Using Virtual Reality to Improve Learning Mindsets and Academic Performance in Post-Secondary Students

by

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Abstract

Recent research indicates that most post-secondary students in North America "felt overwhelming anxiety" in the past few years, negatively affecting well-being and academic performance. Further research revealed that other emotions, biases, perceptions, and negative thoughts, not just anxiety, can similarly affect student academic performance. To address this problem, we classify these counterproductive thought processes, including anxiety, into a broader definition called *Scarcity Mindset;* a self-limiting perspective that appropriates cognitive bandwidth required for essential processes like learning in favour of addressing more critical needs or perceived insufficiencies.

As such, through the lens of *Scarcity Mindset*, we conduct a multi-disciplinary literature analysis of innovative ideas in cognitive science, learning theories and mindsets, and current technology approaches that are suited to address the limitations of scarcity thinking. We identify strategies that help transition students to a more positive *Abundance Mindset*. We identify knowledge gaps, research questions, and a theoretical framework called the Cyclical Priming Methodology (CPM) that proposes priming interventions throughout the Experiential Learning Theory (ELT) cycle. These intervention strategies focus on student preparation, motivation, reflection, and the context of the learning environment. Our research will focus on determining whether these priming interventions, intended to induce abundance thinking, improves academic performance. We demonstrate that these priming intervention strategies with demonstrated empirical effectiveness within non-technology environments can transfer to leading-edge digital environments like Virtual Reality (VR). Further, building on the CPM and using a related technology-based cognitive therapy technique called Virtual Reality Exposure Therapy (VRET) as a comparable model, we propose a specific VR implementation of the CPM called VR Experience Priming (VREP).

Four completed studies validate our hypotheses and key research questions: priming interventions performed within the context of our CPM and VREP theoretical model do improve academic performance and are transferable to VR to increase cognitive availability and academic performance in both preparatory and context priming conditions. Proving in our thesis for all priming conditions was beyond the scope of this research, but we plan to continue this research in 2022 and beyond.

Acknowledgements

The past 4 years have been an incredibly exciting and eventful life journey. When I embarked on this graduate research in the Fall of 2017, I was motivated to understand key student learning challenges, curious about how cognition was impacted by the subtle priming influences in our environments, and ultimately how to design technology solutions to address these challenges; to improve cognition and the overall learning experience for secondary, post-secondary, and adult learners. None of this would have been possible without the support of those around me.

There are so many amazing people in my life that inspired and guided me through this process. Dr. Ali Arya, my thesis supervisor and friend was the reason I embarked on this journey initially, and he has been the guiding force throughout. No one cares more about the student experience, and few can teach better. He also understood the potential for virtual reality technology to change the world. He jokingly refers to the term UniVRsity as part of his future vision. I know it will become real. Together we made something special. This research will open new technology possibilities to improve mental mindsets, empathy, and our capacity to play.

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1. Introduction

1.1.Background and Motivation

Recent statistics indicate that student anxiety has reached concerning levels in post-secondary institutions affecting students' mental health and academic performance. A 2018 survey by the American/National College Health Association observed that over 62% of students felt overwhelming anxiety within the past year (ACHA/NCHA II, 2018), a figure which was reported to worsen later, especially due to the COVID-19 pandemic (Grubic et al., 2020; Broglia et al., 2021).

The American Psychological Association (APA) describes anxiety as the feeling of worry, nervousness, or unease about something with an uncertain outcome, and while anxiety is most often perceived as a negative process, it derives from our primal need to prepare for and respond to potential dangers (Marks and Nesse, 1994). This response is a critical evolutionary process but does become a problem when it is not relevant, proportionate to the threat, or is sustained for a prolonged period (Kim and Kim, 2019; Sapolsky, 2003). Chronic anxiety is particularly concerning among students because of the negative impact on academic performance (Cassady and Johnson, 2002; Yang et al., 2018; Vitasari et al., 2010).

While the anxiety data is alarming, anxiety is not the only counterproductive thought process affecting student academic performance. Further research reveals that other emotional states (negative learning mindsets, cognitive biases, stereotype perceptions, and poverty) also affect student academic performance (Arya et al., 2019; Banakou et al., 2018; Chang et al., 2019). For example, a 2013 study demonstrated how seeding the idea of economic difficulty in certain participant groups (by exposing them to a fictional financial problem) had an immediate and profound negative impact on the cognitive performance of certain (poorer) participants (Mullainathan and Shafir, 2013). The researchers attributed this effect to the induction of *scarcity mindset*: a limiting perspective that appropriates cognitive capacity required for processes like learning to focus on critical needs or perceived insufficiencies. As an antidote to this mindset, they suggest practices to manage it and move towards *abundance mindset* thinking (Mullainathan and Shafir, 2014, Hope, 2022).

