Learning in Virtual Reality

A quantitative study comparing student learning in immersive Virtual Reality and Video, and measuring the efficacy of adding enactment as a learning strategy to the respective media

Artiklens samlede antal tegn
(med mellemrum & fodnoter): 47.947
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Niels Koch Andreasen, Studienummer: 20123226

Vejleder: Lene Tanggaard

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Abstract

In this 2X2 between-subjects experiment we investigated and compared the instructional effectiveness of using immersive Virtual Reality (VR) versus video as media for teaching scientific knowledge. Additionally, we examined the efficacy of enactment as a generative learning strategy in combination with the respective instructional media. A total of 165 high school students (111 females and 54 males) experienced a science lesson, which involved forensic analysis of a collected DNA sample in a realistic laboratory environment and supplementary animations of micro-level biological processes such as DNA replication. The students were randomly distributed across four instructional groups – VR and enactment, video and enactment, only VR, and only video. Outcome measures included declarative knowledge, procedural knowledge, knowledge transfer, and subjective ratings of perceived enjoyment, motivation, self-efficacy, and interest. Results indicated that there were no effects on the outcomes of declarative knowledge. However, there was a significant interaction between media and method for the outcome of procedural knowledge and knowledge transfer with the *VR and enactment* group having the highest performance. Furthermore, media also had a significant effect on student perceived enjoyment and motivation, indicating that the VR groups showed significantly higher enjoyment and motivation scores when learning, than the video groups. Thus, the results deepen our understanding of how we learn with immersive technology and have important implications for implementing immersive VR in schools.

Table of Content

In the process of conducting this study, I would like to thank my supervisor Lene Tanggaard for constructive feedback throughout. Furthermore, I would like to thank Guido Makransky from the 'Virtual Learning Lab' at University of Copenhagen for his daily mentoring, lending materials and pushing me to think in most creative ways.

I wish you a happy reading.

Part a) The Article

1. Introduction

With recent advances in immersive technology and proliferation of Virtual Reality (VR) devices in today's techno-sphere, novel ways of enhancing student learning have emerged into the educational scene (Bonde et al., 2014; Dalgarno & Lee, 2010; Mikropoulos & Natsis, 2011; Parong & Mayer, 2018) and are expected to have wid-spread adoption in few years (Freeman, Becker, Cummins, Davis, & Hall, Giesinger, 2017). Although the technological upsurge certainly has proposed a technological outbreak in education, the growing demand of VR has mostly been credited to business analyses, mainstream reports and large-scale investments from big technology companies, and less to research evidence of its actual educational value (Makransky, Terkildsen, & Mayer, 2017). The growing availability of immersive VR technology for education therefore creates a need to determine if and how immersive VR affects and shapes learning and comprehension (Makransky et al., 2017; Parong & Mayer, 2018), as well as how VR should be implemented in schools in a way that benefits learning processes for both teachers and students. Previous research posits that VR can increase the self-perceived experience of interest, motivation, and learning through sensorial and engaging experiences, that make the specific content relatable and relevant for the students (Makransky & Lilleholt, 2018; Thisgaard & Makransky, 2017). Experiential forms of education have been promoted since the early 1900s by theorists such as John Dewey, who embraced the notion that to understand the world, learners need to interact directly with it (Dewey, 1916). As the interest in VR has increased over the last few years, research further suggests that VR improves learning outcomes only when the technology is appropriately implemented in classrooms based on instructional methods, where students construct knowledge through classroom activities, contextualized to their social and material world (Abrahamson, Sánchez-garcía, & Abrahamson, 2016; Chaia, Child, Dorn, & Frank, 2017; Pande & Chandrasekharan, 2017).

1.1 Learning in Virtual Reality

Though the definition of VR covers a broad spectrum of ideas and technologies, VR is understood as a way of digitally simulating or imitating an environment (Makransky & Lilleholt, 2018). The immersive element of VR is particularly relevant to point out; that is, in the virtual environment the user is removed from the real world, immersed in the artificial one (Lele, 2013). In this article, immersive VR is attained through a head-mounted display (HMD) which has proven to provide a high sense of presence (e.g., Makransky et al., 2017) and offers the learner a way to interact with the environment through head movements. The benefits of using immersive VR for learning is of special interest, as its potential remains unexplored, specifically on its effect on procedural and declarative knowledge. Procedural knowledge can be defined as embodied knowledge, knowing how to do something such as driving a car, while declarative knowledge refers to factual knowledge such as learning a specific name or concept (Schneider & Stern, 2010).

Prior research in immersive VR and learning have investigated the effectiveness of VR on physical training and its impact on procedural knowledge (John, Pop, Day, Ritsos, & Headleand, 2018; Li, Liang, Quigley, Zhao, & Yu, 2017; Murcia-Lopez & Steed, 2018). Conversely, others have compared VR with other less immersive media for teaching of declarative knowledge and found either no differences (Moreno & Mayer, 2002) or reported VR to be significantly worse than the compared media (Makransky et al., 2017; Parong & Mayer, 2018). In this study we investigate the effect of media on both procedural knowledge and declarative knowledge. While previous research has demonstrated that learning of procedural knowledge and skills benefit from the higher fidelity and embodiment afforded by immersive VR (Bertram, Moskaliuk, & Cress, 2015; Pande & Chandrasekharan, 2017) there is also insufficient evidence on VR as a platform for declarative knowledge (Makransky et al., 2017; Parong & Mayer, 2018). We further investigate students' knowledge transfer to see how well they can translate their newly acquired knowledge into other situations and contexts (Larsen-Freeman, 2013).

1.2 Media Effect

The statement that immersive VR is best utilized when the technology is appropriately implemented in classroom-based activities (Abrahamson et al., 2016; Chaia et al., 2017; Pande & Chandrasekharan, 2017) relates to the media effect, which describes the medium's influence on instruction (Clark, 1994). One prominent view in educational theory is that it is not the media itself but the instructional method that provides learning (Clark & Salomon, 1986; Clark, 1994; Schramm, 1977). Hereby, media does "*not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition"* (Clark, 1983, p. 445). This statement is grounded on the premise that evidence has not yet found significant connections between media attributes and learning without adequate instructional methods. In a study by Clark (1994), he evaluated a study comparing traditional classroom teaching to a computer simulation and found that it was the difference in instructional method, and not the media being central to any difference in learning. Other recent studies have also tested the media effect between modern virtual technologies, finding no media effect on learning (Makransky et al., 2017; Moreno & Mayer, 2004). However, in a recent study by Meyer, Omdahl and Makransky (2018) compared immersive VR with a video in combination with pre-training and found that students scored higher on knowledge outcomes only in the immersive VR condition thus showing an interaction that cannot be explained by the effect of the instructional method alone. Recent studies have also found evidence for a media effect on motivational variables (Makransky & Lilleholt, 2018; Makransky, Lilleholt, & Aaby, 2017; Parong & Mayer, 2018). For instance, Makransky and colleagues (2017) found that students were significantly more present and rated a higher perceived enjoyment when using immersive VR compared to less immersive media.

1.3 Objectives

It hereby remains unclear whether there is an interaction between media and method when comparing immersive VR to less immersive media; making it still relevant to investigate. In this study immersive VR and a less immersive video is compared, with and without an instructional method added to the lesson. Additionally, several studies suggest that adding a generative learning strategy as an instructional method, in combination with the respective media can help learners understand the material in deeper ways (Fiorella & Mayer, 2012, 2016; Parong & Mayer, 2018; Pilegard & Mayer, 2016). Specifically, *enactment*, a generative learning strategy that involves engaging task-relevant actions during learning by manipulating respective objects in coordination with the lesson content, has proven to be relevant for learning procedures in simulated environments (Fiorella & Mayer, 2016). Adding enactment as a generative learning strategy in combination with immersive VR might therefore provide a better understanding of the learning potentials of immersive VR. Identifying any studies using enactment in combination with immersive VR has not been possible.

The aim of this study is therefore twofold. First, a comparison in instructional effectiveness of immersive VR versus a less immersive video format is made. The reason for this, is to see if students learn more about a certain subject, when it is delivered via one medium or another. More specifically, the aim is to determine the efficacy of VR as a platform for learning. Although media comparison studies have a history of methodological challenges (Clark, 2001) the research of this study provides pragmatic information concerning if VR formats should be implemented into 21st century classrooms. Second, we seek to compare the instructional effectiveness of adding enactment as a generative learning strategy in combination with the respective instructional media. This serves to investigate if there is a way to increase the effectiveness of VR as a platform for learning, and to examine whether student learning is affected when enactment is added to the lesson.

2. Theory and Predictions

The study's theoretical foundation is based on the Cognitive Theory of Multimedia Learning (CTML)(Richard E. Mayer, 2014a), Generative Learning Theory (Fiorella & Mayer, 2016; Wittrock, 1974, 1989), and motivational theories (Bandura, 1997; Schiefele, 2009).

2.1 Cognitive Theory of Multimedia Learning

The Cognitive Theory of Multimedia Learning (CTML) proposes several empirically based design principles for multimedia, with the goal of enhancing learning (Richard E. Mayer, 2014a). CTML distinguishes between three types of cognitive processing during multimedia instruction: *Extraneous processing, essential processing,* and *generative processing* (Mayer, 2014b, p. 60). Extraneous processing happens when the instructional goal is not supported by the multimedia due to poor instructional designs or distractions during learning. It is therefore linked to the way the material is presented. Previous research suggests that learners experience higher amounts of sensory stimuli in immersive VR when compared to less immersive formats, which can lead to an overload of extraneous processing and as a result hereof decreased learning (Makransky et al., 2017; Richards & Taylor, 2015; Slobounov, Ray, Johnson, Slobounov, & Newell, 2015). Essential processing is linked to the natural complexity of the to-be-learned material. This involves selecting relevant information and further organizing the presented material. Generative processing aims to make sense of the material, caused by the learner's motivation to exert more effort (Richard E. Mayer, 2014b, p. 60). The different cognitive processes are all additive, meaning that if a learner is engaged with something that requires an excessive amount of extraneous processing, the learner will not have enough working memory capacity for essential and generative processing to happen. These cognitive processes further constitute the basis of design principles for multimedia, aiming to increase learning by reducing extraneous processing, managing essential processing so the learner is not experiencing essential overload, and providing deeper understanding of the information by fostering generative processing (Mayer, 2014b). Therefore, an important reason for comparing an immersive VR simulation with a less immersive video, is the assumption that adding immersive VR to a lesson might create extraneous processing in the learner, exceeding the student's ability to engage in cognitive processes aimed at making sense of the material.

2.2 Generative Learning Theory

Consistent with CTML is the Generative Learning Theory (GLT). Generative learning theory is based on Wittrock's (1974, 1989) generative model of learning, positing that learners are not *"passive consumers of information"* (1989, p. 348), but actively *"generate perceptions and meaning that are consistent with their prior knowledge"* (1974, p. 88). This is further consistent with theorists such as John Dewey (1913) stating that student learning happens through practical experiences related to real situations and tasks, in which they actively interact with the environment. GLT provides the basis of different generative learning strategies with the intention of promoting generative learning. These learning strategies are presented by Fiorella and Mayer (2016) as, *Summarizing, Mapping, Drawing, Imagining, Self-testing, Self-explaining, Teaching, and Enacting.* The main purpose of adding a generative learning strategy to a lesson, is to make learners reflect and use prior knowledge to connect with the learning material, and thereby help the learner to construct a more meaningful mental representation of the material (Fiorella & Mayer, 2016). A study conducted by Parong and Mayer (2018) tested the efficacy of *summarizing* in relation to a VR simulation. Their study found that students learn more when they have time in between the simulation to summarize the to-be-learned content, compared to students who did not have time to summarize the to-be-learned content. The relatively short amount of time given to the students hereby gave them time to reflect over the material, thus creating a process for deeper learning.

2.2.1 Enactment as the generative learning strategy

Drawing inspiration from Parong and Mayer's (2018) study, the current study wishes to investigate the efficacy of adding the generative learning strategy, enactment, as an instructional method in combination with both a video and immersive VR. As mentioned, enactment involves engaging in task-relevant actions during learning by manipulating respective objects in coordination with the lesson content, making it particularly relevant for learning procedures in simulated environments (Fiorella & Mayer, 2016). The benefits of enactment are deeply grounded in the learner's physical interactions with the external world, and it is therefore interesting to use in combination with immersive VR, as the medium utilizes physical presence and body movements for learning (Jeremy Bailenson, 2018). In the study by Parong and Mayer (2018), the students declarative knowledge increased when using summarizing as a generative learning strategy. However, enactment relates more to a reflection process based on learning a skill which is associated more with procedural knowledge (e.g. conducting a DNA test and pipetting), rather than declarative knowledge (e.g. learning facts about DNA). Therefore, we posit that enactment may help the learner in a different way, as the learning material in the current study is more physically connected to movements and gesticulations (Carbonneau, Marley, & Selig, 2013; Fiorella & Mayer, 2016). Most of the current research investigating the efficacy of enactment has been conducted in combination with an ordinary teaching lesson in a classroom without any multimedia (Carbonneau et al., 2013; Cook, Mitchell, & Goldin-Meadow, 2008; Fujimura, 2001; Glenberg, Goldberg, & Zhu, 2011).

Based on the theory and prior research, we predict that there will be an interaction between media and method, and thus, that the group receiving a lesson in immersive VR will benefit more from enactment when assessed with post-test measures of procedural knowledge and transfer, than the group receiving the same lesson as a video (Hypothesis 1 and 3). We further hypothesize that enactment will not have any effect between the groups on declarative knowledge, as the instructional method relies heavily on procedural skills (Hypothesis 2).

Table 1: Hypotheses 1-3 summarized

Hypothesis 1:	There will be a positive effect for enactment on procedural knowledge (H1a) and enactment will be specifically beneficial for the immersive VR condition (H1b).
Hypothesis 2:	There will be no difference between the groups on declarative knowledge and no interaction because the enactment was focused only on procedural skills.
Hypothesis 3:	There will be a positive effect for enactment on knowledge transfer (H3a) and enactment will be, specifically beneficial for the immersive VR condition (H3b).

2.3 Motivational Theories

In the current study we are also interested in assessing motivational factors, including motivation, interest, self-efficacy and perceived enjoyment, in order to test the effect of both media and method.

