Effect of Immersion on Students' Test Performance, Achievement Emotions, and Intrinsic Motivation

Ceren Alici

8484481

Supervisor: Yuanyuan Hu

2nd assessor: Michaela Arztmann

Utrecht University, Faculty of Social and Behavioral Sciences

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Abstract

Despite the growing interest in the educational applications of virtual reality, there is limited research available that specifically examines the effectiveness of virtual reality for learning. While virtual reality has been recognized as a beneficial technology for education, there is a need to explore and understand the impact of immersion on various learning outcomes. This study investigates the effect of immersion on test performance, achievement emotions and intrinsic motivation by comparing a high immersion group (VR) to a low immersion group (desktop simulation). The participants were 38 university students. The instruments included achievement emotions questionnaire, intrinsic motivation inventory, and knowledge test. Multiple linear regression analyses and non-parametric tests were performed for the data analyses. The results showed that immersion increases intrinsic motivation and positive emotions and decreases negative emotions. There was no statistically significant effect on test performance. We conclude that high immersive learning environments positively impact student motivation and emotions, but do not significantly affect test performance. Integrating virtual reality in education enhances students' intrinsic motivation and positive emotions but considering cognitive load and instructional design principles is crucial for optimal learning outcomes. Virtual reality technology can be used as a supplementary tool to boost student motivation and emotional well-being.

Keywords: immersion, virtual reality, achievement emotions, intrinsic motivation, test performance.

Introduction

While the educational environment is continually evolving due to the potential provided by technology, it is well known that applications for virtual reality (VR) have benefited education, particularly in recent years (Kandemir & Atmaca Demir, 2020). The sector of education has grown quite interested in VR. On one hand, VR offers several advantages for education as it presents 3D environments, interaction, and provides audio, visual and haptic feedback (Allcoat & Von Mühlenen, 2018). The ability to present learning materials in 3D can be particularly beneficial for subjects such as chemistry and engineering where visualization of the material is crucial for understanding (Allcoat & Von Mühlenen). VR responds to and interacts with user commands and as a result, interaction is one of the most important terms in the definition of VR (Akgün & Atici, 2022). Because VR visualization features make it easier to explain complex and abstract concepts, particularly invisible content, they have been used in many educational settings (Burdea & Coiffet, 2003). Thus, VR applications have been shown to provide learners with more realistic, contextualized, and interactive experiences, which can impact science learning results. On the other hand, there are several potential problems with using VR in education. First, there is limited research on the effectiveness of VR for learning, which may make it difficult for educators to justify incorporating it into their classrooms. Also, educators may require additional training to effectively use VR technology in the classroom, which can be time-consuming and costly (Makransky et al., 2019a).

The key factor that makes VR benefits possible is the level of immersion: the extent to which a technology can create an inclusive, extensive, surrounding, and vivid illusion of reality for the participant through computer displays (Slater & Wilbur, 1997). Immersion is an objective feature of the technology (Parong & Mayer, 2021). VR's potential impact on learning is still to be determined. According to the immersion-as-motivator hypothesis, VR encourages a sense of presence and positivity, which encourages learners to focus more on their course content. The immersion-as-distractor hypothesis, on the contrary, contends that VR promotes perceptual and motor richness, increasing extraneous load and diverting students from cognitive processing. These two ideas have not yet been supported by prior research, which was primarily done by Mayer and colleagues in the fields of science, biology, history, and botany (Makransky et al., 2019a, 2019b; Parong & Mayer, 2021; Sun et al., 2023). According to these studies, VR groups showed improved results in enjoyment, intrinsic motivation, and self-efficacy, as well as in solving problems in a physical lab setting. Compared to the text group, video lessons may be more effective than VR lessons in terms of transfer (Parong & Mayer, 2021; Makransy et al., 2019a). Additionally, students in VR condition had lower learning outcome and higher cognitive load despite feeling more present (Makransky et al., 2019b). Conversely, Liu et al. (2022) found that VR in the classroom significantly improved students' academic performance, motivation towards science, and reduced cognitive load. Sun et al. (2023) found that the use of wearable hybrid VR learning material positively affected high school students' situational interest, engagement, and learning performance.

With the information of previous research, there is a need for more proof from more study groups and topics. The purpose of this study is to compare the effectiveness of learning chemical engineering using a VR simulation versus a desktop simulation. The goal is to determine if one method leads to improved learning outcomes (i.e., test performance, achievement emotions, and intrinsic motivation) compared to the other, through a media comparison.

Theoretical Framework

The Cognitive Affective Theory of Learning with Media (CATLM) contends that one way a multimedia lesson's design can affect learning is through its impact on affect (Moreno

& Mayer, 2007). The main idea of CATML is that the effectiveness of multimedia materials for learning depends on both cognitive and affective factors (Mayer, 2005). Affective factors are emotional or attitudinal factors such as motivation, interest, and engagement. Overall, affective factors play a critical role in the effectiveness of VR as they are closely related to user's motivation and emotional states, which are important for maintaining interest and attention in the VR experience.

Test Performance and Immersion

According to Mayer (2019), people's limited mental resources can be divided among three types of cognitive processing: (a) extraneous processing, which is extraneous and caused by poor instructional design, (b) essential processing, which is necessary for understanding the material and is determined by the complexity of the content, and (c) generative processing, which is the player's effort to make sense of the material and is influenced by their motivation. VR environments have the potential to promote generative processing, but they can also lead to extraneous processing. The design of these environments should aim to minimize extraneous processing, support essential processing, and encourage generative processing. Liu et al. (2022) and Parong and Mayer (2020) suggest that the utilization of VR technology has the potential to enhance both cognitive and affective processes in learners, which can ultimately lead to improved learning outcomes.

Parong and Mayer (2021) investigated the immersion-as-motivator hypothesis and the immersion-as-distractor hypothesis. The immersion-as-motivator hypothesis posits that an increase in affective processing leads to an increase in cognitive processing, resulting in greater effort being put into understanding the material. Conversely, the immersion-as-distractor hypothesis states that the increased affective processing will interfere with cognitive processing. According to the CATML, immersion and the perceptual richness of a VR lesson explain that there could be an increase in extraneous cognitive load during the lesson, leading to less effective learning outcomes (Parong & Mayer, 2021). Also, Parong and Mayer and Makransky et al. (2019b) found in their study that the VR group performed worse on the transfer test and reported more extraneous cognitive load. Conversely, other studies found that VR significantly improved students' academic achievement and decreased their cognitive load (Akgün & Atici, 2022; Guerra-Tamez, 2023; Liu et al., 2022).

Achievement Emotions and Immersion

The control-value theory of achievement emotions (CVT; Pekrun, 2006) provides an integrative framework for analyzing the causes and consequences of emotions encountered in achievement and academic environments. Achievement emotions are defined as emotions that are directly related to achievement activities or outcomes. Activity emotions are linked to ongoing achievement-related activities (e.g., enjoyment, boredom, anger) and outcome emotions are related to the results of these activities (e.g., hope, pride, relief; Pekrun, 2006). The CVT highlights the importance of emotions in predicting learning outcomes, as emotions can influence learners' motivation, cognition, and metacognition (Pekrun & Perry, 2014). Within this study the focus will be on activity emotions since they are the most common in VR (Pekrun et al., 2006).

The CVT of achievement emotions suggests that learners' emotional states, including positive and negative emotions, are influenced by their subjective appraisals of control and value (Harley et al., 2016; Makransky & Lilleholt, 2018; Pekrun, 2006; Pekrun & Perry, 2014). When researching the effectiveness of VR in learning environments, one important factor to consider is the emotional impact of immersion. This is significant since VR encourages a greater level of immersion than traditional media, which could facilitate learning through positive emotions like enjoyment (Makransky & Lilleholt, 2018). The sense of immersion provided by VR technology can enhance user engagement and satisfaction, leading to a greater perceived value (Tamez, 2023). According to Harley et al. (2016), learners who perceive control and value in a task tend to experience enjoyment, whereas a lack of task value can lead to boredom regardless of their sense of control. Immersive experiences through VR have the potential to increase positive emotions and decrease negative emotions by fostering a sense of control and value. Allcoat and Von Mühlenen (2018) and Pallavicini and Pepe (2020) confirm this with their results in which VR had a positive effect on emotion, with participants experiencing an increase in positive emotions (e.g., surprise) and a decrease in negative ones (e.g., anger).

Intrinsic Motivation and Immersion

Studies have shown that the fulfillment of basic psychological needs, such as relatedness, autonomy, and competence, can positively impact intrinsic motivation (Ryan & Deci, 2020). Motivation refers to the drive or willingness of individuals to engage in tasks (Wigfield et al., 2009). When the task itself is rewarding, this drive is referred to as intrinsic motivation (Ryan & Deci, 2000). The self-determination theory (SDT) posits that learners have innate needs for autonomy, competence, and relatedness, and that their motivation to learn will be heightened when they perceive that these needs are being fulfilled in their learning environment (Ryan & Deci, 2000). The autonomy component holds that students, when given the opportunity to follow their own interests while studying, work harder. Based on the competence component, students are more motivated to work harder when they feel they can succeed at a task (Makransky et al., 2019a). Relatedness refers to the feeling of being connected and having a sense of belonging and can be fostered by showing respect and care. Any interference with these three essential needs is considered detrimental for motivation and overall well-being (Ryan & Deci, 2000). By providing learners with a sense of autonomy, competence and relatedness, VR environments can meet their basic psychological needs, which can lead to increased motivation to learn.