Further research into cognitive science, learning theories, and motivational mindsets substantiated the negative impact of counterproductive mental states (Ciani et al., 2010; Dweck, 2008; Mullainathan and Shafir, 2013) but similarly also offered possibilities and potential antidotes to scarcity thinking like the use of *priming* interventions to induce positive affect (Isen et al., 1987; Ashby and Isen, 1999), to change environments and imagery (Bhagwatwar et al., 2013; Burke et al., 2014), and to improve mental mindsets for learning

(Yeager et al., 2019; Paunesku et al., 2015; Dweck, 2008). *Priming* is generally defined as using a stimulus or action to affect the information processing availability for a (most often) subsequent idea or experience (Dennis et al., 2013; Janiszewski and Wyer, 2014). For example, calming music, games, repeated stimulus exposure, or motivational strategies have been shown to improve mindset and performance, as discussed in the literature review (next chapter).

Considering the similar negative impact of these dysfunctional thought processes (anxiety, biases, stereotype perceptions, and negative mindsets) on academic performance by diverting precious mental resources, we posit that these are really an aspect of a more general scarcity mindset. As such, to draw insights from a broader context, we view our research through the lens of this scarcity mindset to determine whether technology-based priming interventions could serve as an antidote to this self-limiting mindset; interventions that could prime the learner by inducing positive thoughts or abundance thinking in an immediate (real-time) manner and within the context of a learning experience. While various media types could be used for such technology-based interventions, we primarily focus on the use of Virtual Reality (VR) due to its engaging affordances (Shin, 2017; Steffen et al., 2019) and existing research suggesting its effect on reducing anxiety (Camara and Hicks, 2019), reducing stereotype threats which are known to adversely affect academic performance (Peck et al., 2020), and improving academic performance and student experiences (Liu et al., 2020; Yu et al., 2018).

1.2. Problem Statement

Our research is motivated by the problem of counterproductive thought processes that negatively impact learning. Through a scarcity lens, we see them as scarcity mindset and specifically address the problem of using technology, particularly VR, to offer priming interventions that ameliorate the negative impact of scarcity mindset on student academic performance. We believe technology can play a role in reducing scarcity thinking in favour of abundance thinking and improving overall academic performance. We focus primarily on university and college-level students and investigate the effectiveness of various VR-based priming interventions.

The scarcity literature provides numerous examples of cognitive capacity impairment (Vince, 1998; Ciani et al., 2010; Mullainathan and Shafir, 2013) and improvement (Isen et al., 1987; Bhagwatwar et al., 2013; Burke et al., 2014) using various forms of priming. While priming, as defined above, is generally a stimulus or action to affect the information processing availability for a subsequent idea or experience, we define priming more generally, in a learning context, to include any deliberate activity or stimuli that helps to improve the student's mindset.

Self-perception has been shown to be critical to cognition. Motivational mindsets like Growth Mindset (GM) research (Dweck, 2008) identify key learning attitudes (growth mindset) that should be fostered and encouraged with students. A fixed mindset, on the other hand, maintains the belief that intelligence is not malleable and cannot be developed beyond the initial genetic allocation. Once the limit is reached, there is no further possibility, and as such, the belief is one of scarcity. The growth mindset, on the other hand, assumes that intelligence is malleable, can be developed, and assumes sufficiency or abundance.

Behaviourism and conditioning theories provide key insights on positive affect inducement, repeated exposure techniques, and how to develop priming activities through associative learning and habituation (Wagner, 1977; Zajonc, 1968; Carl et al., 2019). These and others, such as experiential learning theory (ELT) (Kolb, 1984), provide insights into what methods of priming should be considered and when during the learning cycle.

On the other hand, emerging technologies like VR, Video Games (VG), Artificial Intelligence (AI), and biometrics offer unique affordances that can contribute to improving the learning experience. For example, casual video games (CVG) may allow students to escape into a state of flow as an alternative to anti-depressants (Fish et al., 2018; Csikszentmihalyi, 2000). VR technology can be valuable in therapeutic contexts like cognitive-based training therapy: Virtual Reality Exposure Therapy (VRET) (Carl et al., 2019). VR has also been shown to have the potential to improve learning outcomes by offering more creative environments (Bhagwatwar et al., 2013). The use of VR as a customizable computational technology offers the prospect of scalable priming interventions that can be personalized and delivered uniquely to each student and refined/improved using Artificial Intelligence (AI) and Machine Learning (ML).