Prior research shows that student motivation is important for learning in the classroom, as motivated students show higher engagement during lessons, yield effort to better understand the material, as well as higher resilience when overcoming obstacles in understanding (Parong & Mayer, 2018). A reason for using immersive VR in the classroom is grounded in interest theory and self-efficacy theory (Bandura, 1997; Schiefele, 2009). Interest theory suggests that students work harder when they are intrinsically interested in the material, or if the lesson itself elicits situational interest in the learner (Mayer, 2008; Schiefele, 2009; Wigfield, Tonks & Klauda, 2016). A meta-analysis conducted by Schiefele, Krapp & Winteler (1992)**,** found a correlation between students' self-ratings of how interested they were in specific school subjects and how well they did in school overall. Furthermore VR applications have proven to spark situational interest (Makransky & Lilleholt, 2018; Makransky et al, 2017a; Makransky et al., 2017b; Parong & Mayer, 2018). For instance, in Parong and Mayer (2018) they found that students' situational interest was elicited significantly in the immersive VR group, compared to the control group who watched a PowerPoint slide lesson instead.
Self-efficacy is a social-cognitive concept and has proven to be a critical factor across various areas within psychology, including learning as it is associated with positive outcomes such as academic achievement and persistence (Chemers & Garcia, 2001; Multon, Brown, & Lent, 1991; Richardson, Abraham, & Bond, 2012; Tompson & Dass, 2000). Self-efficacy is defined by Bandura (1997) as: *"the belief in one's abilities to organize and execute courses of action required to produce given attainments"* (p.3). Several studies have found immersive VR to increase students' self-efficacy significantly when compared with other methods of learning (Buttussi & Chittaro, 2018; Makransky, Thisgaard, & Gadegaard, 2016; Thisgaard & Makransky, 2017; Tompson, G. H. & Dass, 2000). A possible explanation could be that immersive VR allow the students to learn through activities in high-fidelity environ-

ments and gaining relevant feedback. Self-efficacy is therefore an important measure when investigating the interactions between media.
The relevance of measuring students' perceived enjoyment lies in, that the benefits of using immersive VR in lessons is grounded in its ability to make learning a fun experience, in which both engagement and motivation is affected (Vogel et al., 2006). This is linked to the fact that positive emotions interact with each other and can serve as mediator between the multimedia lesson and learning outcomes (Pekrun, 2006; Pekrun, Goetz, Frenzel, Barchfeld & Perry, 2011; Pekrun & Stephens, 2010; Reyes, Brackett, Rivers, White, & Salovey, 2012). Furthermore, studies are persistently showing that immersive VR is associated with a higher self-reported perceived enjoyment in learning contexts, compared to more conventional media (e.g., Buttussi & Chittaro, 2018; Makransky & Lilleholt, 2018; Makransky et al., 2017; Parong & Mayer, 2018).

This study therefore predicts a positive effect of motivational factors, in which the group receiving a lesson in immersive VR will score significantly higher immediately after the experiment, on a post-test measure of motivation, interest, self-efficacy, and perceived enjoyment, than the group receiving the same lesson through video (hypothesis 4-7).

Table 2: Hypotheses 4-7 summarized

Hypothesis 4:	We predict a positive effect for media on motivation. That is students will be more motivated after using immersive VR compared to video.
Hypothesis 5:	We predict a positivt effect for media on self-efficacy. That is students will feel a higher self-efficacy after using immersive VR compared to a video.
Hypothesis 6:	We predict a positive effect for media on interest. That is students will be more interested in the specific content after using VR compared to a video.
Hypothesis 7:	We predict a positive effect for media in perceived enjoyment. That is students will feel more perceived enjoyment after using immersive VR compared to a video.

3. Method

3.1 Participants

The sample consisted of 165 high school students (111 females and 54 males) on three different schools, who all gave consent to participating. The participants were recruited by contacting teachers and schools, who showed interest in the experiment and were willing to participate during class time. Therefore, neither teachers nor students had to spend extra time on the experiment. When the class started, the participants were randomly divided into four conditions: Immersive VR (n=42), immersive VR with enactment (n=41), video (n=39), and video with enactment (n=43). Each condition took place in separate classrooms. This was done deliberately, mainly to keep the VR and video conditions separated and prevent participants from distracting each other.

3.2 Procedure

Initially, participants were given a pre-test, which included questions about their prior knowledge and demographic characteristics (age, gender etc.). Then, they were randomly assigned to one of the four conditions. All conditions started with students either experiencing the VR simulation or watching the video. The immersive VR was accessed through an HMD, which is attained with a pair of head mounted goggles that portrays the virtual environment by locating the user's head orientation and position from a tracking system (Makransky & Lilleholt, 2018).
Following the intervention, groups without enactment immediately entered a post-test that tested declarative knowledge, procedural knowledge, and transfer, as well as non-cognitive measurements such as motivation, self-efficacy, interest, and perceived enjoyment in a controlled proctored setting. The groups with enactment went to another room after the intervention and were instructed to manipulate with props on a table that resembled all the laboratory tools and equipment that were present in the virtual laboratory (see figure 1 and 2). The enactment drill was divided into three parts which students had to repeat for a period of two minutes (a total of six minutes). The students were told to enact the exact procedure with the presented props, the same way they remember doing it in the simulation or the video. When the

enactment drill was over, the students would take the same post-test as the other groups.

Figure 1: Screenshots of the CSI simulation

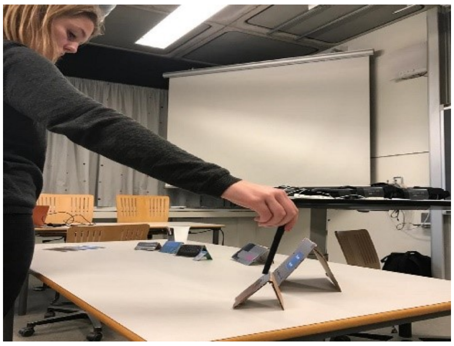


Figure 2: Photo of a student enacting

3.3 The Multimedia Lesson

The learning intervention consisted of either a VR simulation "*Polymerase Chain Reaction Virtual Lab"* developed by Labster (Labster), or a high-quality video recording of the simulation (Figure 1 and 4). The simulation revolves around a crime-scene investigation involving forensic analysis of the collected DNA sample in a realistic laboratory environment and supplementary animations of micro-level biological processes such as DNA replication. A science lesson about this subject was chosen because it utilizes the affordances associated with VR, as it allows the learner to 'be immersed' into micro-biological processes, that are not always visible to the naked eye. In the simulation, the learner is a forensics expert. Finding themselves at a crime-scene, the learner must find biological evidence, and further analyze the material in a real scientific laboratory to find the suspected murderer. During the simulation, information is provided through Labster's pedagogical agent, a lab assistant, who narrates and guides the learner through the simulation.

The VR simulation was administered with a Samsung Galaxy S8 phone and stereoscopically displayed through a Samsung Gear VR HMD with headphones attached (see figure 3). Each participant was given their own HMD with instructions on how to put it on and use it. The interactivity in the simulation occurred through movements of the head, allowing the learner to control where they focus their attention in the 360-degree virtual environment, at their own pace. For the video condition the simulation was screen-captured, creating a video recording. An essential consideration in the process of making the video was recording all the relevant information in order to make sure participants learning through this format had access to similar visual information. The video is therefore considered a recording of an optimal experience of the VR simulation, trying to make the video experience as equivalent as possible to the VR experience. Participants watched the video on their own laptop with headphones attached (see figure 4).

Figure 3: Picture of students using Gear VR

Figure 4: Picture of students watching video

3.4 Enactment material

The enactment material used in this study consisted of homemade props, with the purpose of recreating the laboratorial surroundings as found in the simulation (see figure 5). The props consisted of all the machines and objects needed to make a polymerase chain reaction (PCR) analysis, which the students were already familiar with from watching the video or trying the VR simulation.

Figure 5: Photo of Enactment props

3.5 Pre- and Post-test Questionnaires

Analyses of the questionnaire data were conducted in IBM SPSS version 25. The pre-questionnaire consisted of a prior knowledge test and demographic characteristics. The prior knowledge test contained seven questions related to DNA polymerase chain reaction (e.g. "*Do you know what a PCR-machine is?")*. The prior knowledge measure had a Cronbach's alpha reliability of 0.70.

Psychological measurements such as motivation, self-efficacy, and interest were also tested in the pre-test, and later in the post-test. All of these were rated on a five-point Likert scale ranging from (1) strongly disagree to (5) strongly agree. The mean score for the items was used, meaning that learners could score between one and five on each scale. The motivation scale was adapted from the Intrinsic Motivation Inventory (Deci et al., 1994) and consists of five items (e.g. "*I like to learn through simulations and games*") and had a Cronbach's alpha reliability of 0.83 in the pre-test and 0.88 in the post-test. The self-efficacy of learning scale was adapted from the Motivated Strategies for Learning Questionnaire (MSLQ; (Pintrich, Smith, García, & McKeachie, 2002) and consisted of seven items (e.g. "*I think that I would earn a good grade in biology/biotech*") with a Cronbach's alpha reliability of 0.89 in the pre-test and 0.93 in the post-test. To measure interest, students were asked to indicate their degree of interest in performing six activities common to work within the field of biology and biotech. This way of measuring interest was chosen based on previous research using this method to assess interest in computing disciplines (Lent, Brown, & Hackett, 1994; Lent, Lopez, Lopez, & Sheu, 2008). The scale consisted of 6 items (e.g. "*Indicate how interested you are in gathering and analyzing biological data*") and had a Cronbach's alpha reliability of 0.88 and 0.91 for pre- and post-test, respectively.

Furthermore, the post-test consisted of measurements of students' perceived enjoyment, declarative knowledge, procedural knowledge and transfer. The Perceived enjoyment scale was adapted from Tokel and Isler (2013) and consisted of three items (e.g. "*I find using this kind of simulation enjoyable*") with a Cronbach's alpha reliability of 0.90. The perceived enjoyment scales were also rated on a five-point Likert scale ranging from (1) strongly disagree to (5) strongly agree. The declarative knowledge test included 23 multiple-choice questions and included conceptual and general knowledge questions related to the simulation/video (e.g. "*What does the* *acronym PCR stand for?*") and had a Cronbach's alpha of 0.83. The procedural knowledge test included three open-ended questions (e.g. "*Describe in steps how to use a pipette to prepare laboratory samples. Mention as many steps as possible)*, and three multiple-choice questions measuring how much of specific procedures were retained (e.g. "*In sequential order, what are the three steps of PCR?*"), with a Cronbach's alpha reliability of 0.92. For the open-ended questions, participants were scored from 0 to 25 based on how good the answer was. To reach an objective measuring of the scores, the rating was done blindly, meaning that we had no knowledge about which condition any of the student's belonged to. The transfer test included a case-question that assessed the students' ability to apply the learned knowledge to a novel situation. This was designed to measure how well participants were able to use knowledge from the lesson in a different context. Participants were scored from zero to two based on their answers. In the same way as the procedural knowledge questions, the transfer question answers were rated blindly. For a list of all questions see Appendix 1.

4. Results

Before investigating the research questions, we investigated if the groups differed on personal information characteristics and prior knowledge. One-way ANOVAs indicated that the groups did not differ significantly on prior knowledge ($F_{(3,161)} = 1.004$, $p = .393$). However, a chi-square test indicated that the groups differed significantly in the proportion of boys and girls, $X^2_{(N = 165)} = 11.081$, $p = .011$. In conclusion, there was no evidence of differences between the groups on prior knowledge, but a significant imbalance in gender distribution existed before the start of the experiment.

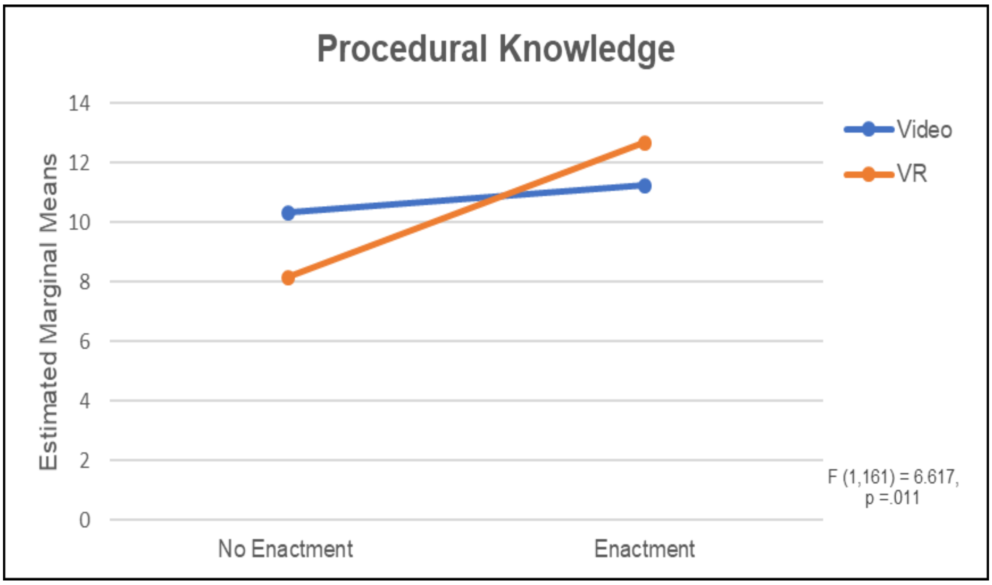
Table 3: Means and standard deviations for the dependent variables measured in the immediate post-test

	Immediate measures						
	Immersive VR		Video		Media	Method	Interaction
Enactment	With	Without	With	Without	p-value	p-value	p-value
Procedural Knowledge	12.68 (3.60)	8.14 (6.19)	11.23 (7.48)	10.33 (6.42)	.727	.011*	.087
Declarative Knowledge	11.41 (3.84)	11.12 (5.33)	11.74 (4.05)	12.66 (5.75)	.211	.676	.417
Transfer	1.46 (0.77)	1.07 (0.92)	1.25 (0.84)	1.10 (0.91)	.514	.045*	.378
Motivation	4.11 (0.76)	4.17 (0.64)	3.56 (0.83)	3.82 (0.64)	.000*	.190	.436
Self-efficacy	3.19 (0.77)	3.40 (0.75)	3.15 (0.77)	3.37 (0.85)	.849	.672	.218
Interest	3.22 (0.90)	3.46 (0.69)	3.15 (0.84)	3.57 (0.71)	.930	.055	.974
Enjoyment	4.00 (0.73)	3.92 (0.95)	3.68 (0.85)	3.58 (0.91)	.018*	.487	.957