Intrinsic motivation is a type of motivation that comes from within an individual, rather than from external factors such as rewards or incentives. It is driven by personal interest, enjoyment, or a desire to learn or achieve something for its own sake (Ryan & Deci, 2020). By providing experiences that are not possible in reality and by enabling learners to manipulate and reason inside these virtual settings, VR may increase intrinsic motivation (Huang et al., 2020). In their study they found that motivation increased when participants switched to a more immersive environment. Their findings imply that VR can enable experiences that are not possible in the real world, providing a unique and novel experience that can also increase intrinsic motivation. Taranilla et al. (2022) found that VR increased student motivation. Kavanagh et al. (2017) suggest that immersion offered by VR may be a crucial factor in directing students' attention towards the learning material and enhancing their motivation.

Present study

According to Hu et al. (2023) it is important to focus on emotion, motivation, and cognition in educational settings because they are interconnected and play crucial roles in learning. Therefore, the present study will test *how immersion (VR vs. desktop simulation) affect test performance, achievement emotions, and intrinsic motivation.* Because of conflicting hypotheses about cognition, we do not formulate hypotheses and instead we will explore the effects of immersion on cognitive outcomes.

The following hypothesis are formulated:

H_1: A high level of immersion environment increases positive emotions to learn chemistry more than a low level of immersion environment.

H_2: A high level of immersion environment decreases negative emotions to learn chemistry more than a low level of immersion environment.

H_3: A high level of immersion environment increases intrinsic motivation to learn chemistry more than a low level of immersion environment.

Method

Design

An experimental study was conducted to examine the impact of immersion (low versus high) on test performance, intrinsic motivation, and achievement emotions. The study included a pre-post knowledge test and post questionnaires for motivation and emotion. In this study, immersion was the independent variable and test performance, intrinsic motivation, and achievement emotions were the dependent variables.

Participants

All participants were students from the University of Applied Sciences Fontys and Avans, and Utrecht University. Participants were recruited from these universities with the help of professors and from social connections. The sample size was determined by performing a power analysis. The desirable ‘a priori’ power is at least 80%. Using the medium effect size (f^2) of .15, the study required 55 participants to produce reliable measurement results, as determined by G*Power (HHU, 2020; see Appendix A). However, the 'post hoc' power, based on the actual sample size of 38, was measured at 64%. Participants all provided their consent to participate through the process of informed consent and were informed of their right to withdraw from the study at any time. The average age of participants was 23.5 years, with a range from 18 to 34 years. The sample consisted of 22 male and 16 female participants. An assessment of the gender distribution of participants between the experimental conditions showed no significant differences, as indicated by a non-significant chi-square test ($\chi^2 = 1.73$, $p = .189$). Table 1 shows the gender distribution of participants in the conditions.

Table 1

Gender Distribution of Participants in the Conditions

Gender	Group		Total
	DS	VR	
Woman	6	10	16
Man	13	9	22
Total	19	19	38

Note. DS denotes desktop simulation. VR denotes virtual reality group.

Instruments

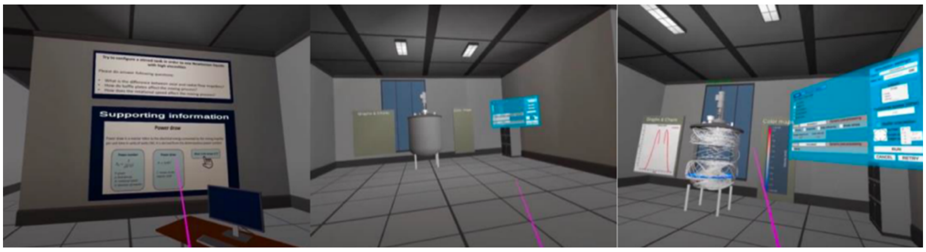
VR Simulation

In this simulation, participants learn computational fluid dynamics (CFD) simulations to design, analyze, and optimize a water treatment process (Solmaz et al., 2022). The simulation includes specific rules and challenges that require students to find solutions within certain constraints and goals. It consists of one task, with different scenarios that participants can view through a visualization panel showing velocity, concentration, and concentration profiles in the water basin. The participants must select the optimal scenario based on specified parameters. The learning task is designed according to a sequential principle, with a gradual increase in complexity within the learning environment. The description of the learning environment and task one can be found in appendix F.

VR Headset. VR that uses a head-mounted display (HMD) is known as head-mounted virtual reality (HDVR). An HMD consists of a screen with separate lenses for each eye, and headphones that deliver sound, while head-motion tracking allows users to interact with and move within the virtual environment. HDVR is considered to have a high level of immersion because it allows users to fully immerse themselves in the virtual world by looking around in 360 degrees (Moreno & Mayer, 2002). Figure 1 shows the scene of the VR learning environment.

Figure 1

Scenes in the VR Simulation Learning Environment

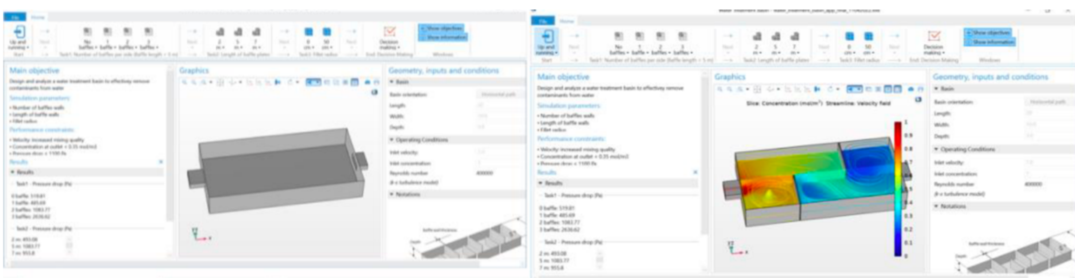


Desktop Simulation

Desktop simulations are VR experiences that are displayed on a computer and involve interaction through mouse and audio through speakers. These simulations are often seen as having low levels of immersion, as they are like playing with minimal presence (Akgün & Atici, 2022; Moreno & Mayer, 2002). Within the desktop simulation, participants learn computational fluid dynamics (CFD) simulations to design, analyze, and optimize a water treatment process, as proposed by Solmaz et al. (2022). The learning environment involves the same task as the VR but is given in 2D and takes the same amount of time to complete. The environment features diverse scenarios that participants can observe through a graphical interface. This provides representations of velocity, concentration, and concentration profiles within the water basin. Participants are required to select the most favorable scenario based on specific parameters. Figure 2 shows the learning environment on desktop.

Figure 2

Screenshot of Desktop Simulation



Questionnaires

Sickness Simulator Questionnaire. The Simulator Sickness Questionnaire (SSQ) is a tool used to measure and assess symptoms of simulator sickness, which can occur when using VR. (Balk et al., 2017). The SSQ was used before participants started the experiment (see Appendix B). Based on the results participants were either denied or approved to start the experiment.

Knowledge test. An expert in chemical engineering created a 24-item multiple-choice knowledge test that assesses the use of panels for water guidance in a basin. For this study, only 16 questions were utilized as it focused solely on task one and general questions because of the feasibility and duration of the study. The questions were split into two parts: a drawing assessment that required participants to anticipate flow patterns, and a decision assessment that tested their ability to choose the most suitable options. The test comprises of various elements that evaluate both the acquired domain knowledge from the learning modules and the lower and higher cognitive skills based on Bloom's taxonomy (Krathwohl, 2002). The test has been used before (Nieuwenhuizen, 2022), which guarantees the validity. Hessen and Van Erp (2020) justified the use of Guttman's $\lambda 2$ as a measure of reliability instead of the commonly employed Cronbach's α due to its superior precision. The reliability was low on the pretest ($\lambda 2$ = -.003) and the posttest ($\lambda 2$ = .36). Despite the seemingly problematic low $\lambda 2$, such findings are anticipated when evaluating a knowledge domain, as noted by Taber (2018). Taber explains that assessing science knowledge typically involves examining various distinct facets of knowledge, rather than emphasizing internal consistency as psychometric tests would. Consequently, the observed low reliability scores were not deemed sufficient grounds for excluding the questions. The knowledge test has been used with the pre- and posttest (see Appendix C).

Achievement Emotions Questionnaire. To measure the emotion of participants after the study, the short version of Achievement Emotions Questionnaire (AEQ-S) was used (Bieleke et al., 2021; see Appendix D). AEQ-S is an existing tool which was based on the CVT and was designed to assess achievement emotions experienced by students in academic settings (Pekrun, 2006; Pekrun et al., 2011). Therefore, this questionnaire has already been validated. The reliability was established using Guttman's $\lambda 2$ and was calculated to be .71. Appendix H provides an overview of the statements and Guttman's lambda values for each item if deleted. Based on the values of Guttman's lambda if item deleted, no items were removed. Within this study, items based on the learning-related section were used. This study adapted the subscale of eight emotions, and focused only on activity emotions, specifically enjoyment, boredom, and anger (Pekrun et al., 2011). Participants were asked to rate the extent to which an emotion applied to them on a scale from 1 "strongly disagree" to 5 "strongly agree". The language was modified to suit the learning environment in which the study was conducted.