While various priming techniques have been shown to improve mental mindsets and learning outcomes, there are many unknowns with regard to using a technology-based solution. Based on our literature review (Chapter 2), we found VR a potential basis for a solution to the scarcity mindset problem in learners. As such, our objectives are to investigate this potential and answer the following high-level questions:

- Can empirically demonstrated priming techniques transfer to a digital realm like VR?
- If transferable in general, what types of priming strategies and methods are most effective, and how and when should they be applied?
- What is the real value of VR immersion and presence in our proposed interventions?

There are many other questions to be considered but are beyond the scope of this research. For example, determining the longer-term effects of our proposed priming strategies may inform the frequency and mechanism of their use. Also, technology use can have its own negative mental effects that need to be properly investigated. Examples of other questions that we do not include in our research are: Who are the most sensitive or suitable to these priming effects, and are these techniques equally impactful to a general student population? What types of content are most sensitive and favourable to these priming applications, and what types of environment or avatar designs work best?

1.3. Research Approach

1.3.1 Proposed Priming Solution

Our proposed solution to the scarcity mindset in learners is two-fold: a theoretical framework followed by a technology implementation using VR. Theoretically, we build on the concepts of priming and various learning theories discussed in Chapter 2: Experiential Learning Theory (ELT), Situated Learning Theory (SLT), Growth Mindset (GM), and Self-Efficacy Theory (SET). We propose a general education priming model that we refer to as Cyclical Priming Methodology (CPM). This model uses two groups of priming strategies to transform scarcity mindsets into abundance thinking.

CPM starts with the more traditional priming that happens prior to a learning activity (Isen et al., 1987; Dennis et al., 2012). It then borrows the concept of timed iteration from the Experiential Learning Theory's learning cycle (a repeating series of cognitive and affective steps) and establishes priming interventions throughout the ELT learning cycle. For priming prior to the learning activity, we consider a variety of options but investigate two particular methods (games and meditation) based on their priming success in non-VR environments. We refer to this type of intervention as Preparatory Experience Priming (PEP). Learning from Situated Learning Theory and based on the importance of learning context and situation (Bhagwatwar et al., 2013; Brown et al., 1989; Lave and Wenger, 1991), we use context as the main priming intervention throughout the learning cycle, creating different settings and environments that can help with reducing the scarcity mindset. For our studies, we chose to investigate an animation studio and a lecture room with various artifacts as the context for an animation course as the example of educational activity. We refer to this type of intervention as Context Oriented Priming (COP).

Combining our technology insights, we present a specific virtual reality implementation of CPM called Virtual Reality Educational Priming (VREP). This extended theoretical framework provides the basis for a technology platform that we will use to create and test the effectiveness of VR-based priming interventions.

As a technology substrate, we have chosen VR, as it offers unique design and psychological affordances needed for our CPM solution, such as realistic simulation, interaction, presence, and immersion (Shin, 2017; Steffen et al., 2019; Slater, 2009). There is also empirical evidence suggesting improved academic performance through VR (Liu et al., 2020; Yu et al., 2018). VR provides the facility to design realistic, situational contexts: environments, artifacts, and avatars (Slater and Sanchez-Vives, 2016). The requirement to create custom environments to prime the learners would be very difficult, if not impossible, without the use of VR, or more generally Extended Reality (XR), a term that includes VR, Augmented Reality (AR), and Mixed Reality (MR). Currently, as a social and learning tool, myriad VR applications (e.g., Oculus Horizons, Workrooms, Campus-VR, and AltspaceVR) are already bringing together globally distributed groups and communities of interest for education and social purposes.

Finally, any technology solution must consider scalability. The choice of VR for implementing CPM is also based on the possibility of combining VR procedural and simulation capabilities with AI/ML to allow educators to create scalable, customizable experiences with priming interventions personalized to the specific learner. That said, scalability itself is beyond the scope of our research. Neither do we separate affective vs. cognitive priming.

1.3.2 Research Questions

As mentioned in Section 1.2, our objectives in this research are to investigate if priming interventions are transferable to the digital/VR domain and what specific priming strategies are more effective. Based on the proposed solution (VR-based priming interventions), we identified the following specific research questions:

RQ1: Do preparatory experience primes (PEP) intended to increase cognitive bandwidth and increase academic performance work, and are they effective in their VR implementation? While there are many possibilities to explore, we will focus on two key activities:

a) Can VR Gaming as a PEP increase cognitive bandwidth and academic performance?
b) Can VR Meditation as a PEP generate a calm mindset and increase cognitive bandwidth and academic performance?