P-values with * indicates significant results ($p < 0.05$)

Hypothesis 1: There will be a positive effect for enactment on procedural knowledge (H1a). Furthermore, we predict that enactment will be specifically beneficial for the immersive VR condition (H1b)

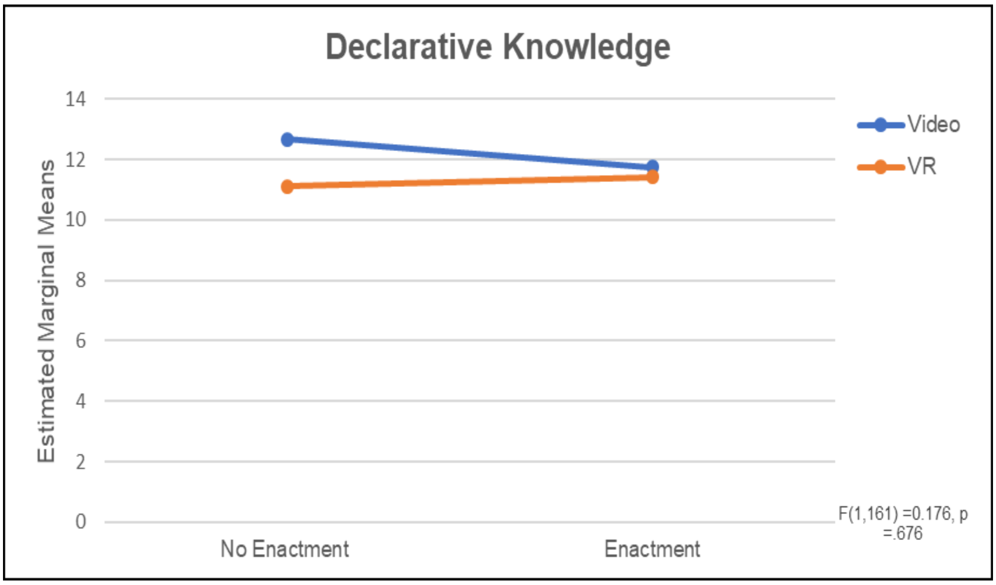
Figure 6: Results regarding procedural knowledge



Hypothesis 1 was investigated with a two factorial ANOVA analysis with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and procedural knowledge as the dependent variable. We hypothesize a positive effect for enactment (H1a) and that enactment will specifically be beneficial for the immersive VR condition (H1b). The results presented in Table 3 indicated that Hypothesis 1 was partially supported; that is, there was a statistical difference on enactment for the outcomes of procedural knowledge $F_{(1.161)} = 6.617$, $p = .011$. Although there was no interaction between media and method $F_{(1.161)} = 2.965$, $p = .087$, the differences within each media condition were investigated with independent samples t-tests. The results indicated that there was a significant difference showing that the enactment (M = 12.68, SD = 6.93) group scored significantly higher than the no enactment group (M = 8.14, SD = 6.19), $t_{(81)}=3.150$, $p = .002$, d = 0.69 when using immersive VR. However, the difference between the enactment (M = 11.23, SD = 7.48) and no enactment (M = 10.33, SD = 6.42) groups was not statistically significant in the video condition $t_{(80)} = 0.581$, $p = .563$, d = 0.13. This supports hypothesis 1a, indicating that enactment improves procedural knowledge, and partially supports hypothesis 1b, suggesting that enactment is specifically beneficial when learning through immersive VR.

Hypothesis 2: There will be no difference between the groups on declarative knowledge. Furthermore, we expect no interaction because the enactment was focused only on procedural skills

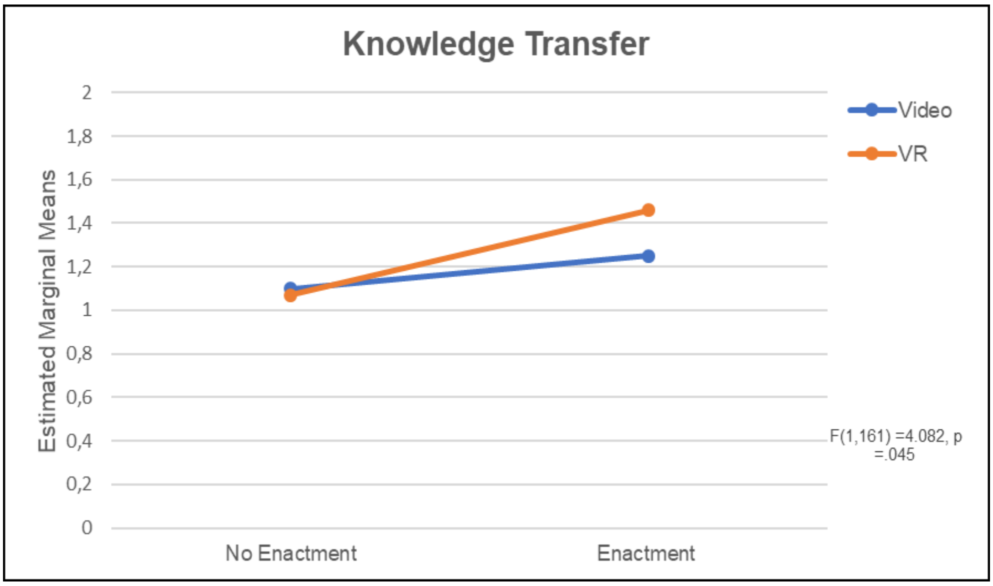
Figure 7: Results regarding declarative knowledge



Hypothesis 2 was also investigated with a two factorial ANOVA analysis with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and declarative knowledge as the dependent variable. We hypothesize no main effect for enactment (H2a), and that enactment will not be beneficial for the immersive VR condition or the video condition (H2b). The results presented in Table 3 indicated that Hypothesis 2 was supported; that is, there was no statistical difference on enactment for the outcomes of declarative knowledge $F_{(1.161)} = 0.176$, $p = .676$. Furthermore there was no interaction between media and method $F_{(1.161)} = 0.663$, $p = .417$, d = 0.07. When investigating the differences within each media condition, independent samples t-tests indicated that there were no significant differences between the enactment (M = 11.41, SD = 3.84) group and the no enactment group (M = 11.12, SD = 5.33), when using immersive VR. Also, the difference between the enactment (M = 11.74, SD = 4.05), and no enactment (M = 12.66, SD = 5.75) groups was not statistically significant in the video condition. This supports hypothesis 2, indicating that this specific enactment drill does not improve declarative knowledge, as the enactment drill primarily relies on procedural knowledge.

Hypothesis 3: There will be a positive effect for enactment on knowledge transfer (H3a). Furthermore, we predict that enactment will be, specifically beneficial for the immersive VR condition (H3b)

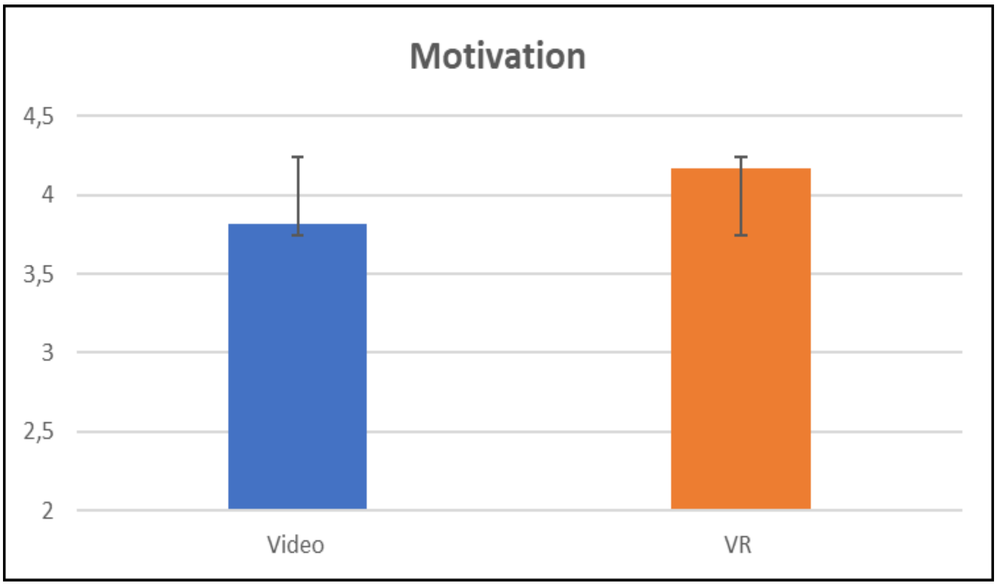
Figure 8: Results regarding knowledge transfer



Hypothesis 3 was also investigated with a two factorial ANOVA analysis with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and knowledge transfer as the dependent variable. As in H1, we hypothesize a main effect for enactment (H3a), and that enactment will specifically be beneficial for the immersive VR condition (H3b). The results presented in Table 3 indicate that hypothesis 3 was partially supported; that is, there was a statistical difference on enactment for the outcomes of knowledge transfer $F_{(1,161)}$ =4.082, p =.045. However, there was no interaction between media and method $F_{(1,161)}$ =0.783, p =.378. When investigating the differences within each media condition, independent samples t-tests indicate that there was a significant difference indicating that the enactment (M = 1.46, SD = 0.77) group scored significantly higher than the no enactment group (M =1.07 , SD = 0.92), $t_{(81)}$=2.092, p = .040, d = 0.46 when using immersive VR. The difference between the enactment (M = 1.25, SD = 0.84), and the no enactment (M = 1.10, SD = 0.91) groups was also statistically significant in the video condition, $t_{(80)}$=0.789, p = .043, d = 0.17. This support hypothesis 3a that enactment improves knowledge transfer.

Hypothesis 4: We predict a positive effect for media on motivation. That is students will be more motivated after using immersive VR compared to a video

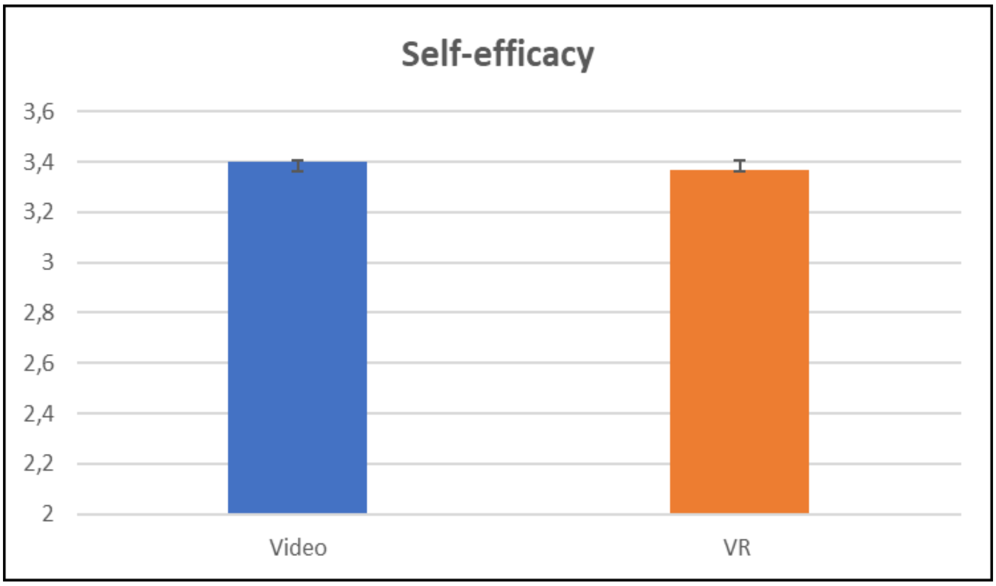
Figure 9: Results regarding motivation



Hypothesis 4 was also investigated with a two factorial ANOVA with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and motivation as the dependent variable. The results in Table 3 indicate that Hypothesis 4 was supported. A positive effect was found for motivation $F_{(1,159)}$ = 12.679, $p < .001$, d = 0.54 (see Figure 9). The results indicate that participants are significantly more motivated when using immersive VR (M = 4.17, SD = 0.64) compared to the video instruction (M =3.82, SD = 0.64). Therefore, we conclude that learners feel significantly more motivated through the immersive VR simulation, than the video. A main effect was identified on media only, as no significant main effect across method was detected, $F_{(1,159)}$ = 1.735, p =.190.

Hypothesis 5: We predict a positive effect for media on self-efficacy. That is students will feel a higher self-efficacy after using immersive VR compared to a video

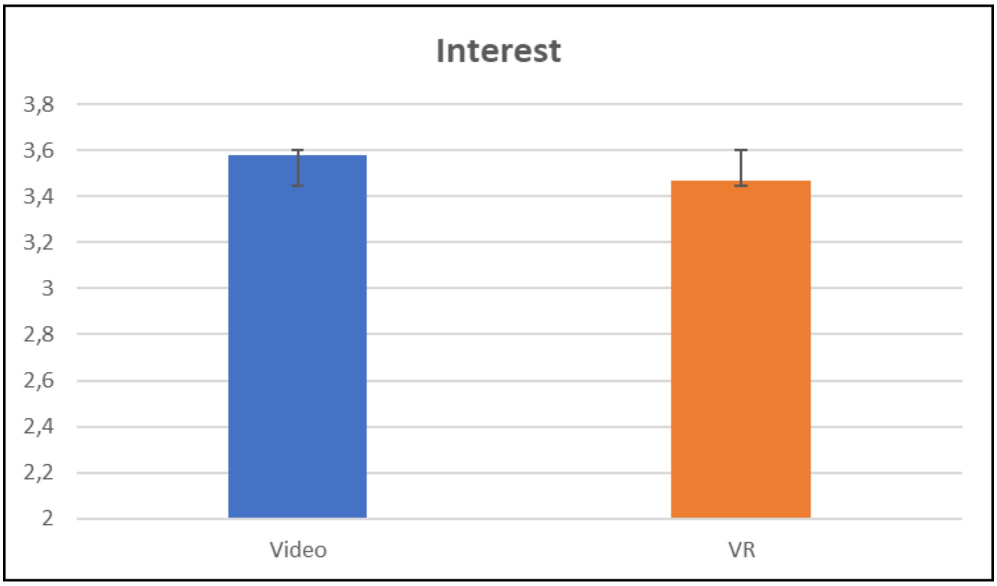
Figure 10: Results regarding self-efficacy



Hypothesis 5 was also investigated with a two factorial ANOVA with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and self-efficacy as the dependent variable. The results in Table 3 indicate that Hypothesis 5 was not supported. No main effect across media was identified $F_{(1,159)}$ =0.036, p =.849, nor across method $F_{(1,159)}$ =0.180, p =.672. Furthermore, there was no significant interaction between media and method for self-efficacy, $F_{(1,159)}$ =1.528, p =.218. The results indicate that there is no difference in students' self-efficacy when the students use immersive VR or video, and when the students do, or do not enact in combination with the media.