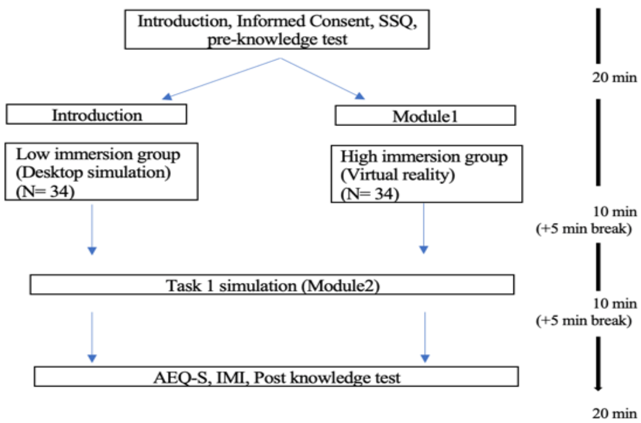
Intrinsic Motivation Inventory. The Intrinsic Motivation Inventory (IMI) is a tool that measures different aspects of intrinsic motivation. It was developed based on the research of Ryan and Deci (2000) and Heindl (2020) and consists of 15 statements related to five subscales: interest/enjoyment, perceived competence, perceived choice, pressure/tension, and value/usefulness. Participants were asked to rate each statement on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree". The questionnaire has been used before (Nieuwenhuizen, 2022) and therefore already been validated. The reliability was established using Guttman's $\lambda 2$ and was calculated to be .85. Appendix H provides an overview of the statements and Guttman's lambda values for each item if deleted. Based on the values of Guttman's lambda if item deleted, no items were removed. The questions were adapted to suit the current study by basing the IMI questions on the learning environment (see Appendix E).

Procedure

The study took place over a maximum of 60 minutes for each participant. Before starting, informed consent was obtained, SSQ was filled in and based on that participants were approved or denied participating in the study (see Figure 3). After, participants were made aware of the potential nausea while using HDVR. The data collection process started with administrating pre-knowledge test of each group in the same environment. After, the participants were split up and received an introduction about the simulation and were instructed on how to play the simulation using either the VR headset (high immersion) or the desktop simulation (low immersion). Both groups began the simulation with a tutorial that lasted approximately 10 minutes and then moved on completing the task (see appendix F for the tutorial description). The researcher was available during the simulation to answer any questions and assist participants if they experienced discomfort. Once the simulation was completed, participants in both groups took the AEQ-S, the IMI, and the post-knowledge test. Every questionnaire took approximately five minutes to complete, and knowledge test took approximately 10 minutes to complete.

Figure 3

Study Procedure



Analysis

To address the research question on whether immersion affects test performance, achievement emotions and intrinsic motivation, statistical analysis with JASP (JASP Team, 2023) was used to examine the data. To test the hypothesis that there is a significant difference between the mean scores of the VR group and desktop simulation on the knowledge, achievement emotions and intrinsic motivation test, multiple linear regression and non-parametric tests were conducted. Before carrying out regression analyses, we ensured that the dataset meets certain assumptions including normality, homoscedasticity, absence of outliers, linearity, and lack of multicollinearity (Field, 2018). Additionally, an evaluation was conducted to determine if there are enough observations in the final data sample to ensure the robustness of the models. The independent variable is immersion, and the dependent variables are test performance, achievement emotions and intrinsic motivation. To differentiate between low and high levels of immersion, a dummy variable was created with a value of 0 assigned to low immersion (desktop simulation) and 1 assigned to high immersion (VR). For test performance, the learning gains of the participants were analyzed by calculating the difference between the post- and pre-knowledge test scores. For positive emotions, the means of the items from enjoyment were calculated. For negative emotions, the means of the items of boredom and anger were calculated. For intrinsic motivation, the means of all items of motivation were calculated.

Assumptions of Multiple Linear Regression

An evaluation of the mean, minimum, maximum, Skewness, Kurtosis and Shapiro-Wilk test and a visual examination of the normal distribution plots for the variables (as shown in Appendix G) suggest that the data follows a normal distribution (Field, 2018). The normality of the dataset was assessed using the Shapiro-Wilk test (Razali & Wah, 2011). The test results suggest that the variables of test performance, intrinsic motivation, and achievement emotions do not deviate statistically from a normal distribution. Only achievement emotions in the desktop simulation yielded a statistically significant result, indicating a potential deviation from normal distribution for this variable. The non-significant results suggest that these variables follow a normal distribution. The assumption regarding the absence of outliers was examined by evaluating the standard residuals, specifically those exceeding a threshold of 3.0. Overall, the assumptions of normality, homoscedasticity, absence of outliers, linearity, and lack of multicollinearity have been met.

Results

Prior to performing the analysis, a randomization check was conducted to assess potential group differences in the pretest. The results of the test indicated no statistically significant disparities in prior knowledge between the groups (p = .155) with a mean of 8.5 in the DS group and 7.7 in the VR group.

Descriptive findings

Table 2 displays the mean, standard deviation, minimum and maximum value for each level of immersion for all variables.

Table 2

Descriptive Statistics

		N	Mean	SD	Min.	Max.
Pre-test TP	DS	19	8.53	1.43	6.00	11.00
	VR	19	7.68	2.08	4.00	12.00
Post-test TP	DS	19	8.05	2.51	4.00	13.00
	VR	19	8.32	2.61	3.00	13.00
Learning gains	DS	19	-0.47	2.53	-6.00	4.00
	VR	19	0.63	2.91	-4.00	6.00

		N	Mean	SD	Min.	Max.
Achievement emotions	DS	19	2.83	0.45	2.33	3.83
	VR	19	2.65	0.36	2.17	3.42
Positive emotions	DS	19	3.33	0.57	2.25	4.25
	VR	19	3.99	0.63	2.50	5.00
Negative emotions	DS	19	2.58	0.77	1.63	4.13
	VR	19	1.97	0.69	1.00	3.63
Intrinsic motivation	DS	19	3.00	0.41	2.07	3.60
	VR	19	3.62	0.36	2.60	4.20

Note. Pre- and posttest of test performance are included, and achievement emotions are divided in positive and negative emotions.

Table 3 shows the Pearson correlation matrix. All correlations are between -0.4 and 0.4, which is acceptable.

Table 3

Pearson's Correlation Matrix

Correlation coefficients		*TP*	*AE*	*IM*
Pearson	*TP*	-		
	AE	-0.409*	-	
	IM	0.273	-0.306	-

Note. TP denotes test performance, AE denotes achievement emotions, IM denotes intrinsic motivation. *Correlation is significant at the 0.01 level (2-tailed).

An initial attempt was made to perform a multiple linear regression analysis. However, considering the limitations associated with the small sample, the assumptions of the linear regression model may not hold. Consequently, a non-parametric test was conducted to ensure more robust and reliable results. For comprehensive reporting, the findings from both the multiple linear regression analysis and non-parametric analysis are provided below and an indication whether the hypotheses are rejected or accepted is included.

Multiple Linear Regression

Table 4

Results of Multiple Linear Regression

	R^2	*B*	β	*t*	*p*
TP	.04	1.11	0.20	1.25	.219
AE	.05	-0.18	-0.23	1.40	.169
PAE	.24	0.66	0.49	3.37	.002
NAE	.16	-0.61	-0.39	-2.57	.015
IM	.40	0.62	0.64	4.94	<.001

Note. TP denotes test performance, AE denotes achievement emotions, PAE denotes positive achievement emotions, NAE denotes negative achievement emotions, IM denotes intrinsic motivation.

In the multiple linear regression analysis, a pre-test was initially used as a covariate to assess its potential impact on the results. However, the analysis yielded non-significant findings, indicating that the pre-test did not have a statistically significant effect on the outcome of test performance ($F = 0.46$, $p = .503$, $\eta^2 = .06$). Subsequently, an additional analysis was conducted without using any covariate. The analysis produced the same results, indicating that the absence of a covariate did not affect the outcome. The analysis revealed no significant effect associated with the pre-test, suggesting that it did not have a meaningful impact on the variables being studied.

With test performance, 4.0% of the variance can be explained by the group difference. The regression coefficient was 1.11, but it did not reach statistical significance ($t = 1.25$, $p = .219$, $f = 0.20$). The effect size measured by Cohen's *f* indicates a small effect (Field, 2018).

When dividing achievement emotions in positive and negative, a statistical effect has been found. With positive emotions, 24% of the variance can be explained by the group difference. The regression coefficient was .66 and it did reach statistical significance (t = 3.37, p = .002, f = is 0.56) with indicating a large effect (Field, 2018). This implies that as the level of immersion increases, there is a tendency for individuals to experience higher levels of positive achievement emotions. With negative emotions, 16% of the variance can be explained by the group difference. The regression coefficient was -0.61 and statistically significant (t = -2.57, p = .015, f = 0.43) indicating a large effect (Field, 2018). The negative regression coefficient of -0.61 suggests that as immersion increases, there is a tendency for negative emotions to decrease. The coefficient being negative indicates an inverse relationship between immersion and negative emotions.