RQ2: Extending our core premise into a specific VR learning context, how effective is context-oriented priming (COP) in custom VR environments to increase cognitive bandwidth and academic performance? We divide this into two more specific questions:

a) Can custom-designed situated learning environments and subject matter artifacts create an effect that increases cognitive bandwidth and academic performance? We compare two custom contexts with a neutral one.

b) Is there a performance difference between immersive VR (IVR) and non-immersive, desktop VR (DVR) context-oriented priming interventions?

These two sets of questions collectively answer the general question of the transferability of priming to VR environments. Each group then relates to a specific type of priming (preparatory and context), while the second group includes variation in the environment and also in immersion.

1.3.3 Research Phases

Our research started with an interdisciplinary and critical review of research targeted at reducing disruptive thought patterns like scarcity, anxiety, biases, stereotypes, and negative mindsets with the goal of improving academic performance for post-secondary students. We identified five key areas that directly related to the inciting material: Anxiety, Scarcity, Priming, Learning Theories, and Technology. This literature review provided our theoretical framework; it established scarcity as our key theoretical concept, priming and various learning theories as our guiding theories, and technologies such as VR and games as our potential solutions. Following the literature review and the conception of the CPM/VREP ideas, we defined our research questions and divided our research into two corresponding phases.

Phase one intended to answer the first research question; whether our priming methods work and are transferable to VR to reduce scarcity mindset and increase cognitive availability. In this phase, we focused on preparatory experience priming (PEP - prior to the learning experience) to determine the subsequent impact on the educational experience. This phase answered research questions 1a and 1b. Study 1a was a small pilot that aimed at verifying the initial idea of VR-based preparatory priming through games, answering research question 1a. Study 1b was more detailed and added meditation priming. Our phase one studies observed a significant effect in anxiety reduction (as a proxy for measuring scarcity mindset) and increased cognitive bandwidth for VR gaming, and while we did observe a reduction in anxiety for our meditation activities, we did not observe improved academic performance. Hence, we conclude that preparatory priming interventions are transferable to the digital realm but do depend on the specific priming method. VR gaming was more effective than meditation in our goal of increasing cognitive bandwidth and academic performance.

Phase two sought to extend our understanding of priming strategies to include context-oriented priming (COP) and to determine the relative performance within varying digital environments, specifically IVR (within a VR Head Mounted Device) and DVR (on a computer desktop). This phase answered research questions 2a and 2b. Study 2a compared three different contexts for an animation course in IVR (two prime conditions; a lecture theatre with animation artifacts and an animation studio) and (one no prime condition: a plain lecture theatre).

Study 2b used the more successful primed environment from study 2a (based on mean as a tiebreaker) and compared the IVR and DVR prime with the no prime environment scenarios. We also compared the identical prime and no prime environments within IVR and DVR environments to determine if there was any effect attributable to full immersion alone.

Based on these two research studies and their findings, we reflected on our theoretical model. We concluded our research by proposing an enhanced version of CPM that includes other priming methods in the learning cycle, particularly for motivation and reflection. We also reflected on expanding the COP methods to be more inclusive of avatar-related priming based on new research related to priming self-image (Banakou et al., 2020). A summary of our research is presented in Figure 1.