Hypothesis 6: We predict a positive effect for media on interest. That is students will be more interested in the specific content after using VR compared to a video

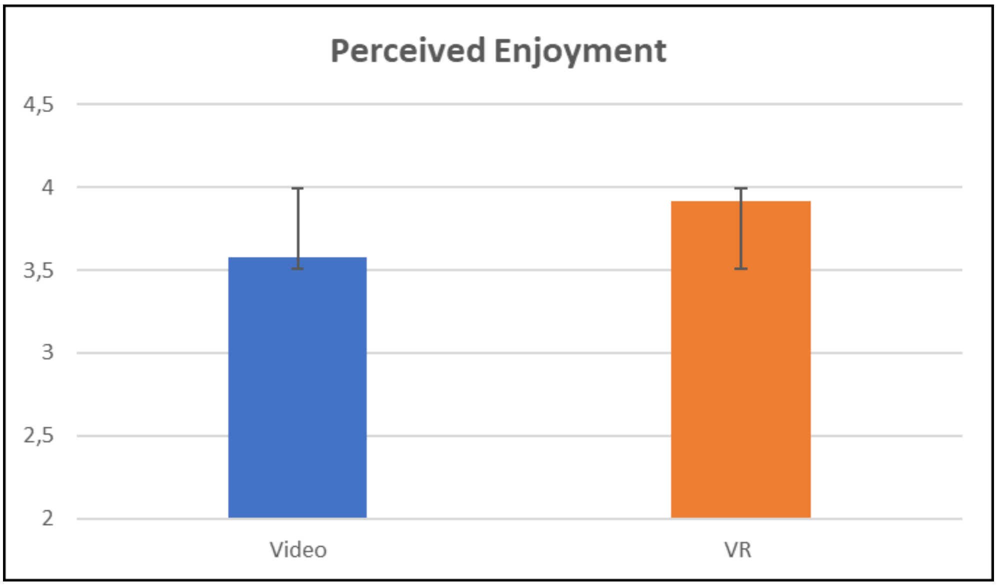
Figure 11: Results regarding interest



Hypothesis 6 was also investigated with a two factorial ANOVA with media (immersive VR vs. video) and method (enactment vs. no enactment) as independent variables, and interest as the dependent variable. The results in Table 3 indicate that Hypothesis 6 was not supported, as no effect for media was found for interest $F_{(1,158)}$ = 0.008, p =.930, d = 0.15 (see Figure 11). This indicates that there are no differences in participants' interest when using immersive VR (M = 3.46, SD = 0.69) compared to the video (M =3.57, SD = 0.71), and we therefore conclude that the students' interest in that particular subject, did not differ when learning through an immersive VR simulation, or a video.

Hypothesis 7: We predict a positive effect for media in perceived enjoyment. That is students will feel more perceived enjoyment after using immersive VR compared to a video

Figure 12: Results regarding perceived enjoyment



Hypothesis 7 was also investigated with a two factorial ANOVA with media (immersive VR vs. video) and method (enactment vs no enactment) as independent variables, and perceived enjoyment as the dependent variable. The results in the final row of Table 3 indicate that Hypothesis 7 was supported. A positive effect for media was found for perceived enjoyment $F_{(1,160)} = 5.571$, p =.018, d = 0.36 (see Figure 12). The results indicate that participants have significantly higher perceived enjoyment when using immersive VR (M = 3.92, SD = 0. 95) compared to the video (M = 3.58, SD = 0.91). Therefore, we conclude that the students feel significantly more enjoyment when learning through an immersive VR simulation, compared to a video.

5. Discussion

The following sections will discuss the study's empirical- and theoretical contributions, as well as practical implications within the study. Furthermore, a section regarding future directions and limitations on the subject matter will be provided.

5.1 Empirical Contributions

The experiment presented in this study investigated the relationship between instructional media (immersive VR vs. video) and method (enactment vs. no enactment). Students who only viewed the immersive VR lesson did not differ on a post-test from those who only viewed a video covering the same material. However, the students reported significantly higher ratings of motivation and perceived enjoyment following the lesson. These findings are consistent with the hypotheses stating that motivational factors in students will be positively affected when learning through immersive VR. Immersive VR can therefore be considered a medium which is highly relevant for engaging students in learning, which is also demonstrated in previous literature (Makransky & Lilleholt, 2018; Thisgaard & Makransky, 2017). However, we did not find significant differences for interest and self-efficacy in between media. This is somewhat inconsistent with prior literature, stating that VR applications can spark situational interest (Makransky et al., 2017; Makransky et al., 2017b) and effectively develop self-efficacy (Bonde et al., 2014; Makransky et al., 2016). The VR application therefore increased students' motivation to learn with the respective media, but it did not change their interest regarding the topic of PCR. The results further indicate that the students' intrinsic interest and self-efficacy did not change between media. As students found immersive VR to be more motivating and enjoyable when learning about PCR, it is however difficult to state if immersive VR works specifically due to its novelty value, which might change if immersive VR eventually becomes a common property.

The results also showed that enactment increased knowledge transfer for both the video and immersive VR groups. Furthermore, enactment significantly improved learning outcomes for procedural knowledge, only in the immersive VR condition. This indicates an interaction between media and method which has not been found in previous studies and cannot be explained by the effect of the instructional method alone. Even though the enactment procedure was relatively easy to perform, it seems that it helped the immersive VR group with recognizing important concepts and further use the experience of being in a lab to develop a spatial mental map of the environment; thereby aiding their learning. Furthermore, the very physical nature of immersive VR is closely related to the enactment exercise, and therefore the learner in immersive VR might have an advantage in recognizing and remembering the content more relatable to procedural knowledge. Assumingly, it might be more difficult for student to imagine themselves performing the task when watching a video, explaining why no significant effect of enactment was found in the video condition.

5.2 Theoretical Contributions

A possible interpretation of the results is that watching a video is equally as effective as immersive VR. As mentioned in earlier sections, CTML explains how learning in multimedia can result in essential processing overload from the complexity of the material, as well as extraneous processing overload from the presentation of the material. Extraneous processing can be harmful to the process of learning because working memory load is increased without it being directly related to the to-be-learned material. In the simulation, the learner had the freedom to look in a 360-degree view in the laboratory environment, which could have added to the student's cognitive load as they also had to pay attention to the pedagogical agent, as well as reading relevant information in the simulation.

Thus, some students might divert their attention from important material, essentially leading to students being unable to properly process the to-be-learned content. Makransky and colleagues (2017a) found that students felt a greater sense of presence when using immersive VR but learned less, when compared to a desktop computer simulation. This is consistent with other studies that found lower levels of learning with more immersive technology, mainly caused by students focusing more on the virtual environment than on the to-be-learned material (Moreno & Mayer, 2002; Van der Heijden, 2004; Richards & Taylor, 2015). However, it can be assumed that the instructional features used in the current immersive VR lesson did not create such overload of extraneous as well as essential processing for the students. Another perspective is that immersive VR provides the learner with added interactivity and agency beneficial to learning, in which they are actively taking control of their pace and their own learning (Makransky & Petersen, 2019). This is consistent with newer studies (Alhalabi, 2016; Webster, 2016) who have found that students learn more in high-immersion VR, partially due to the level of interaction and control. Webster (2016) found that the interactivity in the immersive VR, activated learners' senses which helped aid more learning. Additionally, the results in this study could be an indication that the effect of added immersion and control in the immersive VR simulation were adequate and did not cause any extraneous overload. However, these suggestions are merely considerations, since no statistical differences in learning were found between the two media in the current study.

The current study further demonstrates that students feel more motivated and show higher enjoyment when learning through immersive VR. Drawing from interest theory, immersive VR helps elicit the students' situational interest, through which the learner's motivation to learn is being affected by the media. Immersive VR hereby works as a medium to trigger situational interest by turning a subject into something more interesting. Although motivational factors are not always enough to enhance learning (Dewey, 2004), they can develop into later phases involving individual interest development which have been found to promote positive long-term educational outcomes (Makransky et al., 2017; Renninger & Hidi, 2016). In the same manner, the novelty of the technology and its features can result in different outcomes, depending on the multimedia design; either impeding the participants' learning increasing extraneous workload (Makransky et al., 2017), or increase learning (Alhalabi, 2016; Webster, 2016).

Adding enactment as an instructional method to the respective media further provided evidence for generative learning theory in that promoting meaningful learning through guiding learners in engaging tasks caused learning gains from a lesson. Enacting the material immediately after the lesson, prompted the learners to select, organize, and integrate the information from the lesson into their existing knowledge structures. A major finding in this study is therefore that generative learning strategies can be applied to learning in VR environments. However, it is stated before that no studies have been identified using enactment in combination with immersive VR.

More research is therefore needed to measure the efficacy of generative learning strategies, specifically enactment, in combination with immersive VR.

5.3 Practical Implications

The results imply that there is an interaction between instructional method and media, with enactment being specifically essential for procedural knowledge in immersive VR. Researchers should consequently be aware of these conditions if they are to further test the learning potential of immersive VR. It is therefore important that awareness is brought to the effects of enactment or similar instructional strategies for enhancing deeper learning. For example, a practical way of using enactment could be to include it as part of the regular classroom teaching, where students use the immersive VR to learn about the material as well as enhancing student motivation and enjoyment, and further guiding students through enactment drills, where students can reflect and draw upon their new knowledge. In this regard, enactment is applicable to various learning scenarios in which procedural knowledge is conveyed in VR. However, this study as well as prior research on the subject, suggest that there may not be a strong enough incentive to implement immersive VR in the classroom to help students learn. Even though some studies have found learning outcomes in immersive VR, it is uncertain what exactly causes this. Although the study has provided evidence that immersive VR followed by enactment can increase procedural learning and transfer, it is still a novel subject and more research on the area is required. Since immersive VR is a popular technology among students, as indicated by the increase of students' motivation and perceived enjoyment, using it in combination with a generative learning strategy may be beneficial in fostering student motivation and still sustain learning outcomes when compared to other more traditional media.

5.4 Future Directions and Limitations

Several of the points brought up in this discussion entail an understanding of immersive VR as a medium, which interacts with instructional methods differently than a video. More research is needed to determine the exact relationship of the interaction between media and method, as well as how generative learning strategies can be used to help students promote deeper learning in immersive VR. The current study has offered an interesting way to implement instructional features to an immersive VR lesson, and further established that, to achieve a meaningful technology integration for teaching and learning the technology in hand must be used properly by the teacher with a clear purpose in mind. Ultimately, teachers' personal pedagogical beliefs as well as attitudes, perceptions, and self-confidence toward the technology play a key role in their decisions regarding whether and how to integrate technology within their classroom practices (Dobber, et al., 2017; Holden & Rada, 2011). Although this study has successfully used immersive VR in a classroom setting, a bigger challenge is arguably yet to come; making teachers accept the technology and knowing how immersive VR can be specifically beneficial for learning.

A further concern is the generalizability of this study into other subjects and areas. Research is therefore needed to investigate if the results found in this study are specific to the subject matter and whether the results are generalizable to other technologies. For instance, would implementation of enactment in combination with a regular class lesson be effective at increasing learning outcomes to the same levels as learning from an immersive VR simulation or a video? Furthermore, adding other generative learning strategies to the same learning material both in immersive VR and video, would help contribute to how these strategies can be beneficial for student learning.

Part b

In the curriculum for the master's thesis in Psychology, the second part is defined as a cape in which the study *'develops further on the scientific backgrounds in the article, specific aspects of the investigated subject matter and further perspectives on the subject matter, including a two-page resumé"*(Studieordningen, 2015). The following section will therefore elaborate on these demands, including a brief section about my own background and motivation for conducting this study. Since there was only enough space in the article to briefly explain central concepts and theories, the forthcoming sections will also illuminate these.

6. Resumé

With recent advances in immersive technology and proliferation of VR devices in today's techno-sphere, novel ways of enhancing student learning have emerged in the educational scene (Bonde et al., 2014; Dalgarno & Lee, 2010; Mikropoulos & Natsis, 2011; Parong & Mayer, 2018). Although the technological upsurge certainly has proposed a technological outbreak in education, research suggests that learning with VR only works in terms of learning outcomes when the technology is appropriately implemented based on scientific learning principles, where students construct knowledge through classroom activities, contextualized to their social and material world (Abrahamson et al., 2016; Chaia et al., 2017; Pande & Chandrasekharan, 2017). Preliminary research shows that activities, such as generative learning strategies in combination with VR in a science lesson can increase learning effectiveness (Fiorella & Mayer, 2016; Parong & Mayer, 2018). The present study addresses these issues by comparing student learning about DNA polymerase chain reaction (PCR) procedures through immersive VR with learning through a video, containing identical content, both with and without a generative learning strategy. The generative learning strategy chosen for this study was enactment. It involves engaging in task-relevant actions during learning by manipulating respective objects in coordination with the lesson content, making it particularly relevant for learning procedures in simulated environments (Fiorella & Mayer, 2016). Based on previous research on generative learning strategies (Fiorella & Mayer, 2016) and enactment (Pande & Chandrasekharan, 2017), we specifically predicted that students will exert more generative processing in the immersive VR conditions, which will lead to better learning outcomes, particularly for procedural knowledge and knowledge transfer, as compared to the video condition. We also hypothesized that students feel more perceived enjoyment, motivation, self-efficacy, and interest when learning through immersive VR, when compared to a video.

A total of 165 Danish high school students (111 females) from three different schools learned about the PCR technique through either a video or an immersive VR simulation, with or without enactment as a generative learning strategy. The learning material revolves around a crime-scene investigation involving forensic analysis of the collected DNA sample in a realistic laboratory environment and supplementary animations of micro-level biological processes such as DNA replication. To support students in the enactment conditions, specialized props where provided in the form of printed out lab tools. The pre-session survey included demographic questions and a prior knowledge scale. Psychological measurements such as motivation, self-efficacy, and interest were also tested in the pre-test, and later in the post-test. The post- test further included measurements on perceived enjoyment and three tests for evaluating the participant's declarative knowledge, procedural knowledge and knowledge transfer.