Finally, with intrinsic motivation, 40% of the variance can be attributed to group difference. The regression coefficient for immersion was .62, indicating a significant positive relationship with a large effect (t = 4.94, p < .001, f = 0.82). This suggests that as immersion increases, intrinsic motivation tends to increase too.

Results of the Non-Parametric Test

The non-parametric test focused solely on the variables of interest without considering the potential influence of the pre-test as a covariate.

The Mann-Whitney U-test was conducted to compare the dependent variable to the independent variables. For test-performance, U = 142.50, p = .269. This implies that there is no substantial evidence to support a significant relationship between immersion and test performance in this study. The effect size, as measured by the rank-biserial correlation coefficient, was -.21 indicating a moderate effect size (Field, 2018). Effect size is given in rank-biserial correlation, it seems contradictory due to the formulation, but it aligns with multiple linear regression since the groups are reversed with calculation. In this case, the negative should be understood as a positive.

When dividing achievement emotions in positive and negative emotions, there is a statistically significant effect found. For positive emotions, $U = 75.50$, $p = .002$ shows a statistically significant effect. The effect size = -.58, which is a moderate to strong relationship (Field, 2018). This suggests that as the level of immersion increases, there is a tendency for individuals to experience higher levels of positive achievement emotions. For negative emotions, $U = 257.50$, $p = .025$. The effect size = .43, which is a moderate effect (Field, 2018). This suggests that as immersion increases, there is a tendency for negative emotions to decrease. These results support hypothesis 1, indicating that a high level of immersion increases positive emotions compared to a low level of immersion environment and hypothesis 2 suggesting that a high level of immersion decreases negative emotions compared to a low level of immersion environment.

For intrinsic motivation, $U = 36.00$, $p = <.001$, shows a significant effect. The effect size = -.80, which indicates a strong significant relation between intrinsic motivation and immersion (Field, 2018). The effect size and statistical significance demonstrate that as immersion increases, there is a corresponding increase in intrinsic motivation. These findings provide support for hypothesis 3 that a high level of immersion increases intrinsic motivation compared to a low level of immersion environment. Table 5 shows the results of the non-parametric test.

Table 5

Results of Non-parametric Test

	U	*p*	Effect size
TP	142.50	.269	-.21
AE	221.00	.240	.22
PAE	75.50	.002	-.58
NAE	257.50	.025	.43
IM	36.00	<.001	-.80

Note. SE effect size was .19. The dependent variable is immersion. Effect size is given in rank-biserial correlation, it seems contradictory but due to the formulation, it aligns with multiple linear regression since the groups are reversed with calculation.

Discussion

The primary objective of this study was to investigate the impact of high immersion compared to low immersion when students learn chemistry and how this affects their emotions and intrinsic motivation. By focusing on the level of immersion, this study adds valuable insights to the broader discourse on effective educational strategies, contributing to our understanding of how to optimize learning experiences in an increasingly technology-driven society.

Immersion and test performance

Regarding the learning outcomes, the comparison between the VR group and the desktop simulation did not reveal any statistically significant difference. This result supports the concept of CATML, as described by Moreno and Mayer (2007), which suggests that an increase in extraneous cognitive load can hinder effective learning outcomes. According to the coherence principle, optimal learning occurs when unnecessary details are eliminated from the lesson (Moreno & Mayer, 2000). In the VR simulation, there were irrelevant sounds, animations, and interactions that were not directly relevant for acquiring the information. These additional features might have triggered extraneous cognitive processing. Added immersion could be classified as a seductive detail, that has the potential to distract participants by activating the wrong cognitive schemas and potentially resulting in an incorrect understanding of the subject matter (Makransky et al., 2019b). Due to the inclusion of extraneous stimuli in the VR simulation, which contradicts the coherence principle, the learner's cognitive resources may have been utilized to process these irrelevant stimuli. As a result, the availability of cognitive resources for essential and generative workload would have been diminished. The result is also in line with several previous studies who discovered that the group exposed to immersive VR performed poorly on the transfer test and experienced a higher extraneous cognitive load (Makransky et al., 2019b; Parong & Mayer, 2021). Considering the results of this study, it can be inferred that immersion had no discernible impact on test performance.

Immersion and achievement emotions

Regarding students' emotions, the key findings indicate that the VR group exhibited a notable improvement in positive emotions and a decrease in negative emotions. These findings are consistent with our hypotheses 1 and 2, which proposed that a more immersive environment would enhance positive emotions and diminish negative emotions and is consistent with prior research (Allcoat & Von Mühlenen, 2018; Pallavicini & Pepe, 2020). The findings of this study align with the CVT of achievement emotions as it indicates an increase in positive emotions and a decrease in negative ones. According to the CVT of achievement emotions, when a learning activity such as a VR simulation is positively valued and perceived as controllable, it triggers enjoyment (Pekrun, 2006). Previous research has established a connection between enjoyment and student performance, implying that the utilization of VR has the potential to enhance the learning experience in a positive manner

(Valiente et al., 2011). Enjoyment plays a crucial role in fostering engagement and flow, as described by Csikszentmihalyi (2000), which contributes to satisfaction. Although we did not find an effect on students' learning, understanding the relationship between immersion and emotions enables developers to optimize immersive environments for desired emotional experiences. This knowledge may apply to VR simulations, gaming, and virtual training, enhancing user experiences and achieving specific emotional goals.

Immersion and intrinsic motivation

Regarding students' intrinsic motivation, the results indicate that a high level of immersion in the learning environment leads to increased intrinsic motivation compared to a low level of immersion, which supports hypothesis 3 that postulated the positive impact of higher immersion on intrinsic motivation. These results align with previous research who suggested that immersive experiences facilitated by VR can offer unique and novel opportunities that are not feasible in real-world settings, thereby enhancing intrinsic motivation (Huang et al., 2020; Taranilla et al., 2022). The results also align with the SDT which posits that individuals have innate psychological needs for autonomy, competence, and relatedness (Ryan & Deci, 2000). The immersive nature of learning environments, such as VR, has the potential to enhance these psychological needs. By providing learners with a sense of autonomy and control, VR can increase intrinsic motivation and engagement. This study's findings align with SDT by highlighting how immersion, when appropriately designed, can positively impact motivation. While this study did not directly observe a significant effect on test performance, these findings reinforce the notion that VR holds the potential to enhance intrinsic motivation, even though its impact on academic outcomes may vary.

Implications

Educators and instructional designers can consider integrating high immersive learning environments, such as VR, into their instructional practices. Based on this study, these environments have shown to significantly increase intrinsic motivation and positive emotions and decrease negative emotions among students. By leveraging immersive technologies, educators can create more engaging and captivating educational experiences that stimulate students' interest and enthusiasm for learning. When designing immersive learning scenarios, it is crucial to consider the concept of cognitive load. This involves minimizing extraneous processing to optimize learning outcomes. Specifically, instructional design principles such as the coherence principle (Moreno & Mayer, 2000) can be particularly relevant in immersive learning environments. For example, eliminating irrelevant material that may lead to enjoyable activities but does not contribute to the learning process. Educators could utilize high immersive learning environments as supplementary tools to enhance student motivation and emotional well-being, despite their limited impact on students' learning gains.

Limitations and Future Directions

Several limitations were encountered during this study, which should be taken into consideration when interpreting the results. One significant limitation was the inability to recruit participants who met the specific criteria for this study proved to be challenging. The requirements for mechanical or chemical engineering students further restricted the pool of potential participants. The difficulty in recruitment could introduce a potential bias and limit the generalizability of the findings. Despite efforts to reach out to potential participants, the desired sample size could not be achieved. The study was conducted with a relatively small sample size, which might have reduced the statistical power to detect significant effects and therefore increased the chance of Type-II errors (Cohen, 1992). Consequently, the representativeness of the sample to the broader population of interest may be called into question. Future research should prioritize expanding the sample size and ensuring the inclusion of participants who meet the specific criteria, ensuring a larger and more representative sample to enhance statistical power, generalizability, and validity of the findings.

Second, another significant limitation that needs to be carefully considered is the lack of observed learning outcomes following the intervention. It was evident that participants did not experience notable improvements in their learning. This outcome raises questions about the effectiveness of the instructional material used and its alignment with the needs, prior knowledge, and learning preferences of the target audience. As a result, any conclusions drawn regarding the impact on learning should be approached with caution and nuanced interpretation. Future research should focus on refining the instructional materials, ensuring their alignment with the target audience, addressing individual differences in prior knowledge, and considering the optimal duration and intensity of the learning environment to enhance the potential for meaningful learning outcomes.

Third, within this study we did not measure cognitive load which is the mental effort required for learning and processing information. The absence of cognitive load measurement prevents us from fully understanding the potential impact of cognitive demands on participants' learning experiences and outcomes. Future studies should measure cognitive load to understand its impact on participants' learning experiences and outcomes. This will provide valuable insights into the cognitive demands of instructional materials or interventions used. Additionally, exploring the relationship between cognitive load and factors like prior knowledge, learning styles, and instructional design can inform the development of personalized and adaptive learning environments that optimize learning experiences.