Thesis Study Summary								
Studies	Research Intent	Tests	Priming Method	Type of Study	Content	Target Users	Type of Study	Compensation
Phase 1 - Answering the main research question: Does priming work and is it transferrable to VR? Focus on PEP: RQ1a: For VR Gaming; RQ1b: For Meditation.								
Study 1a	Determine impact of VR Gaming experience (PEP) on anxiety reduction and cognitive availability.	Preliminary UCMRT and STAI	Preparatory Experience Priming (PEP)	Within Subjects VR Gaming Prime (PEP) vs No Prime to improve cognitive performance	Beat Sabre Game	Informal test - 10 Participants between 16 and 50.	Within Subjects	no compensation
Study 1b	Compare the impact of VR Gaming vs. Meditation on anxiety reduction and cognitive performance/	UCMRT, STAI, General UX	Preparatory Experiencing Prime (PEP)	Between Subjects VR Gaming and VR Meditation, Within Subjects VR Prime vs No Prime	Beat Sabre Game and Custom Designed VR Meditation App	56 Participants (44 students and 12 non-students)	2x2 Between Subjects and Within Subjects	$30 for 90 minutes
Study 1a: Research Paper: Assessing the Effectiveness of Virtual Reality Gaming to Increase Cognitive Bandwidth and academic performance. Published as short paper AIVR 2020.								
Study 1b: Research Paper: VR-based Student Priming to Reduce Anxiety and Increase Cognitive Bandwidth. Published as Conference paper to IEEE VR March 2021 (Honourable Mention)								
Phase 2 - Assessing the effects of Context Oriented Priming (COP) within Immersive and Non-Immersive VR Learning Environments. Focus on ELT/Situated Learning effects								
Study 2a	Determine the impact of context (COP) priming and situated learning within a Virtual Reality Classroom.	PANAS, STAI, Specific Course Content Test and UX Questions .	Context Oriented Priming	Between subjects VR Prime vs. No Prime Conditions	30 minute VR short courses - How to Make an Animated Movie. IVR	51 Students, 18 Years or older	1x3 Between Subjects	$20 for 60 minutes
Study 2b	Compare the Effectiveness of the optimal immersive priming methods within non-immersive VR environment	PANAS, STAI, Specific Course Content Test and UX Questions	Context Oriented Priming for IVR and DVR	Between subjects immersive vs. non-immersive VR, between subjects VR Prime vs. No Prime	30 minute VR short courses - How to Make an Animated Movie. IVR and DVR views	68 Students, 18 years or older	2x2 Between Subjects	$20 for 60 minutes
Research Reflection	Research Summary: Reflects on the latest literature and research results to improve theoretical model and provide design input to a best practices framework	N/A	N/A	N/A	Reflective Analysis of multidisciplinary research and study results included within the final thesis.	N/A	N/A	N/A
Study 2a: Research Paper: Assessing the Effectiveness of VR Context Priming. Paper presented as Poster Paper IEEEVR 2022, Full Paper submitted to IEEE ILRN in Feb 2022								
Study 2b: Research Paper: Compare the Effectiveness of VR Context Priming in IVR vs. DVR contexts. Full Paper submitted to IEEE ILRN in Feb 2022								
Reflective Research Report included with Chapter 6. Reflective analysis of research and potential improvements and upgrades to theoretical model.								
Proposed Future Research:To assess efficacy of other priming interventions like MOPs, REPs, and aggregate multipriming effect; to study long-term mindset effects on academic performance; to study priming sensitivity to varying academic subjects (e.g. Math, Science, Geography, History, Art, etc...); to study prime effectiveness and sensitivity based on personality types; to study contextual priming effects of avatar embodiment (self and others) towards prosocial behaviour								

Figure 1 Thesis Study Overview

1.4.Contributions

- **Overall Contribution** - Through this research, we propose a novel theoretical priming framework to be used within the educational process: specifically, within the experiential learning cycle. The intent of the proposed Cyclical Priming Methodology **(CPM)** is to transform scarcity thinking into abundance thinking in an immediate (real-time) manner to improve cognitive availability and academic performance. Further, we propose Virtual Reality Educational Priming **(VREP)**, a specific VR implementation of the CPM to exploit the powerful affordances of VR.

- **Phase 1 Contribution** – Using VREP, we demonstrated that the Preparatory Experience Priming (PEP) through meditation and games worked to reduce student anxiety and VREP gaming had the effect of increasing cognitive bandwidth and academic performance.

- **Phase 2 Contribution –** Using VREP, we demonstrated that Context-Oriented Priming (COP), through situated learning environments, worked to increase cognitive bandwidth and academic performance for both immersive and non-immersive VR environments.

- **Reflective Contributions –** Reflecting on our studies, we proposed extensions to CPM/VREP by introducing Reflective Experience Prime (REP) and Motivation-Oriented Prime (MOP).

Research Papers (all by Dan Hawes and Ali Arya):

- Preliminary assessment to determine whether the priming activities were promising. (IEEE AIVR Conference, December 2020)
- VR-based Student Priming to Reduce Anxiety and Increase Cognitive Bandwidth. (IEEE VR Conference, March 2021, Honourable Mention)
- VR-Based Context Priming to Increase Student Engagement and Academic performance. Short Paper, (IEEE VR Conference, 2022, Poster Session)
- VR-Based Context Priming to Increase Student Engagement and Academic performance. Full Paper (Conference paper – ILRN22 for May 2022)
- Comparing VR-Based Context Priming in Desktop VR to Immersive VR to Increase Academic Performance. (Conference paper – ILRN22 May 2022)
- Final paper to be submitting the Journal of Computers in Higher Education (May 2022).