The results indicated that there was a statistical difference on enactment for the outcomes of procedural knowledge $F_{(1.161)} = 6.617$, p =.011, and further a significant difference showing that the enactment (M = 12.68, SD = 6.93) group scored significantly higher than the no enactment group (M = 8.14, SD = 6.19), $t_{(81)}$=3.150, p = .002, d = 0.69 when using immersive VR. There was a statistical difference on enactment for the outcomes of knowledge transfer $F_{(1,161)}$ =4.082, p =.045. When investigating the differences within each media condition, independent samples t-tests showed that there was a significant difference indicating that the enactment (M = 1.46, SD = 0.77) group scored significantly higher than the no enactment group (M =1.07 , SD = 0.92), $t_{(81)}$=2.092, p = .040, d = 0.46 when using immersive VR. The difference between the enactment (M = 1.25, SD = 0.84), and the no enactment (M = 1.10, SD = 0.91) groups was also statistically significant in the video condition,

$t_{(80)}$=0.789, p = .043, d = 0.17. A positive effect was further found for motivation $F_{(1,159)}$ = 12.679, p < .001, d = 0.54, and perceived enjoyment $F_{(1,160)}$ = 5.571, p =.018, d = 0.36, indicating that participants are significantly more motivated and have significantly higher perceived enjoyment when using immersive VR compared to the video instruction.

7. Background and Motivation

The current study is based on an initial interest for the interplay between technology and psychology, which has been a repeated subject matter throughout my studies. This has both provided insights about the potential of technology but also about its limitations as well. During an internship I helped measuring the usability of a medico device in which we found that eye-tracking can bring information which interviews, self-reports and observations cannot (Koester, Brøsted, Jakobsen, Malmros, & Andreasen, 2017); and in the 9th semester project, we wrote a literature-review concerning VR as a prophylactic tool to mitigate mental illness in military personnel (Andreasen & Bach, 2017).

Now, as a student-assistant at the 'Virtual Learning Lab' at the University of Copenhagen, I was motivated to conduct a study as part of my master's thesis to investigate immersive VR's strengths and limitations for student learning. The research group mainly focuses on understanding psychological mechanisms of learning in immersive learning environments within the disciplines of cognitive science. The motivation was based on my own beliefs that immersive VR can have a positive influence on student learning in future classrooms. However, implementations of new technology are often misconceived with very little scientific research on its applicability. In this regard, immersive VR is no different. The motivation was therefore also to provide a critical discussion if, and why immersive VR should even be implemented in schools. The research conducted by 'Virtual Learning Lab' is further based on the conviction that technology can indeed provide positive learning outcomes, only if the technology is used with a clear purpose in mind. The research is therefore interested in investigating learning outcomes through immersive VR, just as much as research is interested in investigating how immersive VR can be facilitated to help both students and teachers in the learning process.

8. Virtual Reality in Psychology

The proliferation of immersive VR has increased as a psychological research field over the last twenty years, being a tool that can activate several sensorial stimuli at the same time (Wilson & Soranzo, 2015). This provides the opportunity to use VR within different psychological disciplines, in this case within educational psychology by measuring students' learning outcomes. However, most empirical evidence demonstrating the effects of VR is found within the discipline of clinical psychology, particularly in studies using exposure therapy for clients with different phobic disorders (Wilson & Soranzo, 2015). One of the first psychological experiments using VR technology investigated the efficacy of immersive VR in relation to exposure therapy, specifically in relation to agoraphobia and fear of heights (Hodges et al., 1995). Later, VR was used in different experiments with other types of anxiety and stress conditions, for example Pertaub, Slater, and Barker (2001) investigated if the feeling of anxiety when speaking in front of larger crowds could be incited with VR technology. More recently, research have found positive effects of using immersive VR in treatments of anxiety, phobic disorders, OCD and PTSD (Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015; Miloff et al., 2016; Reger et al., 2016; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Wiederhold & Buochard, 2014). Additionally, and as mentioned before, during a 9th semester project we conducted a literature review in which 25 articles showed that VR can be used as a training tool to decrease levels of stress and negative reactions in military personnel and have a positive effect on their performance (Andreasen & Bach, 2017). These studies, including this current study, indicate a certain versatility in immersive VR as a medium, which makes it interesting to investigate its qualities and usability within the many disciplines of psychology.

9. Literature Review

To ensure that the study was updated with the newest literature on immersive VR and learning, a literature review was performed before writing the article (see appendix 2). Since immersive VR and learning is the focus in the project, the search strings ("virtual reality" OR "VR" AND "learning") were evaluated as relevant keywords for the study and thus prominent in every search. Obtaining the most successful results possible these were also combined with other search strings to specify the research, ("procedural knowledge", "declarative knowledge", "knowledge transfer", "enactment", "generative learning strategies"). Much research was also found by looking through lists of references, as well as "quoted by", which is a function in PRIMO. Research was further identified along the process of writing the article. The articles were processed with a pragmatic epistemology. Knowledge is therefore considered as "whatever works" and is useful to solve practical assignments. Thus, knowledge is valid if it is usable (Rønn, 2006). This gave a total of 19 articles investigating different learning outcomes in immersive VR (see appendix 2).

10. Clarification of Concepts

The following section seek to explain the concepts of *immersive VR, procedural knowledge, declarative knowledge* and *knowledge transfer,* as these were explained in the article to a rather limited extent.

10.1 Virtual Reality

Though the definition of VR covers a broad spectrum of ideas in the overall technology domain, VR is emphasized as being a way of digitally simulating or imitating an environment (Makransky & Lilleholt, 2018). Jaron Lanier, founder of one of the original business houses selling VR systems, defines VR as *"a computer-generated, interactive, three-dimensional environment in which a person is immersed"* (Aukstakalnis & Blatner, 1992; In Lele, 2013). VR can be accessed through various displays, such as a desktop VR, VR with a head-mounted display (HMD), or a cave automatic virtual environment (CAVE) (Buttussi & Chittaro, 2018). Desktop VR is generated as a 3-D image on a computer screen and can be explored interactively by using either a keyboard, a mouse, a joystick, or a touch screen (Lee & Wong, 2014). VR with an HMD, which was used in the current study, is attained with a pair of head mounted goggles that portrays the virtual environment by locating the user's head orientation and position from a tracking system (Makransky & Lilleholt, 2018), and a CAVE system is where the user is in a room where all the walls, as well as the floor, are projection screens (Freina & Ott, 2015). CAVEs are however currently very expensive to install and maintain, as well as limited, as it accommodates only about a dozen users at a time (Schott & Marshall, 2018). The interactive element of VR is particularly relevant to point out; that is, in the virtual environment the user is away from the real world, completely immersed in the artificial one (Lele, 2013). In relation to this, a clear distinction between these types of VR is the degree of immersion (Cummings & Bailenson, 2016; Makransky & Lilleholt, 2018), which is an objective measure based on the vividness offered and the extent to which a media shuts out the outside world (Cummings & Bailenson, 2016). Consequently, desktop VR is considered low-immersion virtual environments (VE), whereas VR accessed through an HMD or a CAVE is regarded as a high-immersion VE, because the user is surrounded by the VE.

10.2 Different Concepts of Knowledge

In the article, different measurements of knowledge were investigated to better understand how VR and enactment is beneficial for learning comprehension. The learning content in the study consisted of information about polymerase chain reaction, in which the learner tries to solve a murder case by combining a suspected murderer's fingerprints with biological evidence found at the crime-scene. This includes general information about essential biological concepts such as DNA replication, while the learner is being guided through the entire process from collecting biological evidence at the crime-scene to analyzing the data in the lab.

The article divides knowledge into different concepts: *Procedural knowledge* and *Declarative knowledge.* The distinction between these two concepts of knowledge are used in many different psychological disciplines, such as developmental psychol-

ogy, cognitive sciences (Goldstone & Kersten, 2003) and educational psychology (Schneider & Stern, 2010). *Procedural knowledge* is also known as imperative knowledge and is viewed as knowledge of operators and the conditions under which they can be applied to reach certain goals (Schneider & Stern, 2010).
This can be defined as embodied knowledge, knowing how to do something such as driving a car. In the learning material, procedural knowledge is conveyed as the learner is guided through the process of preparing a pipette and making a polymerase chain reaction in a laboratory environment. *Declarative knowledge* on the other hand is viewed as general and abstract knowledge of the core principles and their interrelations in a domain (Schneider & Stern, 2010). This refers to factual knowledge such as learning a specific name or concept and is conveyed in the learning material as information about DNA and other concepts are explained as the learner progresses in the learning material.

Procedural and declarative knowledge hereby describe the amount of information the learner has acquired in different systems. However, they do not necessarily account for the learner's ability to translate their newly acquired knowledge into other situations and contexts. The study is therefore also concerned with the students' ability to transfer their knowledge into other situations where knowledge about polymerase chain reaction can be applied. This is called *knowledge transfer,* or learning transfer, and describes the learners' ability to transfer learning in one context to another (Larsen-Freeman, 2013).

11. Selection of Theories

The theories used in the study are the Cognitive Theory of Multimedia Learning, General Learning Theory and different motivational theories. The following section will provide a general overview of the theories used in the article.

11.1 Cognitive Theory of Multimedia Learning

The Cognitive Theory of Multimedia Learning (CTML) proposes several empirically based design principles for multimedia, with the goal of enhancing learning (Mayer, 2014a). Multimedia learning refers to learning from words and pictures (Parong & Mayer, 2018), through which instructional messages are designed in light of how the human mind works. According to the CTML the human information processing system contains an auditory/verbal channel and a visual/pictorial channel (*The dual-channel assumption)* (Mayer, 2014b, p. 43). A person will therefore process information in the visual channel if the material is presented visually (e.g. illustrations, videos), and in the auditory channel if presented through sounds (e.g. narration, speaker) (Mayer, 2014b, p. 47f). Furthermore, the person whether it being processed through the visual or auditory system, will only remember portions of the presented material, rather than the full picture or recording. These assumptions are closely related to Paivio's dual-coding theory, stating that people process the learning material through verbal associations and visual imagery (Paivio, 1986), and Baddeley's model of working memory explaining the human memory as a multi-part-system that temporarily stores information as we perform different tasks (Baddeley, Eysenck, & Anderson, 2009).

If a learner is to fully comprehend and understand the presented information, the learner needs to engage in the process, first by selecting and organizing relevant information in the presented material, and then integrate the selected material, bridging the gap between that and the learner's prior knowledge (Mayer, 2014b, p 51). For example, in any given multimedia message, the learner will first have to pay attention to words and/or images, then arrange them into a meaningful structure and lastly relate the content to prior knowledge that may help the learner easier relate to the to-be-learned content.

11.1.1 Extraneous, Essential and Generative Processing

So, what is then the theoretical basis for predicting that an immersive VR simulation would lead to better or worse learning outcomes? The CTML distinguishes between three types of cognitive processing that can happen during multimedia instruction: these are *extraneous processing, essential processing, and generative processing* (Mayer, 2014b, p. 60).

These are all additive, meaning that if a learner is engaged with something that requires an excessive amount of extraneous processing, the learner will not have enough working memory capacity for essential and generative processing to happen. Extraneous processing happens when the instructional goal is not supported because of poor instructional design or distractions during learning. It is therefore linked to the way the material is presented. For example, if a narration with relevant information is given at the same time as music is being played, the listener might divert from the essential task at hand by paying attention to the music. This can lead to extraneous processing overload, resulting in loss of cognitive capacity (Mayer, 2014b). A concern for using an immersive VR simulation to learn scientific content is therefore grounded in the CTML, as the visual effects in immersive VR can create an overload of information resulting in extraneous processing which has proven to prevent the learner from properly making sense of the to-be-learned material (Makransky et al., 2017).

Conversely, essential processing is linked to the natural complexity of the to-be-learned material. This involves selecting relevant information and further organizing the presented material. For example, managing essential processing can be achieved by presenting the lesson in smaller bits making it easier for the learner to work with the incoming information which is described as *the segmenting principle* (Mayer, 2014). A study conducted by Parong and Mayer (2018) tested the segmenting principle and found, that students learn more in an immersive VR simulation when they have time in between the simulation, to summarize the to-be-learned content, compared to students who tried the simulation in one stretch.

Generative processing is aimed at making sense of the material, caused by the learner's motivation to exert more effort (Mayer, 2014b, p. 60). According to Mayer (2014c) social cues prime the learners deeper cognitive processing during learning. For instance, people tend to learn more deeply when words in a multimedia presentation are in conversational style rather than formal style (Moreno and Mayer, 2004). Furthermore, a study by Mayer, Sobko and Mautone (2003) found that students performed better if the voice in the narration had a standard accent rather than a foreign accent and if the voice was human, rather than robot-like. Additionally, Dunsworth and Atkinson (2007) demonstrated that students learn more from an agent programmed with gaze and pointing, than from an agent who only narrated the information. Thus, it seems that the more on-screen agents display humanlike gesturing, movements, eye contact, and facial expressions the better learning outcomes.

In this way, the CTML can be applied when designing an effective learning multimedia, which aims to reduce extraneous processing, manage essential processing and foster generative processing. According to the theory these goals will be easier achieved, if an immersive VR learning simulation was designed based on the above-mentioned principles.

11.2 Generative Learning Theory

Another aim with the study was to apply a generative learning strategy in combination with either video or immersive VR to foster generative learning. This is based on generative learning theory (GLT). GLT is based on Wittrock's (1974, 1989) generative model of learning, positing that learners are not *"passive consumers of information"* (1989, p. 348), but actively *"generate perceptions and meaning that are consistent with their prior knowledge"* (1974, p. 88). Generation is a fundamental cognitive process in comprehension and refers to the connections a learner builds between the different elements of the presented material, and the learner's prior knowledge (Fiorella & Mayer, 2016). Generative learning is therefore closely related to the CTML, as it deals with the process of taking incoming information and transforming it into usable information by mentally reorganizing and integrating it with one's prior knowledge; thereby enabling learners to apply what they have learned to new situations (Fiorella & Mayer, 2016; Parong & Mayer, 2018).
The generative learning theory is also closely related to Bartlett's (1932) view on learning as an act of construction, in which people invest *effort after meaning* by integrating new experiences within their existing knowledge; as well as Piaget's (1926) theory of cognitive development on learning as a process of biological maturation and interaction with the environment. Furthermore, generative learning theory is much inspired by the discipline of cognitive psychology including Atkinson and Shiffrin's models of memory (1968), which stated that memory is a process through which information is transferred from one storage area to another. These all contribute to an understanding of human learning and memory, as a constructive process, in

which learning involves the process of building meaningful knowledge structures which can be applied to new situations.