Conclusion

High immersive learning environments significantly increase intrinsic motivation and positive emotions and decreases the negative emotions of students. There is no significant effect found on students' test performance. The findings provide valuable insights into the effects of immersion on student emotions and motivation. These findings align with previous research, highlighting the potential of immersive technologies, such as VR, to foster a more positive and engaging educational environment. The results contribute to the advancement of theories related to immersion and its influence on student experiences. By exploring the effects of immersion on student emotions and motivation, the findings provide valuable insights that can inform instructional practices and the design of immersive educational experiences. In conclusion, educators can incorporate high immersive learning environments, like VR, as supplementary tools to enrich student motivation and emotional well-being, even though their impact on learning gains may be limited. Overall, the study's contributions advance theories related to immersion and its influence on student experiences, thus enriching the knowledge base and guiding future research and implementation of immersive learning technologies in education.

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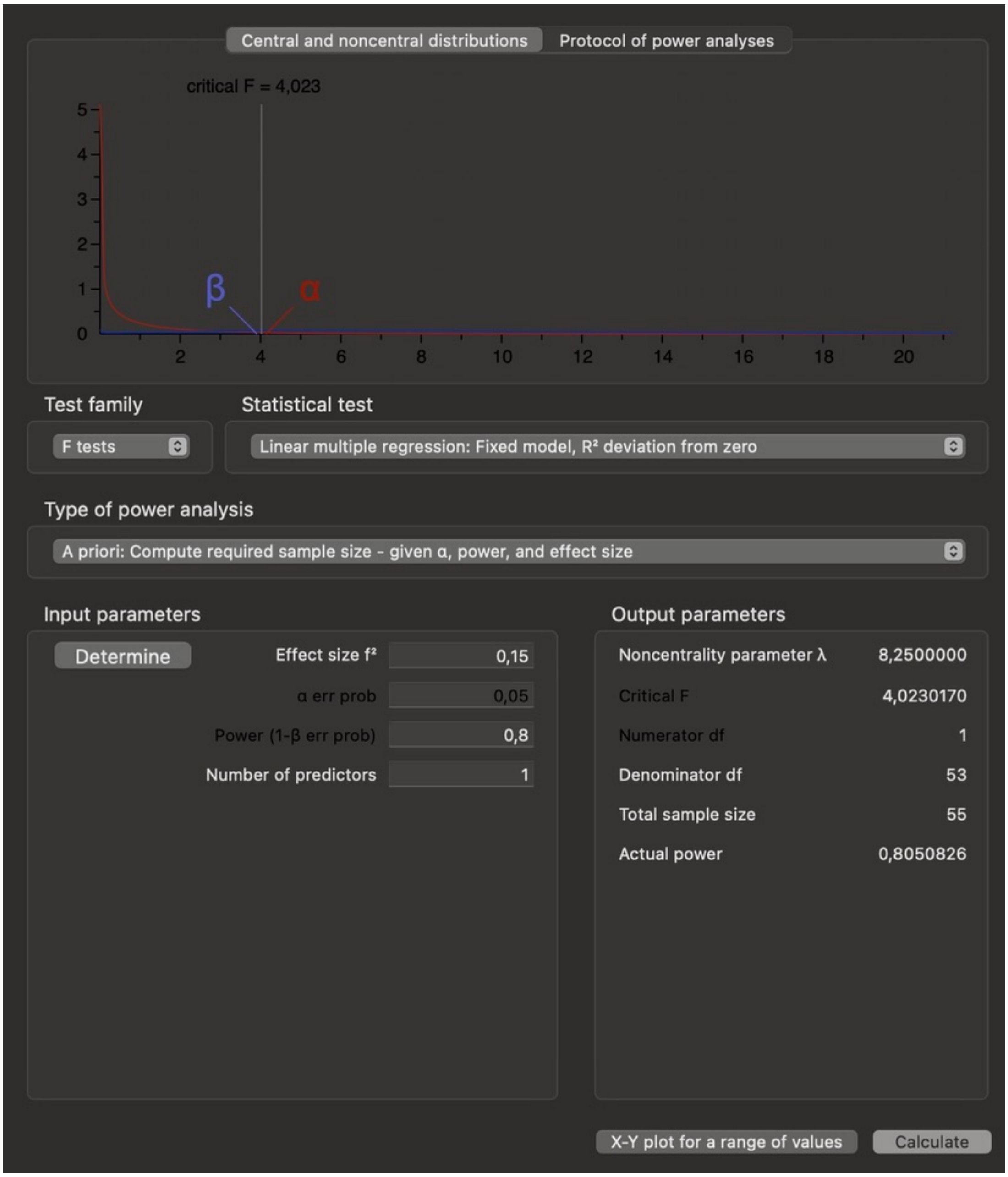
Appendix A: Screenshot Power Analysis

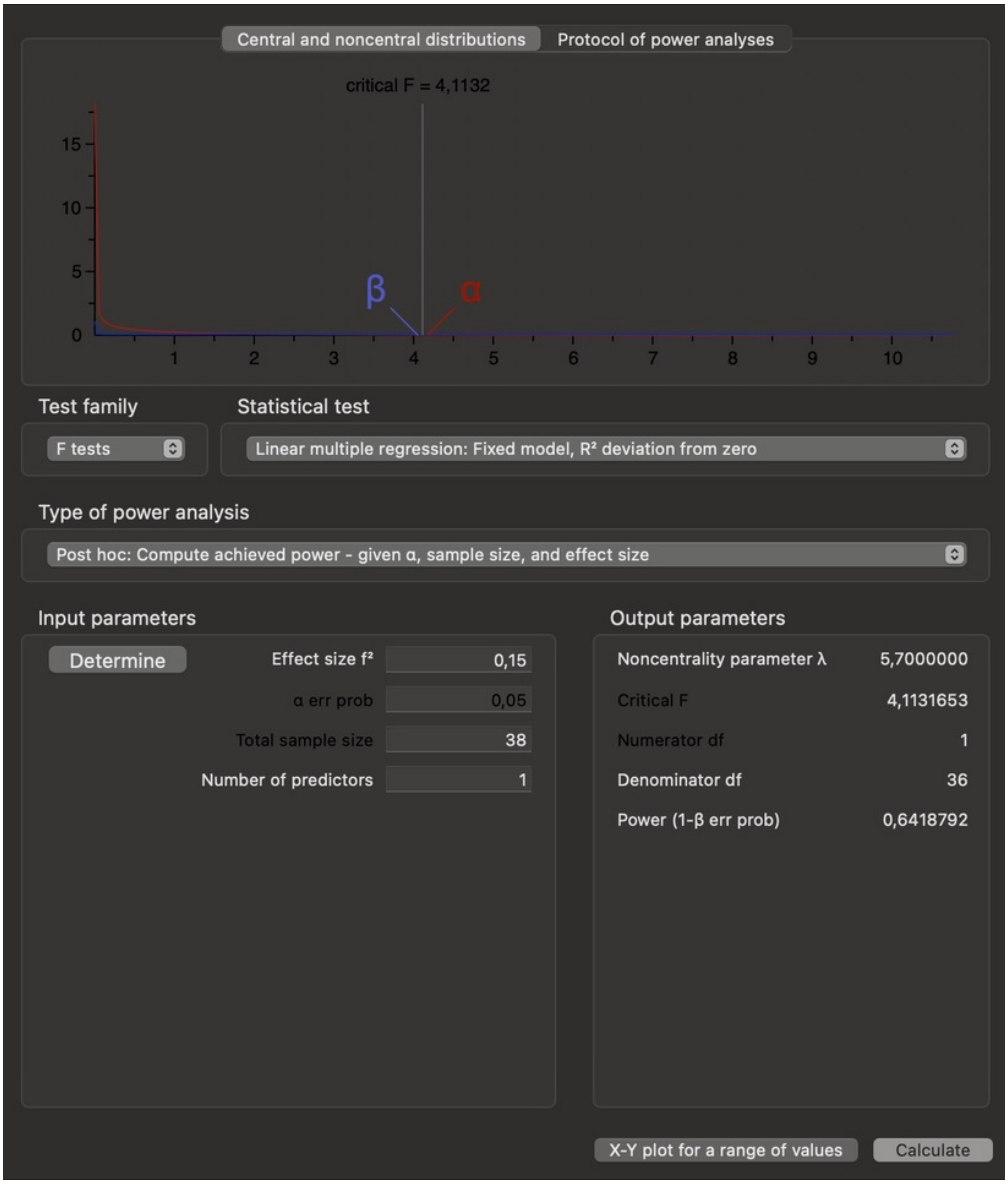
Screenshot A1

A priori



Screenshot A2

Post hoc



Appendix B: Simulator Sickness Questionnaire

Are you motion sick now? Circle YES or NO

Circle how much each symptom below is affecting you now.