1.5.Document Structure

The remainder of this thesis is organized as follows:

- Chapter 2 presents a multidisciplinary overview of learning mindsets, cognitive priming, and technology affordances to be considered in the design of technology solutions. The research includes a gap analysis and proposed research questions.
- Chapter 3 describes CPM and VREP for applying VR-based priming interventions that will inform our technology design and research studies.
- Chapter 4 describes the research approach taken in phase one to answer our key research questions and provides the details and results of studies 1a and 1b.
- Chapter 5 outlines the research in phase two and provides the study details and results of studies 2a and 2b.
- Chapter 6 provides post-study research reflections and an expanded theoretical priming framework.
- Chapter 7 concludes what we have accomplished, key findings and a summary of future work to complete.

2. Literature Review

For our research, we identified five key areas that directly related to the inciting material: Anxiety, Scarcity, Priming, Learning Theories, and Technology Solutions. Using the forward and backward snowballing method (Wohlin, 2014), we searched through the references to identify disciplines of relevance. With successful iterations, we honed our initial search down to 96 most critical papers. These publications were used to perform a critical review of the field, generate interdisciplinary insights, and identify research gaps. We followed the literature review with a theoretical development to propose our new model, followed by a series of user studies to evaluate and refine it. We continued to explore, and research based on new studies and insights based on our key areas of research throughout the process of this thesis. Since 2019, there have been many new research studies supporting and refining our previous research proposal (2020). As such, we included and updated this literature review throughout the process.

2.1. Anxiety and Biases

Anxiety can have an extremely negative impact on learning performance and general health (Beiter et al., 2015) (Russell and Topham, 2012). Cue Utilization Theory (Easterbrook, 1959) suggests a narrowing of focus that restricts our utilization of environmental cues, cues that may be very relevant to our learning situations. The weapon focus effect (Loftus et al., 1987) is perhaps the most extreme but best example of what stress and anxiety can do to performance. When viewing a situation where a gun is present (e.g., a holdup at a store), to deal with the immediate threat, a process of cognitive tunnelling is induced that excludes other relevant information in the environment. While this focus effect is critical to survival, in chronic conditions of anxiety, this narrowed focus becomes a barrier to learning. In situations of intense or prolonged anxiety, social judgment and cognitive performance suffer (Sapolsky, 2003). The human body reacts to stress by secreting neurotransmitters that elevate blood pressure, and while there may be short-term positive effects on performance, it is generally considered degenerative in the long run. Prolonged stress may result in a permanent hormonal loss in the hippocampus. If students are continually exposed to stressors, their cognitive functions may be impaired. (Kim and Kim, 2019; Dashir et al., 1993).

While the negative effects of chronic anxiety on cognitive performance are generally accepted, the research suggests that anxiety is not the only counterproductive thought process affecting student academic performance. Further research reveals that other emotional states (negative mindsets, biases, stereotype perceptions, and poverty) also affect student academic performance (Arya et al., 2019; Banakou et al., 2018; Chang et al., 2019), not just anxiety. For example, a 2013 study demonstrated how seeding the idea of economic scarcity with poorer participant groups, without their conscious awareness, had an immediate and profoundly negative impact on academic performance (Mullainathan and Shafir, 2013).

How we view the world is far more subjective than most people would like to believe. While we assume that we are in complete control of our decisions, there are many influences that shape our perceptions in ways that we are not aware of. Cognitive biases affect how we think, feel, and act. They are lenses through which we experience our world. Often evolutionary in nature, these biases may have helped us survive in the past but can make us vulnerable to external influences in our changing world (Marks and Nesse, 1994; Pitesa et al., 2018)). Fear/Negativity bias, for example, genetically wires us to focus disproportionately on worst-case scenarios that may keep us safe. Assuming a movement in the bush ahead is a lion rather than a wind disturbance may save our life, while the cost of assuming the worst-case scenario is generally negligible considering the potential risk (Ito et al., 1998; Soroka et al., 2018; Mathews and Macleod, 2002). Implicit bias, stereotypes, and prejudices pre-condition us to analyze, categorize, and favour the familiar. If an individual looked and acted like our tribal members, they were less likely to be a threat to our survival or that of the tribe (Greenwald and Krieger, 2006; Marks and Nesse, 1994). This genetic predisposition can be effective in some situations but can easily run amok as the context of modern life changes.

Attentional Bias refers to the concept of hyperattention to threatening material where we selectively attend to a stimulus in the environment while tending to overlook or ignore other relevant stimuli (MacLeod et al., 1986). If we are facing that lion, this hyper-focus could save our lives, but may be counterproductive otherwise. This human attentional bias was made famous by a 1999 study performed in a gymnasium where participants were simply asked to count the number of basketballs passed between players (Simons and Chabris, 1999). Dubbed “Gorillas in our Midst”, this study was a classic demonstration of inattentional blindness. During the basketball passing exercise, a person in a gorilla suit passed through the frame, with most participants failing to notice.