Other important aspects in the model are *motivation, attention* and *memory,* which refer to a learner's willingness to make an effort towards understanding the material; the learners' cognitive capacities to maintain focus; and the learner's prior knowledge, experiences and beliefs (Fiorella & Mayer, 2016; Wittrock, 1989).

11.2.1 Generative Learning Strategies

In GLT, different generative learning strategies can provide a pragmatic approach aiming to promote students understanding (Fiorella & Mayer, 2016). Fiorella and Mayer (2016) present eight learning strategies: *summarizing, mapping, drawing, imagining, self-testing, self-explaining, teaching,* and *enacting.*
The main purpose of using a generative learning strategy, is making students reflect over the learning material. Furthermore, the reflection can aid learners in connecting the learning material to prior knowledge, and thereby help the learner construct a more meaningful mental representation of the material (Fiorella & Mayer, 2016).
In the article, the chosen generative learning strategy was enactment, which involves engaging in task-relevant actions during learning by manipulating respective objects in coordination with the lesson content (Fiorella & Mayer, 2016). Enactment is also based on *grounded cognition* (Barsalou, 2008), which states that people use sensory-motor representations of the external world to represent knowledge. Grounded cognition therefore suggests that cognitive processes relate to one's physical interactions with the world, much like generative learning theory posits that learners use their prior knowledge to connect with their world. The idea with enactment was also to create a practical environment, in which students could visualize a purpose for their learning. This is closely related to the pedagogical psychological term *situated learning* which refers to one's proficiencies and learning processes being context-based (Nielsen & Tanggaard, 2018).

Although it was not possible to identify any studies measuring the efficacy of enactment during an immersive VR lesson, the efficiency of enactment has been investigated in other occasions, in which the use of concrete manipulatives for teaching problem-solving strategies during instruction has increased student learning outcomes (Carbonneau et al., 2013; Cook et al., 2008; Goldin-Meadow, Cook, & Mitchell, 2009). Glenberg and colleagues (2004) further found significant improvements in children's text comprehension when toys were manipulated to represent characters and events while a story was narrated, compared to children who did not enact with toys. Subsequent studies (Biazak, Marley, & Levin, 2010; Glenberg et al., 2011; Marley, Levin, & Glenberg, 2010; Marley & Szabo, 2010) have found similar results with other student populations, learning materials, and types of manipulatives.

11.3 Motivational Theories

Motivational theories are included in the study since is not enough to focus exclusively on how the learner acquires knowledge; it is also important to make the learner more interested in the to-be-learned material and ideally motivate the learner to further pursue relevant topics (Niels & Tanggaard, 2018). Furthermore, it is proven that student motivation is essential for deeper learning in the classroom (Wentzel & Miele, 2016: Parong & Mayer, 2018). The reason for using immersive VR for student learning is based on motivation theory, interest theory and self-efficacy theory (Bandura, 1997; Dewey, 1913; Schiefele, 2009).

Prior research shows that student motivation is important for learning in the classroom, as motivated students show higher engagement during lessons, more effort in understanding the material, as well as higher resilience when overcoming obstacles in understanding (Parong & Mayer, 2018). *Motivation* is defined as *"affective power and effort toward accomplishing a task"*(Simsek, 2013, p. 1530), in which the source of motivation can either be internal or external. Internal motivation is when the learner tries to learn something for his/her own sake, whereas external motivation is often generated with external motives and incentives (Simsek, 2013). Some learners find intrinsic value in learning new information, so they demonstrate natural effort without any expectation, while others expect encouragement and reinforcement to learn. Motivation is furthermore not determined biologically once and for all but is gradually changing through the activities in which we participate in (Niels & Tanggaard, 2018). Closely related to motivation is *interest*, which is defined as *"continued attention and natural tendency toward an object, situation, task, or activity"* (Simsek, 2013, p. 1530). This is consistent with interest theory, which suggests that students work harder when they are intrinsically interested in the material, or if the lesson itself elicits situational interest in the learner (Mayer, 2008; Schiefele, 2009; Wigfield et al., 2016). A meta-analysis conducted by Schiefele et al. (1992), found a correlation between students' self-ratings of how interested they were in specific school subjects and how well they did in school overall. Additionally, studies have shown that both student motivation and interest is elicited from learning in immersive VR (Bonde et al., 2014; Makransky & Petersen, 2019).

Another important factor which is presumed to have an indirect influence on student motivation is the student's self-efficacy. *Self-efficacy* is a social-cognitive concept defined by Bandura (1997) as: *"the belief in one's abilities to organize and execute courses of action required to produce given attainments"* (p.3). This belief is based on a person's knowledge and subjective believes in one's abilities, rather than what is objectively true. Self-efficacy thereby constitutes a central factor in human action; if a person does not have the confidence to perform or execute a specific action to achieve a certain goal, that same person will not even exert the effort to try (Bandura, 1997). Furthermore, self-efficacy is not occupied with the level of success a person achieves in those actions, but rather focus on the determination and ability to carry out the necessary actions to achieve such goals. Self-efficacy is therefore distinguished from self-esteem, as it specifies to certain areas and at the same time gives motivation to keep challenging oneself and develop new skills (Gallagher, 2012). Self-efficacy is thereby primarily concerned with the learner's confidence, as well as one's personal view in one's own abilities. According to Wittrock (1991), self-efficient learners are in control of their learning environment and believe that effort will pay off, meaning they have confidence in their own abilities to influence success or failure in school as well as controlling their achievement test scores and grades. This is emphasized in several other studies, in which self-efficacy has proven to be a critical predictor for student learning, associated with positive outcomes such as academic achievement and persistence. Furthermore, immersive VR has proven to be effective in increasing students' self-efficacy (Makransky & Petersen, 2019; Meyer et al., 2018; Tompson & Dass, 2000).

The article also aims to gain insight into the level of enjoyment students experience when learning through immersive VR. Perceived Enjoyment is related to the benefits of using VR to make learning a fun experience, in which both interest, motivation and self-efficacy is affected (Vogel et al., 2006). This is linked to the fact that positive emotions interact with each other and can serve as mediator between the multimedia lesson and learning outcomes (Pekrun, 2006; Pekrun et al., 2011; Pekrun & Stephens, 2010; Reyes et al., 2012). Studies are persistently proving that immersive VR is associated with a higher self-reported perceived enjoyment in learning contexts, compared to conventional media (e.g., Buttussi & Chittaro, 2018; Makransky & Lilleholt, 2018; Makransky et al., 2017; Parong & Mayer, 2018).

12. Theory of Science

In this study, student learning in immersive VR has mainly been described within a cognitive psychological understanding with Cognitive Theory of Multimedia Learning and Generative Learning Theory providing the theoretical foundation. The following section briefly describes the theory of science within the current study.

Theory of Science is a term concerned about knowledge and how knowledge is achieved within a scientific practice. In a scientific practice, it is important that the theory of science is included in the study as a reflection over the scientific foundation, from where knowledge is achieved and produced (Jacobsen, Lippert-Rasmussen & Nedergaard, 2012). In this study, knowledge is conveyed through an empirical approach, in which learning is measured through a quantitative method, trying to obtain objectivity with statistical analyses (Sonne-Ragans, 2013). This is not to suggest that the study's outlook on knowledge exclude an eclectic approach, in which a qualitative research method could have been combined as a mixed method study. Accordingly, psychologist Preben Bertelsen (2001) captures this eclectic approach, in which he posits that the complexity of psychology is inextricably connected between the history of human nature, culture and life. History of nature refers to the connectedness a person has to his or her biology. The history of culture refers to the characteristics of human social abilities and how one's surroundings create both possibilities and limitations; and the history of life refers to human personality and describe how the individual's life story is important to understand a certain psychological phenomenon (Bertelsen, 2001). According to Bertelsen (2001) all three explanations must be part of the study to achieve a nuanced understanding (p. 10f). In this study, theory and scientific research concerning learning comprehension is mainly based on the first explanation, in which the theories CTML and GLT are placed predominantly within the discipline of cognitive psychology, aiming to describe how humans acquire, store, transform and make use of incoming information. According to Bertelsen (2001) an extension of the study would therefore be in order to prove a more nuanced picture of learning comprehension, illuminating the complexity of learning. The aim of these considerations is therefore not to choose sides on sciences, but rather share a pragmatic approach, focusing on its functional side of the presented knowledge (Rønn, 2006, p. 232). The project is therefore mostly interested in which practice possibilities the respective theories allow, with in mind that the theories in the study only shed light on learning comprehension to an extent that do not cover the full picture.

13. Methodological Considerations

The following section will describe what methodological considerations were present when conducting the study. This includes considerations about ensuring a high validity and reliability in the study, as well as considerations concerning the tests applied in the study to measure the results.

13.1 Quantitative Field Study

The article is using a quantitative approach with the aim of narrowing down information gathered to investigate the subject matter. This is secured by using a highly structured design consisting of an experiment and surveys. The experiment used in this study is classified as a field study, meaning that it is conducted outside the laboratory in a natural school class environment (Coolican, 2009, p. 107). A field study permits an insight into natural behavior as it occurs in everyday life, thereby making this method most valuable to see if immersive VR can be facilitated in a classroom setting with potential extraneous barriers. The most optimal method of measuring learning in immersive VR would be a true experiment, in which complete control over all variables was maintained. However, this would completely neglect the sole purpose of the study, which is measuring immersive VR for learning in a pragmatic way, ensuring a high ecological validity. In addition, making a true experiment study was not possible as it would entail a laboratory setting running fewer participants at a time and thus, collecting a powerful sample size would be too time consuming.

13.2 Pre- and Post-Questionnaires

All participants were asked to complete a questionnaire before and after they participated in the experiment. The pre-questionnaire was designed to assess the students' prior knowledge as well as their prior motivation towards the learning material displayed in the simulation/video. In order to anonymize all participants, students were issued a unique test identification number consisting of a letter followed by a number (e.g. A1 for VR condition). The number written on the questionnaire, made possible to connect the participant's answers on the pre- and post-questionnaires. To ensure a high validity within the study measuring what was originally intended, the construction of the questionnaires was inspired by questionnaires used to assess participants in other studies measuring same dependent variables (Coolican, 2009, p. 84). The motivation scale was adapted from the Intrinsic Motivation Inventory (Deci et al., 1994), which is a measurement device intended to assess participants subjective experience related to an activity in laboratory experiments. The self-efficacy of learning scale was adapted from the Motivated Strategies for Learning Questionnaire (MSLQ; (Pintrich et al., 2002) to properly asses self-efficacy related to learning about polymerase chain reaction. The scale measuring students' interest was developed based on previous research assessing interest in computing disciplines (Lent et al., 1994, 2008). The perceived enjoyment scale was further adapted from Tokel and Isler (2013), who investigated people's perceived enjoyment of using virtual worlds as learning spaces.

Finally, the post-questionnaire consisted of a declarative knowledge test which included 23 multiple-choice questions based on the lesson (e.g. "*What does the acro-*

nym PCR stand for?") (appendix 1), and a procedural knowledge test, which included 6 questions; three open-ended questions (e.g. "*Describe in steps how to use a pipette to prepare laboratory samples. Mention as many steps as possible)* (appendix 1), and three multiple-choice questions measuring how much of specific procedures were retained (e.g "*In sequential order, what are the three steps of PCR?*") (appendix 1). For the open-ended questions, participants were scored from 0 to 25 based on how good the answer was. To reach an objective measuring of the scores, the rating was done blindly, meaning that we had no knowledge about which condition any of the students belonged to. This method is necessary to avoid expectancies and other biases (Coolican, 2009, p. 97). The transfer test included a case-question that assessed the students' ability to apply the learned knowledge to a novel situation. This was designed to measure how well participants were able to use the knowledge from the lesson in a different context. Participants were scored from 0 to 2 based on their answers. In the same way as the procedural knowledge questions, the transfer question answers were rated blindly. To further ensure a strong reliability of the scoring, it is planned that another blind scorer will rate the answers in the nearest future.

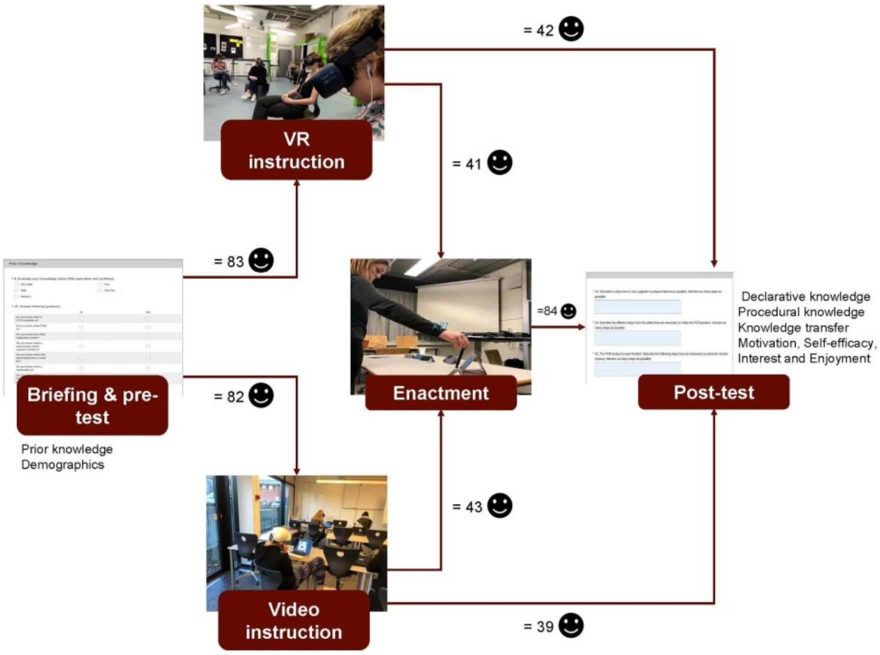
13.3 Validity Threats

The aim was to investigate whether there is a significant difference in student learning between using immersive VR or video, with and without enactment as a generative learning strategy. When looking at variables a distinction is made between three types of variables; independent variables, dependent variables and confounding variables (Coolican, 2009, p. 59). The independent variables are the media (immersive VR vs. video) and method (enactment vs. no enactment), whereas the dependent variables are cognitive measurements (procedural-, declarative-, transfer knowledge) as well as non-cognitive measurements (motivation, interest, self-efficacy and perceived enjoyment). Confounding variables are variables that can interfere with the experiment's validity, disrupting the participants' performance (Coolican, 2009, p. 59). In the study the hypotheses were tested by investigating the participants' answers on the post-tests, while striving to control that no confounding variables would affect the experiment. However, the field study did not take into account the randomization of a sample size of 165 high school students, in which only 54 of the participants were boys ($X^2_{(N = 165)} = 11.081$, $p = .011$), which further resulted in a distribution of 50% boys in the VR condition, 52% boys in the VR enactment condition, 44% boys in the video condition, and 19% boys in the video enactment condition. A possible confounder in the study is therefore the unequal distributions of males and females, questioning the study's validity. Looking at the results, the VR enactment groups for instance did significantly better than the video enactment groups on procedural knowledge outcomes but had a more equal gender distribution with 52% boys, compared to only 19% boys in the video enactment group. The sampling bias therefore questions whether the results are more an indication of gender differences rather than representative measurements of student learning. Furthermore, maintaining an equal distribution of participants in each condition was also very difficult. In the beginning of the experiment students received an ID which they were told to keep and remember throughout the entire experiment. The ID was critical as it would determine which condition the students should be in, and what survey they would enter, after the experiment. A few numbers of students missed this information which led them to participate in the wrong condition, creating an unequal distribution across the conditions. Furthermore, technological problems caused an elimination of seven students as they never completed the simulation and were therefore excluded from the sample size. This resulted in a sample size distribution of 42 (VR), 41 (VR with enactment), 39 (video) and 43 (video with enactment). Ideally, there would be an equal distribution both in gender and in condition, which would also have been easier to achieve if a true experiment was facilitated.

