

-No I have used Nearpod multiple times in the past.

Question 3: What do you think about using Nearpod in this lesson?

-I think Nearpod made it maybe a bit easier because they were in chunks in stead of getting all the information at once.

Question 4: What do you think about using Nearpod in education?

-I think it is a good way to know how someone understand something because the questions are very much on topic for what you just learned. Very specific.

Lesson

Question 5: What do you normally think about this subject?

-Well, I haven't really done much science in space and astrology, when it comes to science I am doing, it is not as interesting in my opinion.

Question 6: How do you normally like to learn in this subject (science)?

-Usually I prefer to do things that are different, so maybe watch at video then answer questions but then the next time do something like a performance task.
Question 7: What did you enjoy the most in this lesson? Question 7b: was it in a specific part that happened?

-I’d say I enjoyed the part where it was easy to take all the information in. Like I was able to understand it very well. Probably when I read the stuff and it was pretty straight forward.

Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?

-Yeah I think so.

Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?

Presence/ experience

-I think Nearpod is great but also it is very just reading and writing that is all it is.

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual environment?

-I just felt like I was reading something and answering questions.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?

-I mean, it probably would not come up to me right away, but if I was talking about a subject might randomly remember some facts or things like that but not like a 100% talk all about it have a full blown conversation.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?

-No I don’t think I have more.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?

-I thought it was really cool and different because I was actually in the solar system.

Question 2: Did you feel sick or unwell during the lesson?

-Maybe a little bit, I wasn’t feeling sick, but maybe a little tired.
VR

Question 3: Was this your first time using VR?
-Yes.

Question 4: What do you think about using VR in this lesson?
-I think it is really smart because you get to see where the planets are, and all the different places and what they actually look like from a distance and really close.

Question 5: What do you think about using VR in education?
I think it would be really cool because the students would be really excited to use the VR in class.

Why do you think students would be excited or be most excited about?
I think the most exciting part would be how they actually get to be in the solar system or wherever, and actually get to do things manually and be in control.

Lesson

Question 6: What did you enjoy the most in this lesson?
-My favorite part was the view because I was able to see the planets up close and then from far away and move the time make it faster or slower.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?
-Yes.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?
-In the video I was not able to stop it or pause it.

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?
-I felt very present because obviously it felt like I was actually in space.

Question 10: How real did the overall experience feel?
-I think it was pretty real because I was actually seeing everything and also I was able to go anywhere I wanted to go and see all around myself and see everywhere.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-Ehm I think so, but like the last time, it not something that is going to pop into my head unless I go further into the subject.

Question 12: Would you describe the VR experience as different than a TV or PC experience? Please explain.

-I think it is very different because you are actually doing things yourself and you are learning it while you are doing it manually, but the same time you are in VR

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-I don’t think so.

Participant M5

Lesson 1 Control Lesson Nearpod

Question 1: What do you think about this lesson?

-Well, it was... It gave information but not in the greatest way I guess.

Do you want to explain what you meant by that?

-It was just, they gave you a paragraph and then you would read that and that is how you got the information,

Nearpod

Question 2: Was this your first time using Nearpod?

-No I have used in school before.

Question 3: What do you think about using Nearpod in this lesson?
-I mean it defiantly gives you... like it teaches you good enough, but people I guess don’t want to do it, they are not motivated to do it.

**Question 4: What do you think about using Nearpod in education?**

-Well, I guess it is easy to get a bunch of different power points to learn, like there is a bunch of different resources where you can get them from. But it is again, not really what you want to be doing. This is very interesting to hear, do you think it is easy for a teacher to just find and assign a Nearpod presentation?

-Yes I do.

**Lesson**

**Question 5: What do you normally think about this subject?**

-Well, right now in school what my teacher usually does is give us an article to read and then she gives us 10-20 questions to answer from the article.

**Are your school online right now?**

-Yes.

**Was it different when you were physically in school?**

-We did more experiments.

**Question 6: How do you normally like to learn in this subject (science)?**

-Well in science I know every month we would do a lab. It was not like you read something and you answered questions, you were doing it.

**Question 7: What did you enjoy the most in this lesson?**

-I did not really have a favorite part, but the thing I would rather do is the activities. Like the drawing activity I guess.

**Question 8: Did you become more curious about space, planets, and the galaxy after this lesson?**

-No, not really.
Question 9: Is there anything you especially didn’t like about using Nearpod in the lesson?
-Well, it was fine but again not really my favorite way of learning.

Presence/ experience

Question 10: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?
-Really I was reading it and answering some questions, I was not really engaged in it.

Question 11: Do you think you can use what you learned here in the real world, or in your lessons in school?
-Maybe, if I was like a scientist, but right now no I would not use it.

Question 12: Is there anything else you want to add about this lesson, Nearpod, or education?
-Well I know when I have done Neapods before sometimes they use like Google Maps where you are actually there, that makes it more interesting.

Lesson 2 Experimental Lesson VR

Question 1: What do you think about this lesson?
-It was certainly more interactive. I could actually do stuff, I could pick up the planets, make them bigger, smaller, speed up the time. And it was defiantly more fun than just reading some text.

Question 2: Did you feel sick or unwell during the lesson?
-No.

VR

Question 3: Was this your first time using VR?
-No, I have tried it a few times before. [The intro session to the research project].

Question 4: What do you think about using VR in this lesson?
-I think it was, at least I liked it, and I think other people would also like it. The only thing that I would change was that it should have been more similar information about the planets.
Question 5: What do you think about using VR in education?