Chronic anxiety and these cognitive biases are symptomatic of scarcity thinking, a survival mindset that pre-conditions us to focus our mental and physical energies on meeting the most pressing needs at the expense of other important goals (Tomm and Zhao, 2016, Mullainathan and Shafir, 2013). This can make us more effective in provisioning for basic survival needs but may create barriers to learning and other non-scarce activities. The following scarcity research study illustrates the nature of such thinking.

2.2.Scarcity

In a classic scarcity study at a Suburban New Jersey shopping mall (Mullainathan and Shafir, 2013), participants across the socioeconomic spectrum were tested for the cognitive effects of various hypothetical scenarios. Based on the participant's median reported household income, study participants were placed into one of two categories: rich or poor. Both groups were presented with one question prior to commencing a test of fluid intelligence based on geometric shapes and pattern recognition, called the Raven's Progressive Matrices (RPM). Fluid intelligence refers to the ability to perceive abstract relationships and solve problems independent of previous learning. It is generally considered a less biased measure of cognitive capacity that eliminates cultural or previous learning influences.

The question: Imagine your car has some trouble, which requires a $300 service. Your auto insurance will cover half the cost. You need to decide whether to go ahead and get the car fixed or take a chance and hope that it lasts a while longer. How would you go about making such a decision? Financially, would it be easy or difficult for you to make? The second group, also categorized as rich or poor, was presented with the identical scenario with one exception. The financial consequences were an order of magnitude higher; $3000 for the cost of the service as opposed to $300. As with the first study group, they were then presented with a series of RPM problems.

The rich and poor groups performed comparably in the first ($300) scenario. However, in the second ($3000) scenario, where the financial consequence was far graver, the poor group performed 13 IQ points lower on the subsequent RPM problems. The researchers concluded that the poorer group had been primed into a scarcity mindset that diminished their cognitive capacity in the more dire scenario. What is interesting and concerning is that none of these scenarios presented to rich or poor groups were real; they were simply hypothetical questions yet had a profound negative effect on the poor participants, an effect of which all participants were not aware. This is not a conscious process but one that competes in a bottom-up manner with the top-down directions for attentional focus. The scarcity mindset, as evidenced in this study, exhibits the following critical behaviours (Mullainathan and Shafir, 2013):

- Disproportionate thinking that captures the mind and creates attentional biases related to these insufficiencies.
- Cognitive capacity (fluid intelligence) and executive control are reduced.
- Concurrent thought processes increase vulnerability to the bottom-up distractions and mind wandering related to resource scarcity.
- Crisis orientation as short-term tunnelling effects invokes further scarcity deficits.

These critical behaviours are similarly present within dysfunctional anxiety cycles (Dashir et al.; Humphreys & Revelle, 1984; Eysenck et al., 1992) and the biases discussed above. As such, we classify these dysfunctional thought patterns as symptomatic of a larger category called *Scarcity Mindset.* These biases and negative mindsets share a lens of self-perceived insufficiency or inability to address a need, whether real or imagined. The opposite of scarcity mindset is *Abundance Mindset*, a self-perceived feeling of sufficiency.

While the concepts of scarcity and abundance may resemble topics in less rigorous literature, they are well-recognized in scientific fields such as evolutionary psychology (Peschel, 2021), behavioural psychology (Mullainathan and Shafir, 2013; Bruijn and Antonides, 2021; Zhao and Tomm, 2018), and at the intersection of social and economic theory. Daoud has suggested the idea of Scarcity-Abundance-Sufficiency (SAS) as a more general concept that is intimately linked to famine, want, property, market, justice, action, and conflict (Daoud, 2011). As such, we felt that the concepts of *Scarcity* and *Abundance* best represented the unique characteristics of the counterproductive/productive mindsets that can afflict our thinking and impair the learning process.

To illustrate the commonality of these counterproductive/productive mindsets, Figure 2 demonstrates the scarcity and abundance parallels between various biases and mental states. Scarcity mindset causes disproportionate thinking about perceived risks drawing key resources from critical tasks to address perceived insufficiencies or threats. Abundance mindset, on the other, presents a positive narrative while the behaviour remains healthy and balanced between short-term and long-term needs (Mullainathan and Shafir, 2014). This is not to say that scarcity and abundance are diametrically negative and positive, respectively. Scarcity thinking is a critical evolutionary process that amplifies our thinking to meet critical needs of critical survival requirements (Maslow, 1958), affording a focused dividend that can meet critical short-term needs (Mullainathan and Shafir, 2013). Too much abundance, on the other hand, can diminish focus in favour of other areas of perceived scarcity.