0 = “not at all” 1 = “mild” 2 = “moderate” 3 = “never”

1. General discomfort	0	1	2	3
2. Fatigue	0	1	2	3
3. Headache	0	1	2	3
4. Eyestrain	0	1	2	3
5. Difficulty focusing	0	1	2	3
6. Increased salivation	0	1	2	3
7. Sweating	0	1	2	3
8. Nausea	0	1	2	3
9. Difficulty concentrating	0	1	2	3
10. Fullness of head	0	1	2	3
11. Blurred vision	0	1	2	3
12. Dizziness (eyes open)	0	1	2	3
13. Dizziness (eyes closed)	0	1	2	3
14. Vertigo*	0	1	2	3
15. Stomach awareness*	0	1	2	3
16. Bumping	0	1	2	3

*Vertigo is experiences as loss of orientation with respect to vertical upright.

**Stomach awareness is usually used to indicate a feeling of discomfort that is just short of nausea.

Appendix C: Knowledge Test (pre and post)

General questions: overall performance

1. Which of the following options best illustrates the typical use of a water treatment basin?

   a) Facilitates a mixing chamber
   b) Eliminates contaminants (*)
   c) Reduces the concentration of chlorine

2. What is the impact of chlorine on a water treatment process?

   a) To give a better taste and odor to tap water
   b) To disinfect disease-causing microorganisms in water (*)
   c) Is used to raise the pH-value of dirty water

3. What parameters are important in the design of a water treatment basin?

   a) Chlorine residuals, velocity profiles, flow patterns, desalination
   b) Residence time, chlorine residuals, velocity profiles, flow patterns (*)
   c) Desalination, ambient temperature, residence time, flow patterns

4. A chlorine residual is a level of chlorine remaining in water after its initial application. Sometimes the chlorine residual is still slightly high after eliminating all contaminants from water supplies. What does this mean?

   a) Water is unsafe and still contains parasites, bacteria or viruses
   b) Water is safe but can still contain disease-causing germs
   c) Water is safe but it can give an unpleasant taste and odor (*)

5. Why might a long residence time be necessary for a water treatment process with chlorine?

   a) It takes time to disinfect the entire basin (*)
   b) It takes time to obtain a uniform water temperature
   c) It takes time to prevent unpleasant taste and odor

6. Why is turbulent flow preferred over laminar flow in a water treatment process with chlorine?

a) Faster mixing and lower residence time
b) Cheaper mixing and lower pressure loss
c) Better mixing and elimination of dead zones (*)

7. Which of the following best illustrates the significance of the pressure loss in the design of a water treatment basin?

a) Pressure loss determines the inlet velocity to reduce operating cost
b) Pressure loss determines the size of the pump forcing the flow through the basin (*)
c) Pressure loss determines the chlorine residuals and residence time distribution

8. Which of the following effects do baffle walls have on the design of water treatment basins?

a) Eliminate dead zones, lower pressure loss, better mixing
b) Better mixing, higher pressure loss, elimination of dead zones (*)
c) Lower pressure loss, better mixing, higher chlorine residuals,

Questions TASK1: Number of walls per side

9. What is indicated if the number of baffle walls increases in a water treatment basin?

a) Increasing mixing quality (*)
b) Increasing velocity
c) Increasing chlorine concentration

10. Which of the following parameters are necessary to determine the number of baffle walls in a water treatment basin?

a) Pressure loss, chlorine concentration, inlet velocity, flow patterns
b) Flow patterns, ambient temperature, chlorine concentration, velocity profiles
c) Velocity profiles, pressure loss, flow patterns, chlorine concentration (*)

11. Which of the following options best illustrates the effect of increasing the length of baffle walls on the chlorine concentration?

a) Reduce chlorine concentration (*)
b) Keep chlorine concentration constant
c) Increase chlorine concentration

12. Which of the following statements provides the best reasoning to limit the number of baffle walls in a water treatment basin?

a) Installation and operating costs significantly increase after a certain number of baffle walls
b) Residence time and deal pressure loss unreasonably increase after a certain number of baffle walls
c) No substantial change occurs in water treatment performance after a certain number of baffle walls (*)

General questions: End

13. Which of the statements below is correct?

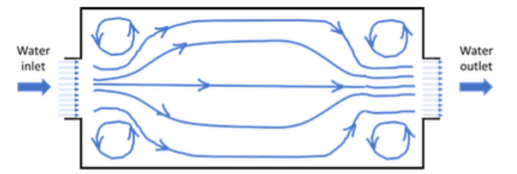
a) The orientation of the baffle walls does not significantly influence on residence time and pressure loss
b) The concentration profile, combined with the flow field, shows regions where the chlorine concentration may increase
c) The regions immediately behind the baffle walls have a slightly lower chlorine concentration since these are recirculation zones for the flow (*)

14. Which one of the following illustrates the best order of parameters, by means of importance, in the design of a water treatment basin?

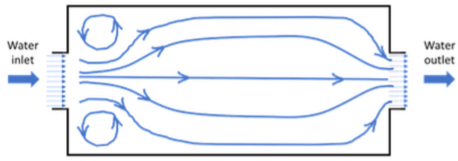
a) Chlorine residuals > flow patterns > pressure loss > installation cost (*)
b) Flow patterns > pressure loss > chlorine residuals > installation cost
c) Pressure loss > chlorine residuals > flow patterns > installation cost

15. Which of the following correctly illustrates the fluid flow throughout the basin?

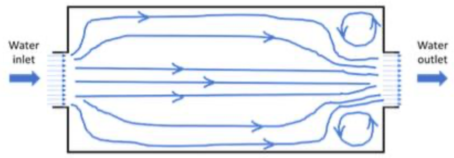
a)



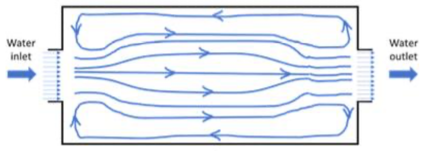
b)



c)

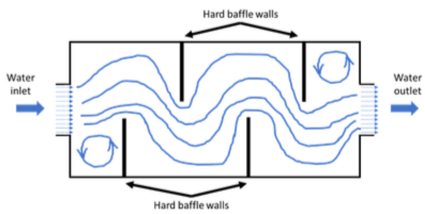


d) *

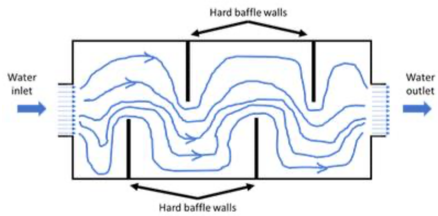


16. Which one of the following correctly illustrates the fluid flow throughout the basin?

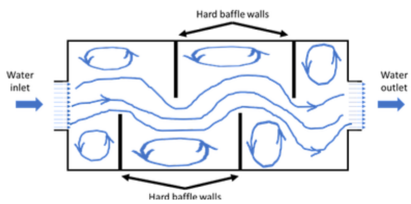
a)



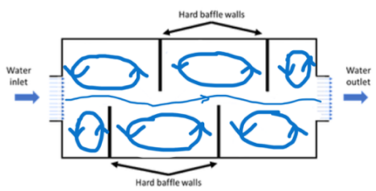
b)



c) *



d)



Appendix D: Achievement Emotions Questionnaire Short

Learning can induce different feelings. The following questions refer to emotions you may experience when learning in the environment. Before answering, please recall some typically situation of learning which you have experienced during the learning environment. Please indicate how you feel, typically when learning. please read each statement carefully and respond using the scale provided.

Enjoyment

1. I enjoy the challenge of learning the material.
2. I enjoy dealing with the learning material.
3. I am so happy about the progress I made that I am motivated to continue studying.
4. When my studies are going well, it gives me a rush.

Anger

5. Learning makes me irritated.
6. I get so angry I feel like throwing the equipment out of the window.
7. When I am learning in this environment for a long time, my irritation makes me restless.
8. I get annoyed about having to learn.

Boredom

9. The material is so boring that I find myself daydreaming.
10. Learning bores me.
11. I would rather put off this boring work till tomorrow.
12. While learning, I seem to drift off because it's so boring.

Appendix E: Intrinsic Motivation Inventory

Interest/enjoyment

1. I enjoyed working in the learning environment.
2. I found the activity in the learning environment very interesting.
3. The activity in the learning environment was entertaining.

Perceived competence

4. I am satisfied with my performance in the learning environment.
5. I did my job skillfully in the learning environment.
6. I think I was pretty good in the learning environment.

Perceived choice

7. I was able to control the activity in the learning environment myself.
8. Working in the learning environment allowed me to choose how to do it.
9. I was able to do what I wanted to do in the learning environment.

Pressure/tension

10. I felt under pressure while working in the learning environment.
11. I felt tense while working in the learning environment.
12. I had concerns about whether I would be able to do the work in the learning environment well.

Value/usefulness

13. I believe the learning environment is useful to me.
14. I believe that the learning environment is useful for me.
15. I believe that the learning environment is important.