13.4 Ensuring Reliability

Another challenge in the experimental design was ensuring a high reliability throughout. One of the challenges was ensuring that enough personnel were present to facilitate the experiment in four different rooms, providing the exact same instructions. When the experiment was ready, the students would go to their respective classroom with an instructor, where the instructor would facilitate the intervention (VR or video) with and without enactment, and make sure they entered the correct test afterwards (see figure 13 down below). In all classes, except for two (out of seven classes) it was possible to have an instructor for each condition, facilitating the experiment. However, in the last two classes only three instructors had to coordinate four conditions, meaning that the instructional design changed. To make sure that the reliability of the study was sustained, all students who watched the video were put in one room, and all the students trying immersive VR were put in another, each with an instructor. When the students with their correct ID either finished the video or immersive VR simulation, they were told to go to another room, where a third instructor would give them the instructions needed to do the post-test. The students who stayed in the room, would perform the enactment drill before doing the post-test.

Figure 13: Experimental procedure



Each instructor had a manual which they followed from beginning to end, making sure that the students were given the exact same instructions. During the enactment drill instructors were specifically told not to mention anything that would prime the students' answers in the following post-test. In the enactment drill students are pretending to prepare a pipette by mixing the DNA sample with 'master mix' before putting the sample into the PCR-machine. As the words 'pipette', 'DNA sample', 'master mix' and 'PCR' were all possible answers in the post-test, the instructor avoided using them when introducing students to their task.

Other confounding variables could be that participants were not tested at the same time during the day. Participants were tested on different times varying from 8 in the morning to 3 midday, which allows variables such as fatigue, satiety or hunger to have an influence on the students' performance.

13.5 Tests applied in the study

Estimating the reliability within the study, Cronbach's alpha was measured for each item (presented in figure 14). The measurement of Cronbach's alpha depends on how people vary on individual items. If the students varied a lot on the individual items, compared to how much they vary overall on the test, then the test is assessed as unreliable and a low value for alpha is hereby achieved (Coolican, 2009, p. 195). A very good reliability is represented with alpha values from around 0.75 up to 1, indicating that this study has a good reliability overall. Only prior knowledge items in the study had a Cronbach's alpha slightly below with a Cronbach's alpha on 0.70, which is still acceptable.

Figure 14: Cronbach's alpha overview on different items

Items	Alpha pre-test	Alpha post-test
Prior knowledge: 7 items		0.70
Procedural knowledge: 3 multiple choice + 3 open-ended questions		0.92
Declarative knowledge: 23 multiple choice questions		0.82
Transfer: Case		
Motivation: 5 Likert	0.83	0.88
Self-efficacy: 7 Likert	0.89	0.93
Interest: 6 Likert	0.88	0.91
Enjoyment: 3 Likert		0.90

Furthermore, a two factorial ANOVA analysis was used to determine if two different factors (VR and video) have an effect on a measured variable (e.g. procedural knowledge) or not (Coolican, 2009). To measure if a significant difference were found between VR and video a significance test was done to help decide whether the hypotheses in the study were true or not. A normal distinction is a 5% significance level, meaning that if the p-value is below 0.05 a significant difference is found (Coolican, 2009). To detect significant differences between two samples an independent t-test was also made, in which each media condition was investigated. As an example, the independent t-test helped to clarify that the enactment group scored significantly higher than the no enactment group, $t_{(81)}$=3.150, p = .002, d = 0.69 when using immersive VR, compared to the video enactment group, $t_{(80)}$=0.581, p = .563, d = 0.13. If a t-test was not conducted the result might have been misinterpreted as the two-factorial ANOVA results showed a statistical difference on enactment for the outcomes of procedural knowledge, $F_{(1.161)}$ = 6.617, p =.011, claiming that enactment significantly increases procedural knowledge in both media groups.

14. Final Remarks

This study was divided into two parts, a) an article and, b) a cape illuminating the scientific backgrounds of the article. The article investigated and compared the instructional effectiveness of immersive VR versus video as media for teaching scientific knowledge, as well as examining the efficacy of enactment as a generative learning strategy, in combination with the respective media. The results indicated that there was a significant interaction between media and method in procedural knowledge with the *VR and enactment* group having the highest performance. Enactment also improved the students' performance in knowledge transfer, for both *VR* and *video* groups. Furthermore, media also had a significant effect on student perceived enjoyment and motivation, indicating that the VR groups showed significantly higher enjoyment and motivation scores when learning, than the video groups. The cape further elucidated the scientific backgrounds of the article including motivational backgrounds for conducting this study, a theoretical overview, a clarification of different important concepts, and provided methodical considerations discussing the validity and reliability of the experimental design.

15. Perspectivations

The argument for implementing immersive VR in schools is based on the findings that immersive VR can provide better learning outcomes if the students enact following the simulation, and that students feel higher levels of perceived enjoyment and motivation when they learn through immersive VR, when compared to video. The results further deepen our understanding of how we learn with immersive technology providing important implications for implementing immersive VR in schools. In the following sections, new perspectives on the study are offered as suggestions to new directions.

15.1 Follow-Up Study

The current study, as well as the research presented in the article, only measured students' learning outcomes immediately after the intervention. An obvious extension to the study is therefore investigating students' long term learning outcomes, conveying a follow up post-test. Conducting a follow up post-test has been conceived as an important yet underdeveloped research topic (Makransky et al., 2017a). Additionally, it has only been possible to identify one study, assessing the outcomes both in a post-test directly after the learning intervention, and again one week after the intervention to investigate the delayed effects of learning in immersive VR (Meyer et al., 2018). The study measured the effects of pre-training when learning through immersive VR compared to a video, in which they found that pre-training had a positive effect on knowledge, transfer, and self-efficacy directly following the intervention; and on self-efficacy in a one-week delayed post-test in the immersive VR condition. Having the students perform a post-test immediately after the intervention, and then do it again after some time, will make it possible to see how much their acquired knowledge has been retained. This type of study is relatively easy to conduct as it can be facilitated a week or a month after the intervention, during a class lesson with only one teacher present. In Meyer et al. (2018) the students completed the follow up post-test from home, questioning the study's reliability by not knowing whether the students cheated or not, as well as the study's power since fewer students responded on the follow up post-test.

15.2 Adding Other Generative Learning Strategies

Furthermore, as enactment proved to promote students' procedural learning and transfer, the present study speaks in favor of replicating the study by adding other generative learning strategies to the experimental design. As mentioned in the above sections, Fiorella and Mayer (2016) suggest eight ways of promoting generative learning, which are all applicable in combination with immersive VR. Only Parong and Mayer's study (2018) and the present study have added a generative learning strategy in combination with immersive VR, and future research must therefore investigate what these learning strategies can offer to the respective multimedia. In both studies, students' learning outcomes improved when adding a generative learning strategy to immersive VR enhancing students' declarative knowledge by summarizing (Parong & Mayer, 2018), as well as procedural knowledge and knowledge transfer with enactment. The findings further indicate that it is possible to choose a generative learning strategy suiting its learning purpose. If enhancing declarative knowledge is the matter of the issue, using summarizing in immersive VR could be suggested, whereas enactment would be the selection of choice if the main purpose is to enhance procedural knowledge. However as mentioned in the theory section, prior research also states that enactment can foster declarative knowledge (Biazak et al., 2010; Glenberg et al., 2011, 2004; Marley et al., 2010). To further test this, a future direction could be to investigate if *summarizing* can be used to foster declarative knowledge as in Paron and Mayer's study (2018). However, these are merely guidelines and suggestions without much evidence, as very little research in the efficacy of generative learning strategies have been used in combination with immersive VR.

15.3 Conducting a True Experiment

As mentioned, the experimental design is classified as a field study in which students' learning outcomes and non-cognitive measurements were investigated in a real classroom setting. Although it was attempted to mitigate confounding variables there are areas as mentioned in the sections above that challenges the study's validity and reliability. To completely avoid confounders and maintain control over these variables within the study, conducting a true experiment in a laboratory setting is a recommended option (Coolican, 2009, p. 115). A true experiment attempts to isolate cause and effect, and to eliminate alternative explanations of observed relationships between variables (Coolican, 2009, p.56). In the current study there were big differences in gender in some of the conditions, resulting in a sampling bias. It is therefore very difficult to determine whether the results of the study are solely due to the intervention, or if gender differences also affect the outcomes. Furthermore, it is impossible to state if the results would look differently if the distribution was more even across conditions. For example, if we want to see the true efficacy of enactment in combination with immersive VR then we need to compare this behavior with what would occur without the enactment drill, while preventing any extraneous influences ultimately affecting the validity and reliability of the experiment. An observation made whilst facilitating the experiment was that some students became very self-aware during the experiment. Many students had never tried VR before and were very excited about the whole experience. This might have distracted them and prevented them focusing on the task. In the enactment drill some of the students also seemed self-aware, feeling silly in the act. By conducting a true experiment, we can for example control the environment by running only one student a time removing the need to perform for their peers. Doing so, the experimenter will also have the full responsibility, ensuring that the students perform in the right condition, thus eliminating students misinterpreting the information given as was the case in the current study. Furthermore, if technological problems intervene with the experiment, the experimenter can either choose to restart or stop the experiment without it affecting the sample size distribution. However, manipulating with the environment like this might elicit other problems. For instance, the student might feel that the experiment is reminiscent to an exam situation, which might lead to the student feeling nervous and because of that underperform in the task. Conducting an experiment without any confounding variables is therefore more complex than presumed.

Since immersive VR is already being used in some schools, a true experiment was however avoided as the interest relied on how immersive VR can be used in a real learning environment, despite the many extraneous barriers that may take part in the everyday classroom. Conducting the field study further made it possible to collect a powerful sample size within short time.

15.4 Changing the Scope

The current study has focused on the general student in a high school class. Thereby, focus has not been directed at student minorities who might benefit even more from immersive VR compared to the traditional teaching setting. The dominating discourse in today's school system is built on qualities such as writing, reading and calculating, which ultimately affects students who struggle with concentration and attention difficulties in class, impulsive behavior and lacks the ability to receive instructions (Niels & Tanggaard, 2018). In Denmark alone, the amount of ADHD patients who struggle to accommodate the abovementioned qualities, has drastically increased (Niels & Tanggaard, 2018).

A literature review investigating the benefits of immersive VR for ADHD patients, found that VR technologies are very helpful to asses, provide training, and improve conditions such as working memory, executive functioning, and attention in children with ADHD (Bashiri, Ghazisaeedi, & Shahmoradi, 2003). The results further indicated that immersive VR can support children with ADHD by delivering stable and controlled stimuli to make steady progress; provide a safe learning environment that minimize errors, time, and costs; and improve the users' motivation through enjoyable and user-friendly environments. To further extent this study, an interest hereby lies in the investigation of ADHD children, or younger students who might benefit from learning in immersive VR, even more than the general high school student.

15.5 The Teacher's Role

To present a more nuanced dimension to the study, the teacher's role is an aspect which cannot be ignored, in which teachers are in many ways definitive for students' learning processes. As presented in the article, the results emphasize that immersive VR should not be used as a standalone tool, but instead used thoughtfully as part of the classroom teaching. Therefore, the biggest challenge is arguably yet to come; making teachers accept the technology, as well as understanding in which ways immersive VR is specifically beneficial for learning. This is not a new observation, as B. F. Skinner (1978) describes teachers as *behavioral engineers* who organizes and reinforces student development and specific kinds of behavior. According to Nielsen and Tanggaard (2018, p. 48f) the teacher's role is not only to teach students directly but also to provide an environment for students to learn through gradually more demanding tasks, while at the same time becoming more skilled in those tasks. Using immersive VR in a learning situation is therefore a teacher's act to facilitate an environment where student's learning processes take place before, during and after experiencing the learning material in the virtual environment. From a pedagogical psychological standpoint, the implementation of the medium therefore heavily relies on teacher's beliefs and attitudes towards it, and whether the specific immersive VR application fits into the students' academic needs. In Ottaway (1983) the teacher's role is defined as a *change agent* much like B.F Skinner's *behavioral engineer* definition, whereas Attrup and Olsson (2008) defines teachers as *hostages*. They are agents of change because teachers are the ones who must execute and facilitate new implementations in the classrooms, and hostages because the teachers might feel they have little influence on the decisions being made coming from management. The implementation of immersive VR might therefore receive different positions depending on the teacher's relation to technology, which ultimately affects the quality of the lesson for better or for worse. Dohn and Hansen (2016) state that it is essential from the school management to identify teachers with both positive and negative attitudes towards the new intervention (p. 224f). This further advocate that teachers who will potentially use immersive VR in the lesson are those who intuitively uses technology as a tool in meaningful situations where the technology supports the desired learning processes. These teachers will also know when not to use the media, which is equally as important. Conversely, teachers who hesitate to use the technology because they are not feeling competent for the task, will most likely not use the technology as they only see the challenges and complications that would be present in the implementation of VR (Dohn & Hansen, 2016, p. 228). While conducting the study I often experienced technological problems with the immersive VR device, which instantly elicited higher levels of stress. Much of that was associated to my concern of losing important data, but my personal belief is that many of the technologically hesitant teachers will feel the same experience when being confronted with technological problems, disrupting their lesson.