-I think people would defiantly want to go to school more. What do think they would like about it? I liked that you could more around and see 3D. Also make it bigger and smaller and see the planets.

Lesson

Question 6: What did you enjoy the most in this lesson?

-I liked how you were able to move around and see different angles.

Question 7: Did you become more curious about space, planets, and the galaxy after this lesson?

-Yes I think that it defiantly looks a lot cooler here than in the Nearpod.

Question 8: Is there anything you especially didn’t like about using VR in the lesson?

-Yes, I think they could add a little more information, but that is it.

Presence/ experience

Question 9: To what extent did you experience a sense of being ‘really there’ in space/ virtual Environment?

-I defiantly felt like I was really there. I could like grab the planets which was really cool, so I was defiantly very engaged.

Question 10: How real did the overall experience feel?

-I think it was really real, except for how you could go into the planets maybe.

Question 11: Do you think you can use what you learned in VR in the real world, or in your lessons in school?

-Well, I might just give out a fun fact that I learned here.

Question 12: Would you describe the VR experience as different than a TV or PC experience?

Please explain.

-Yes. It is defiantly different.

What would you say is the main difference?
-I guess your focused on it there is like nothing else there [in your field of view] and it is also in 3D.

Question 13: Is there anything else you want to add about this lesson, VR, or education?

-No, I think that’s it.
## Appendix J: Assignment Results

<table>
<thead>
<tr>
<th>Participant</th>
<th>Control Lesson Nearpod</th>
<th>Experimental Lesson VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>The inner rocky planets move slower than the outer gass planets. The gas planets have more moons than the rock planets. The asteroid belt is called &quot;space&quot; trash&quot;.</td>
<td>Plutos moon is so big that Pluto and its moon orbit each other. Earths moon is bigger than Plutos. Mars has the biggest canyon.</td>
</tr>
<tr>
<td>F2</td>
<td>I find the asteroid belt interesting. The fact that it is made from bits of planets is really cool. I also think that what Saturn's rings are made out of is interesting.</td>
<td>I didn't know that there are other dwarf planets in our solar system. I thought it was just Pluto. I also it didn't know that venus and earth were sort of like sisters in a way.</td>
</tr>
<tr>
<td>F3</td>
<td>One fact I found interesting about the solar system where That planets can be made up of helium. Another fact that I could interesting is that Jupiter has 63 moons!</td>
<td>One fact that I could out about the solar system is that different planets move at different times, so their years orbiting the sun are different.</td>
</tr>
<tr>
<td>F4</td>
<td>That the gas planets all have rings, that the rocky planets are separated from the gas planets by an asteroid belt.</td>
<td>I thought it was really interesting that I could speed up the time and see how the different planets moved. The outer planets were orbiting really slowly. Almost like they weren’t moving at all.</td>
</tr>
<tr>
<td>F5</td>
<td>A planet can be made from helium.</td>
<td>Sometimes you can see Venus I think it was during the day. One of the planets was flipped over on its side.</td>
</tr>
<tr>
<td>F6</td>
<td>1: that planets take so long to orbit around the sun. 2: that most of the planets are made of rock. 3: that the sun is really far from Earth.</td>
<td>That Pluto and its moon circle around each other.</td>
</tr>
<tr>
<td>M1</td>
<td>That the rings around certain planets are made of ice and rock. That there is a belt of asteroids. And finally some planets are made of gas.</td>
<td>How far and how long it takes to get to Pluto. How Pluto forms its own mini system. And that Venus is very similar to Earth.</td>
</tr>
<tr>
<td>M2</td>
<td>Rocks can float have have no gravitational pull. Rings can form and you can’t run on them. Planets can be made of gas.</td>
<td>1. the moon Io is corroded as it looks. 2. Asteroid belt is dead planets. 3 there are a lot of constellations.</td>
</tr>
<tr>
<td>M3</td>
<td>It is interesting to know that all outer planets have rings around them, I also didn't know that Pluto was unclassified as a planet in 2006 and that Uranus is made of mostly gasses</td>
<td>1. there is a dwarf planet in the asteroid belt called Ceris. 2. methane doesn't let red light through which makes Neptune and Uranus look blue. 3. we have named an asteroid in the asteroid belt</td>
</tr>
<tr>
<td>M4</td>
<td>I find it interesting that the outer planets tend to have more moons than the inner planets, Pluto is not considered a planet that is a part of our solar system and the inner planets are rocky and the outer planets are gaseous.</td>
<td>I found it interesting that I was able to go up close to the different planets and see them from different points of view.</td>
</tr>
<tr>
<td>M5</td>
<td>1. Planets can be made of rock, or gas. 2. The sun is at the center of the solar system. 3. Pluto is not a planet anymore.</td>
<td>I think something that was very interesting was that I was able to see all of the planets in 3D which really helped me become engaged with the lesson. Also I liked the different features in the lesson like being able to increase the size, and be able to move around the solar system.</td>
</tr>
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Appendix K: Time Spent on Learning Task

Minutes Spent Working on Lessons.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Control Lesson</th>
<th>Experimental Lesson</th>
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</thead>
<tbody>
<tr>
<td>F1</td>
<td>15</td>
<td>25</td>
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<td>F2</td>
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<td>F3</td>
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<td>M1</td>
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<tr>
<td>M4</td>
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<td>19</td>
</tr>
<tr>
<td>M5</td>
<td>12</td>
<td>10</td>
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</tbody>
</table>

Mean | 12.36 | 19.73 |
     | (2.76) | (4.05) |