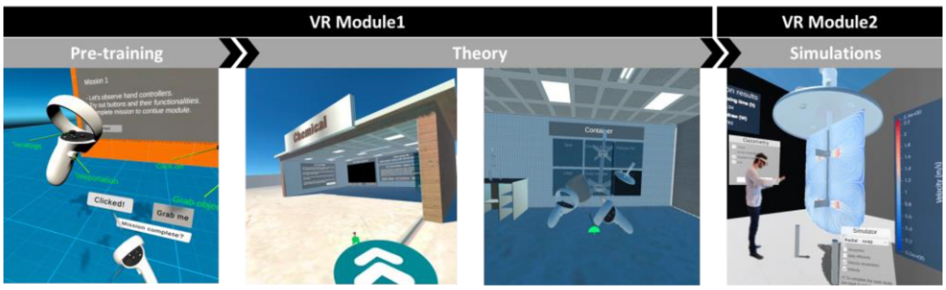
Appendix F: Learning Environment Description

The Water Basin application is designed to serve as a demonstration of how to model turbulent flow in liquids. Specifically, the application features a learning environment that simulates a chlorination basin used in water treatment. It showcases the use of fully parameterized geometries and cumulative selections to accurately represent turbulent flows. The learning environment provides an information screen that displays all relevant data and locked parameters. The basin parameters that students can modify include the number of walls per side, the length of walls, and the radius of corners. The concentration at outlet and pressure drop are predetermined at <0.35 mol/m^3 and <1100 Pa, respectively, to indicate a desirable scenario. By adjusting the basin parameters, students can select the most favorable setup based on the given fixed parameters. Moreover, the environment includes a visual representation of the basin that displays the waterflows, which adjust to reflect any parameter changes made by the students. For example, if a student opts to have two walls, the basin will be updated to reflect this, with the velocity profile and water flow adjusted accordingly.

Task 1 involves presenting participants with four different situations, each with varying numbers of walls (0, 1, 2, or 3 walls per side) in the basin. The aim is for participants to study all four situations and choose the one that best fits the fixed parameters by examining the velocity profile and waterflow. Figure F1 shows the introduction and simulation part as described as Module1 and Module2.

Figure F1

Scenes in the VR Environment, Module 1 and Module 2



Module1 consists of both theory and pre-training components. The pre-training module aims to educate users on VR interactions and provide them with opportunities to familiarize themselves with the VR learning environment and its usability features. Within Module1, users navigate the VR environment to access supportive information that they can apply to problem-solving in Module2 with simulation data. Both sections took approximately 20 minutes to complete.

Appendix G: Assumptions Regression Analysis

Table G1

Descriptive Statistics

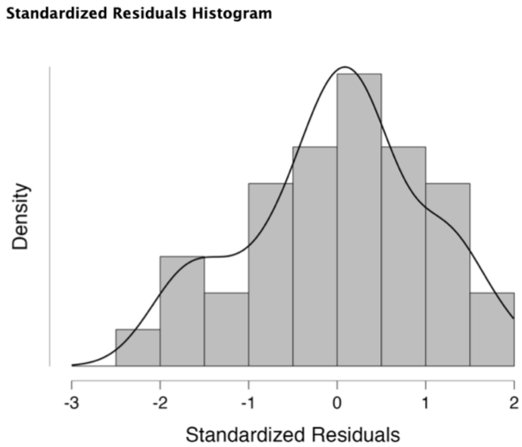
	Posttest		TP		AE		PAE		NAE		IM	
	DS	VR	DS	VR	DS	VR	DS	VR	DS	VR	DS	VR
Valid	19	19	19	19	19	19	19	19	19	19	19	19
Missing	0	0	0	0	0	0	0	0	0	0	0	0
Mean	8.05	8.32	-0.47	0.63	2.83	2.65	3.33	3.99	2.58	1.97	3.99	3.62
SD	2.51	2.61	2.53	2.91	0.45	0.36	0.57	0.63	0.77	0.69	0.41	0.36
Skewness	0.36	-0.11	-0.53	0.02	0.88	0.35	-0.50	-0.70	0.65	0.50	-0.64	-0.91
SE Skewness	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52
Kurtosis	-0.32	-0.36	0.33	-0.73	-0.27	-0.53	-0.32	0.29	-0.61	0.37	0.02	2.47
SE Kurtosis	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01

	Posttest		TP		AE		PAE		NAE		IM	
Shapiro-Wilk	.95	.97	.96	.95	.88	.95	.94	.96	.93	.96	.95	.92
p-value Shapiro-Wilk	.352	.784	.562	.347	.025*	.400	.28	.52	.15	.50	.327	.101
Min.	4.00	3.00	-6.00	-4.00	2.33	2.17	2.25	2.50	1.63	1.00	2.07	2.60
Max.	13.00	13.00	4.00	6.00	3.83	3.42	4.25	5.00	4.13	3.63	3.60	4.20

Note. TP denotes test performance; AE denotes achievement emotions; PAE denotes positive achievement emotions; DAE denotes negative achievement emotions; IM denotes intrinsic motivation. Skewness and Kurtosis values were assessed using the general rule of thumb, where values between -2 and 2 are within an acceptable range. *Achievement emotions in the desktop simulation yielded a significant result, meaning that it did not follow a normal distribution.