15.6 Conducting a mixed method study

To investigate teachers' experiences and attitudes toward immersive VR as a teaching method, adding a qualitative research interview could be done in this regard, conveying a mixed method study. A mixed method study combines elements from the qualitative and quantitative methods, trying to counterbalance each other's strengths and weaknesses (see table 4 down below). The two methods have earlier been considered incompatible, but this conception has gradually changed as researchers have discovered the advantages by breaking the traditional methodical boundaries and make use of both methods (Creswell, 2009). The two methods can therefore be used to investigate the same subject matter, but with a difference in the nature of data and how this data will be processed (Coolican, 2009). In the current study, statistical analyses are provided as part of the quantitative method, in which the data are gathered into boxes and categories, allowing to end up with a numerical result. Adding a qualitative element, for example a qualitative research interview, new important perspectives and nuances might arise, providing insights in the individual's lifeworld and understand certain incidents, situations or phenomena in their life (Brinkmann & Tanggaard, 2010, p. 31). In addition to this study, conducting an interview will produce a detailed and intensive analysis, in which a limited and collected amount of people will express their experiences concerning the respective multimedia. In contrast to the quantitative approach, a strong sample size in number of participants are not necessarily the main goal, but rather conducting a thorough well-researched analysis from which knowledge is derived. The interview is an obvious choice to better understand the teacher's role in the implementation of immersive VR, thus welcoming Bertelsen's (2001) advocacy of coming closer to a more nuanced understanding of its potentials. Besides interviewing teachers, another obvious direction would be to conduct interviews on students participating in one of each of the four conditions to hear about their experiences with the respective multimedia, aside from the survey answers.

There are several advantages to be found when using a qualitative methodology in addition to a quantitative project such as this. As mentioned, it might give a deeper insight into how both students and teachers subjectively feel about using immersive VR in schools. This could contribute to a more holistic picture when trying to explain how immersive VR affects student's learning outcome and motivation (Brinkmann, Svend & Tanggaard, 2010, p. 426). Furthermore, a small qualitative study could be used as a pilot study as well. Doing so, we could learn more about the group of people we wish to investigate before conducting a quantitative study to ensure a stronger experimental design with better knowledge of what's relevant to test, and to avoid possible pitfalls along the way.

Table 4: The difference between quantitative and quantitative research methods as presented in Coolican (2009), p. 52

Information	**Quantitative methods and data**	**Qualitative methods and data**
Interpretation	Narrow	Objective
Setting	Artificial	Subjective
Design	Highly structured	Loosely or non-structured
Realism	Low	High
Reliability	High	Low
Reflexivity	Low	High

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Appendix 1 – Questionnaire overview

Table 5

Mean Ratings of Interest, Motivation, Perceived Enjoyment, and self-efficacy During the Lesson Between Virtual Reality (VR) and video Groups

Post-Questionnaire Item	VR group only (N= 42) *M (SD)*	Video group only(N= 39) *M (SD)*	VR enactment group (N= 41) *M (SD)*	Video enactment group (N= 43) *M (SD)*
Motivation: ”Jeg kan godt lide at lære gennem simulation og spil” ”Det er sjovt at lære gennem simulationer og spil” ”Læringssimulationer og spil er kedelige” ”Læringssimulation og spil fastholder overhovedet ikke min opmærksomhed” ”Jeg ville beskrive læringssimulation og spil som meget intere sante”	**4.17 (.64)**	**3.8 (.64)**	**4.1 (.76)**	**3.56 (.76)**

Interest: Indiker hvor interesseret du er i at: ”Indsamle og analysere biologisk data” ”Evaluere, analysere eller fortolke genetiske laboratorie resultater” ”Undersøge og håndtere biologisk materiale” ”Evaluere genetisk data ved at udføre relevante matematiske eller statistiske beregninger og analyser” ”Analysere identificere og klassificere biologisk materiale” ”Lære om basale biologiske principper og teorier”	**3.46 (.69)**	**3.57 (.71)**	**3.22 (.90)**	**3.15 (.84)**
Self-efficacy: ”Jeg tror, jeg vil få en rigtig god karakter i biologi/biotek” ”Jeg er sikker på, at jeg kan forstå det sværeste litteratur i biologi/biotek” ”Jeg er sikker på at jeg kan forstå de grundlæggende begreber der undervises i, i biologi/biotek” ”Jeg er sikker på, at jeg kan forstå de mest komplekse emner, jeg bliver præsenteret for i biologi/biotek” ”Jeg er sikker på, at jeg vil klare mig godt i opgaver og til eksamen i biologi/biotek” ”Jeg er sikker på, at jeg kan mestre de færdigheder, der undervises i, i biologi/biotek”	**3.40 (.75)**	**3.37 (.85)**	**3.19 (.77)**	**3.15 (.77)**
Perceived Enjoyment: ”Jeg kan godt lide at lære om biologi/biokemi/bioteknologi på denne måde (fx spille en VR-simulation (eller video))” ”At anvende denne læringsmetode (spille en VR-simulation eller video) til at lære om biologi/biokemi/bioteknologi er behageligt” ”Jeg synes det er sjovt at anvende denne læringsmetode (fx spille en VR-simulation (eller video) til at lære om biologi/biokemi/bioteknologi”	**3.92 (.95)**	**3.58 (.91)**	**4.00 (.73)**	**3.68 (.85)**

Note. A 5-point rating scale from 1 (strongly disagree) to 5(strongly agree) was used.

Table 6

Mean Scores and Standard Deviations on Posttest for Summarizing Group and Control Group

Post-Test Items	VR group only (N= 42) *M (SD)*	Video group only(N= 39) *M (SD)*	VR enactment group (N= 41) *M (SD)*	Video enactment group (N= 43) *M (SD)*
Procedural Knowledge (3 open-ended questions + 3 multiple choice questions): ”Describe in steps how to use a pipette to prepare laboratory samples. Mention as many steps as possible” “Describe the different steps from the simulation that are necessary to make the PCR product. Mention as many steps as possible”. The PCR product is now finished. Describe the following steps that are necessary to solve the murder mystery. Mention as many steps as possible” “In sequential order, what are the three steps of PCR?” “A pipette is used for?” “I just used the pipette to transfer the DNA sample into the tube, and now I want to use the same pipette to transfer the master mix into the tube. What should I do first?”	**8.14 (6.18)**	**10.33 (6.4)**	**12.68 (6.92)***	**11.23 (7.48)**
Declarative Knowledge: “DNA is found in the ___ of cell” “The twisted ladder shape of DNA is known as the….” “Which of the following is usually collected at a crime scene?” “What does the acronym PCR stand for”? “During the second step in the PCR…” “What does the acronym NGS stand for?” “PCR is used…” “PCR can make multiple copies….” “What is the approximated price of both the NGS and the transmission microscope presented in the material?” “What technique can determine if the murderer is related to the victim?” “How can the suspect in the simulation be definitely linked to the murder?”	**11.11 (5.33)**	**12.66 (5.75)**	**11.41 (3.84)**	**11.74 (4.05)**

"Which technique among the following is useful to match the DNA?" "what are you supposed to do with blood samples before they can be applied for PCR?" "Which function do the primers in a PCR?" "What is a DNA polymerase doing?" "What would happen if DNA polymerase wasn't added to the PCR?" "When the DNA sample is ready in the simulation, the PCR has repeated how many times?" "What happens if you use the same set of primers on two different DNA tests?" "What among the following will separate the DNA fragments?" "To identify a match, the DNA sample from the crime scene and the genetic fingerprint of the suspect has to be…."				
Knowledge Transfer (case question): "In 2014, a two-months old girl-baby was accidentally separated from her parents in a park in Copenhagen. The parents immediately reported this to the police, so the police could search for their missing child. A few years later, the police found an orphan girl in an orphanage that the parents claimed to be their daughters. Based on you knowledge of PCR and gel electrophoresis, do you think these techniques could be used to confirm if the girl is their daughter or not? Describe exactly how you would confirm that".	**1.07 (.92)**	**1.10 (.91)**	**1.46 (.77)***	**1.25 (.84)***

*p < .05**

Appendix 2 – Feature map

Table 7

Summary of the effect of immersive Virtual Reality (VR) on learning outcomes compared to non-immersive VR or other training methods.

References	**Participants**	**The virtual simulation mode**	**Effect on learning outcomes**
Alhalabi (2016)	48 university students (gender and age are not specified)	VR applied in engineering education	Using any VR system dramatically improves the students' performance. HMD VR is superior over CCS (Corner Cave System with a tracking system)
Aïm et al. (2018)	A comprehensive systematic review performed of articles of VR training in orthopedic surgery	Effectiveness of Virtual Reality Training in Orthopedic Surgery	VR training leads to an improvement of technical skills in orthopedic surgery
Bertram et al. 2015	24 participants	Student Field study part of a larger project conducted by the police training department of a German federal state	The standard training resulted in more motivation, perceived value of the training and knowledge after the training session than virtual training. But with regard to the learning transfer measured by the be-

			havior in a real and complex situation, the virtual training was as good as the standard training
Bonde et al. (2014)	149 students from two biology classes at Archbishop Williams High School, and 57 students from four Danish high schools	Aim was to improve biotech education through gamified laboratory simulations compared to traditional teaching methods	Gamified laboratory simulations motivate students and improve learning outcomes compared with traditional teaching methods.
Bric et al. (2015)	Meta-review on the use of virtual reality simulation in the acquisition of robotic surgical skills	Student The virtual da Vinci Surgical System	Training with immersive VR simulations significantly improves basic robotic surgical skills but skills gained from VR training are similar to those attained via traditional robotic dry laboratory simulation training.
Buttussi & Chittaro (2018)	96 participants (41 females and 55 males) ages ranging from 18 to 36 (M = 23.81, SD = 3.58)	A serious game that simulates a runway overrun accident in VR.	Changing the type of display affected users' engagement and sense of presence, while it did not significantly affect the increase in knowledge and self-efficacy.
John et al. (2018)	7 males, 25 males. Age range was from 20 to over 60 with the majority being under 29.	Student Wheelchair training simulation in VR	The study results indicate that there is an improvement in driving skills from the use of immersive VR system
Li et al. (2017)	96 participants, whose ages ranged from 20 to 30.	A virtual earthquake training exercise simulation.	Virtual reality training is effective, with the participants performing better, on average, than those trained by alternative approaches.
Makransky, Therkildsen & Mayer (2018)	52 students (22 males and 30 females) ages ranging from 19 to 42 (M = 23.8 years, SD = 4.5)	A virtual science lab simulation	Students feel a greater sense of presence when using high immersive HMD VR but learn less compared to a low immersive version on a desktop computer.
Makransky & Lilleholt, 2018	Two studies were conducted that describe the development of a standardized multidimensional measure of presence (the MPS) for a VR learning context	A new scale measuring physical, social, and self-presence was developed	The results from Study 1 indicated that the items used in the MPS measure a three-dimensional theoretical model of presence: physical, social, and self-presence. The results of Study 2,

			supported the validity and generalizability of the MPS in a new context
Makransky, Thisgaard & Gadegaard (2016)	A total of 189 students who were participating in an undergraduate biology course	Student The aim was to investigate if a virtual laboratory simulation (vLAB) could be used to replace a face to face tutorial (demonstration) to prepare students for a laboratory exercise in microbiology	There were no significant differences between the two groups on their lab scores, and both groups had similar increases in knowledge of microbiology, intrinsic motivation to study microbiology, as well as self-efficacy in the field of microbiology.
Makransky & Petersen (2019)	The sample consisted of 199 university students (120 females	Students learned from a desktop VR genetics simulation as a mandatory part of an undergraduate medical genetics course	Results indicated that desktop VR led to increases in the amount of learning following a VR lesson: an affective path that went through VR features, presence, intrinsic motivation, and self-efficacy; and a cognitive path that went through VR features, usability, cognitive benefits, and self-efficacy
Moreno & Mayer (2002)	75 college students (gender and age are not specified)	A virtual agen-based multimedia game	Student gave higher ratings of presence when learning with VR HMDs, but media did not affect performance on measures of retention, transfer, or program ratings
Moreno & Mayer (2004)	The participants were 48 college students recruited from the Psychology Subject Pool at the University of California, Santa Barbara (27 women and 21 men). The mean age of the participants was 19.54 years	College students learned how to design the roots, stem, and leaves of plants to survive in five different virtual reality environments through an agent-based multimedia educational game	Students who received personalized agent messages performed better on retention and problem-solving transfer tests. Although students reported higher levels of physical presence with high rather than low immersion, higher immersion did not lead to better performance on tests of retention or transfer
Parong & Mayer (2018)	57 students (36 females and 21 males) ages ranging from 18-22	An interactive biology simulation	Students who viewed the slideshow performed significantly better on the posttest than the VR group. The VR group who summarized performed

			better than the VR group who did not summarize
Richards & Taylor (2015)	129 biology students	The study compared the knowledge of students after a traditional classroom lecture using a 2D simulation tool versus a 3D virtual world	the two-dimensional NetLogo model delivered better learning outcomes.
Slobounov et al. (2015)	12 subjects with no history of neurological disorders aged 18 +/− 2.3 years old (6 males and 6 females)	Examined behavioral and neural underpinning of spatial navigation tasks using electroencephalography (EEG)	Immersive 3D VR induced a higher subjective sense of presence along with enhanced success rate of spatial navigation compared to 2D
Tompson & Dass (2000)	252 students	Investigates the relative contribution of simulations and case studies for improving students' self-efficacy in strategic management	The results suggest that total enterprise simulations are an effective way to enhance students' self-efficacy
Webster (2016)	140 participants (4 females) with a mean age of 29.64 and median age of 28.00 years (SD = 8.03), range 19–59	Virtual learning environments for the US Army.	Both HDM VR- and classroom training will increase learning. VR-based training did produce higher gain scores and there was a statistically significant interaction between instruction type and time.