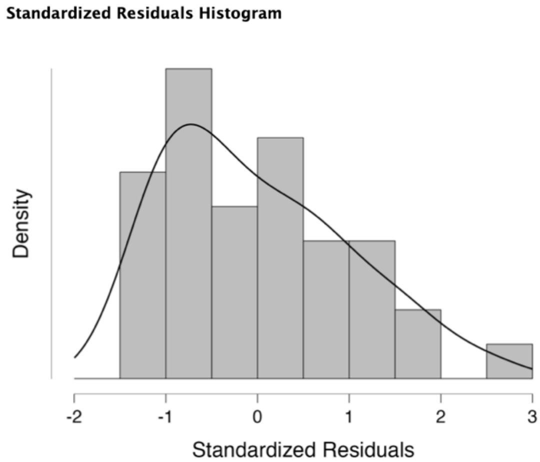
Graph G1

Normal Distribution of Test Performance



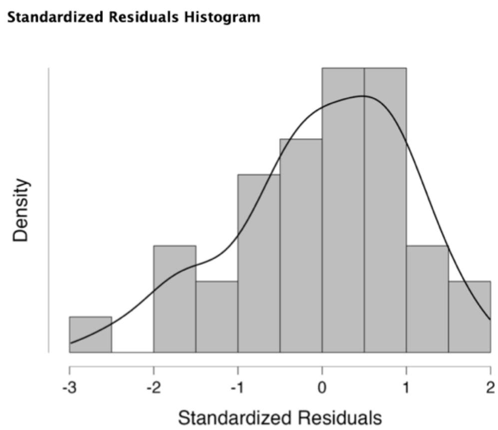
Graph G2

Normal Distribution of Achievement Emotions



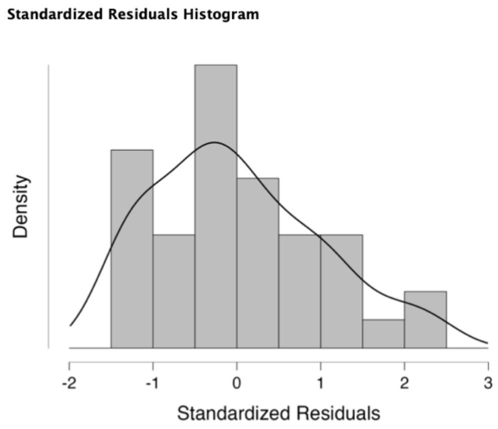
Graph G3

Normal Distribution of Positive Achievement Emotions



Graph G4

Normal Distribution of Negative Achievement Emotions



Graph G5

Normal Distribution of Intrinsic Motivation

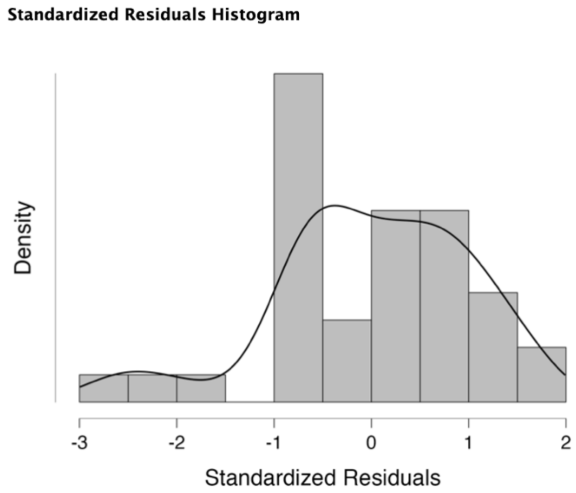


Figure G1

Homoscedasticity of Test Performance

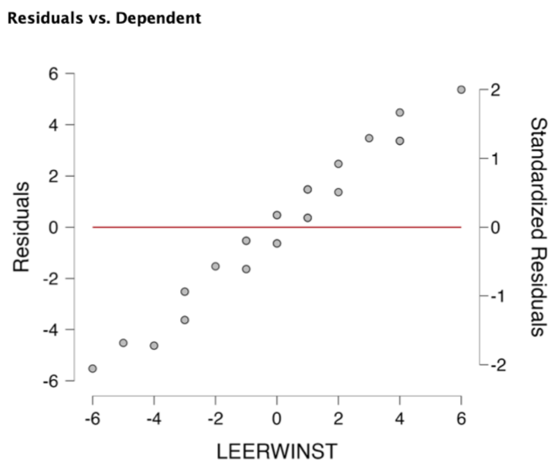


Figure G2

Homoscedasticity of Achievement Emotions

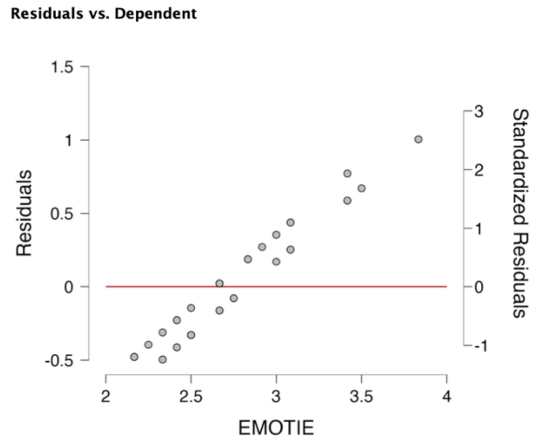


Figure G3

Homoscedasticity of Positive Achievement Emotions

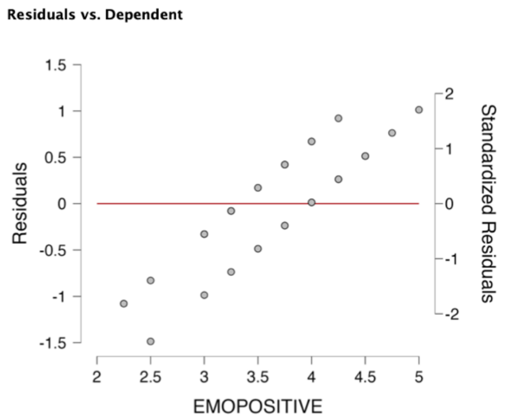


Figure G4

Homoscedasticity of Negative Achievement Emotions

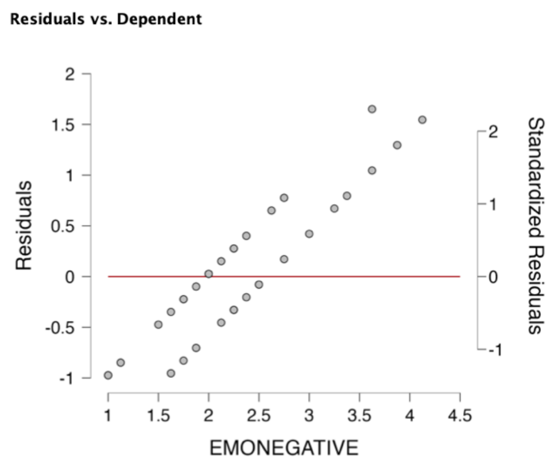
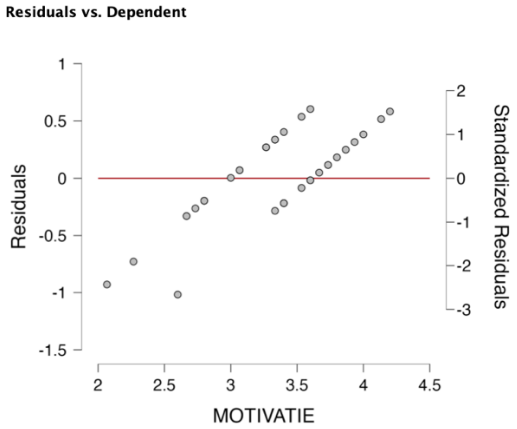


Figure G5

Homoscedasticity of Intrinsic Motivation



Appendix H: Internal Consistency Guttman's Lambda

Table H1

Guttman's Lambda if Item Deleted on Statements Used to Measure Students' Achievement Emotions

Statement	Guttman's Lambda if item deleted
AE1: I enjoy the challenge of learning the material.	*.760*
AE2: I enjoy dealing with the learning material.	*.752*
AE3: I am so happy about the progress I made that I am motivated to continue studying.	*.778*
AE4: When my studies are going well, it gives me a rush.	*.744*
AE5: Learning makes me irritated.	*.636*
AE6: I get so angry I feel like throwing the equipment out of the window.	*.606*
AE7: when I am learning in this environment for a long time, my irritation makes me restless.	*.656*
AE8: I get annoyed about having to learn.	*.656*
AE9: The material is so boring I find myself daydreaming.	*.654*
AE10: Learning bores me.	*.681*
AE11: I would rather put off this boring work till tomorrow.	*.647*
AE12: While learning, I seem to drift off because it's so boring.	*.628*

Table H2

Guttman's Lambda if Item Deleted on Statements Used to Measure Students' Intrinsic Motivation

Statement	Guttman's Lambda if item deleted
M1: I enjoyed working in the learning environment.	*.810*
M2: I found the activity in the learning environment very interesting.	*.824*
M3: The activity in the learning environment was entertaining.	*.819*
M4: I am satisfied with my performance in the learning environment.	*.829*
M5: I did my job skillfully in the learning environment.	*.833*
M6: I think I was pretty good at the learning environment.	*.849*
M7: I was able to control the activity in the learning environment myself.	*.834*
M8: Working in the learning environment allowed me to choose how to do it.	*.835*
M9: I was able to do what I wanted to do in the learning environment.	*.836*
M10: I felt under pressure whole working in the learning environment.	*.859*
M11: I felt tense while working in the learning environment.	*.867*
M12: I had concerns about whether I would be able to do the work in the learning environment well.	*.870*
M13: I believe the learning environment is useful to me.	*.815*
M14: I believe that the learning environment is helpful for me.	*.813*
M15: I believe that the learning environment is important.	*.852*

Table H3

Guttman's Lambda if Item Deleted on Statements Used to Measure Students' Pre and Post Knowledge

Question	Guttman's Lambda if item deleted	
	Pretest	Posttest
Q1	.022	.384
Q2	.016	.354
Q3	.066	.287
Q4	.260	.262
Q5	-.142	.326
Q6	.012	.461
Q7	.101	.363
Q8.	-.170	.376
Q9	-.013	.295
Q10.	-.096	.389
Q11	-.075	.327
Q12	.097	.361
Q13	.050	.326
Q14	.024	.334
Q15	-.074	.272
Q16	-.034	.394

Appendix I: Assignment 4

The participants will be university students. They will give consent through an informed consent form and will be aware of the nauseousness. Potential participants will be provided with an informed consent form that explains the aim of the study, including the fact that it is an experimental study, that participation is voluntary, and a summary of the research aims, time frame, and procedures. The informed consent form will also mention that using virtual reality goggles may come with some potential side effects, such as nausea, dizziness, and dry eyes. To minimize these risks, the following steps will be taken: limiting exposure time in virtual reality to around 20 minutes per task and using a simple digital environment with few digital artifacts. Participants fill in a sickness simulator questionnaire before participating in the study. Based on their answers they can be denied from participating. Participants are also allowed to take a break when needed and can stop anytime if they cannot play any longer, also because of the long time of the experiment.

The instruments being used will be the VR glasses Quest2 with hand controllers for the high-immersion group and laptops for the low immersion group. The learning environment that will be played will be about water basin treatments. Questionnaires will be used to measure the effects but also participants get the opportunity to answer questions about how they felt during the study. The pre- and posttest will be administered online. All answers will be stored anonymously, and data storage will be in YoDa. The data will be stored for a maximum of ten years.

Appendix J: Planning Master Thesis

When	What	Extra
Week 46 and 47	Orient on subject, find literature	
Week 47	Narrow research question	
23 November 13.30 – 14.00	Meeting supervisor	Together with co-student
23 November	Give peer feedback	(To Anne)
30 November	Make a time plan	
30 November	Work further on introduction about GBL and immersion	
4 December	Find more literature	
6 and 7 December	Further elaborate introduction, start theoretical framework	
7 December	Give peer feedback	(To Ilse)
7 December	Meeting supervisor	
Week 49	Write theoretical framework, make a table for method	
14 December	Teacher feedback draft	
18 and 20 December	Work on method	
21 December	Prepare presentation for roundtable	
9 January	Finish draft research plan	

When	What	Extra
11 January	Decide date for submitting FERB-application, work on the feedback received by supervisor	After finishing draft, begin February
16 January	Give peer feedback	(To Teun)
17 January	Meeting supervisor, finalize draft	
26 January	Engage in a joint writing session, finalize draft	
29 January	Submit final research plan	
6 February onwards	Work on AVT thesis plan	Deadline is 22 feb
22 February	Hand in AVT	
28 February onwards	Process feedback and work on FERB application form	
1 March	Start getting data collection ready	
16 March	FERB application approved	
16 March onwards	Getting data collection ready, VR and DS & questionnaires	
4 April – 23 April	Data collection	
26 April	Start data analyses and interpret results	

When	What	Extra
3 May onwards	Write results, discussion and conclusion section	
3 May	Roundtable about results	
17 May	Deadline draft	
20 May onwards	Produce feedback	
6 June	Ask and give peer feedback	(With Teun)
12 June	Deadline thesis	
10 July	Deadline AVT thesis (if needed)	