In our learning context, we define scarcity thinking more narrowly as counterproductive learning mindsets that may be induced by chronic anxiety, cognitive biases, resource scarcity, or any other feeling of insufficiency that can reduce cognitive bandwidth and our learning capacity. We define abundance thinking as productive learning mindsets that may be already present or induced by external actions or influences. The process that we propose to transform scarcity learning mindsets to abundance learning mindsets is priming (an action or stimuli that affects cognitive or affective processes and subsequent behaviour), more fully explored in section 2.3.

Scarcity/Abundance Common Mindsets	Scarcity		Abundance		
Mindset/Focus	**Narrative**	**Behaviour/Effects**	**Narrative**	**Behaviour**	**Key References**
Economic Scarcity	My financial resources are insufficient to meet my needs	anxiety, attentional bias and disproportionate focus on financials, lack of focus, crisis orientation, reduced cognitive capacity and executive control	My financial resources are sufficient to meet my needs	healthy balanced focus on financial needs	Mullainathan and Shafir, 2014
Fear	I am at risk	anxiety, attentional bias and disproportionate focus on threat, crisis orientation, reduced cognitive capacity and executive control	I am not afraid	balanced approach to mitigating risk and reducing chronic fear	Loftus, Zhao, Mullainathan
Negativity Bias	This is a negative event	negativity lens on all events, seek problems, reduced cognitive capacity and executive control	This event is neither good nor bad	observation without bias	Ito et al., 1988
Attentional Bias	My focus is causal	disproportionate attention on what is focal, crisis orientation, reduced cognitive capacity and executive control	This event may or may not be causal	observation without bias and balanced focus on short and long term effects	Simons and Chabris
Stereotype Threat	I am part of a group that is inferior	I will perform as expected by the group stereotype	I am proud of who I am and not limited by stereotypes	performance will be at level of true capability	Chang et al., 2019; Spencer et al., 1999; Peck at al., 2020

Figure 2 Scarcity - Abundance Framework

Scarcity thinking induces impairment in commercial domains that can impact our ability to understand a critical concept leading to counterproductive behaviour. To illustrate this, in a study performed at the University of British Columbia called "Scarcity Captures Attention and Induces Neglect", the poor participants focused longer on the prices but missed important discount details that would have saved them money. While this narrowing attentional effect may have enabled some productive trade-off thinking, it was at the expense of relevant long-term information that would have saved them money (Zhao and Tomm, 2018).

Based on the scarcity/abundance research, finding ways of reducing scarcity thinking and inducing abundance thinking could be a critical strategy to address the negative consequences of scarcity mindset. Scarcity is an enigmatic concept where the very perception of scarcity or "perceived critical insufficiency" immediately appropriates scarce cognitive resources to address the need. (Mullainathan and Shafir, 2013). This self-propelling mindset can lead to increased and unnecessary demands on scarce resources.

Similar scarcity effects can also be drawn from Abraham Maslow's theory of human motivation (Maslow, 1958). While Maslow's research was initially conceived as a concurrent list of factors affecting human motivation and focus, subsequent visualizations have presented a simple way of characterizing the prioritization of needs in terms of a pyramid, as presented in Figure 3. It is important to note that based on the original theory, the pursuit of lower-level needs did not preclude the pursuit of higher-level goals. In many cases, these are concurrent processes where the pursuit of higher-level needs incorporates lower-level needs within, like how a Russian Matryoshka (nesting) doll incorporates dolls of smaller sizes within the larger model (Kaufman, 2020). For example, one might find it difficult to accomplish higher-level personal and professional goals without basic nutrition or a supportive working environment.

In Maslow's research, he refers to two types of needs; deficiency needs and growth needs. He argues that many people are focused on meeting their deficiency needs at the expense of the more important growth needs. (Maslow, 1958; Kaufman, 2020). If the perceived need to address deficiency needs is induced, as in the scarcity research (Mullainathan and Shafir, 2014), some of the cognitive capacity would be allocated to meeting these perceived needs deemed most critical. This would cause focus to be diverted to low-level needs like food, shelter, safety, social belonging, or any other perceived insufficiency, appropriating cognitive bandwidth and leaving less available to service higher-level psychological needs like personal development and learning.

As presented in the previous Scarcity/Abundance paradigm (Figure 3), Maslow's hierarchy also falls into the scarcity paradigm (Figure 4).

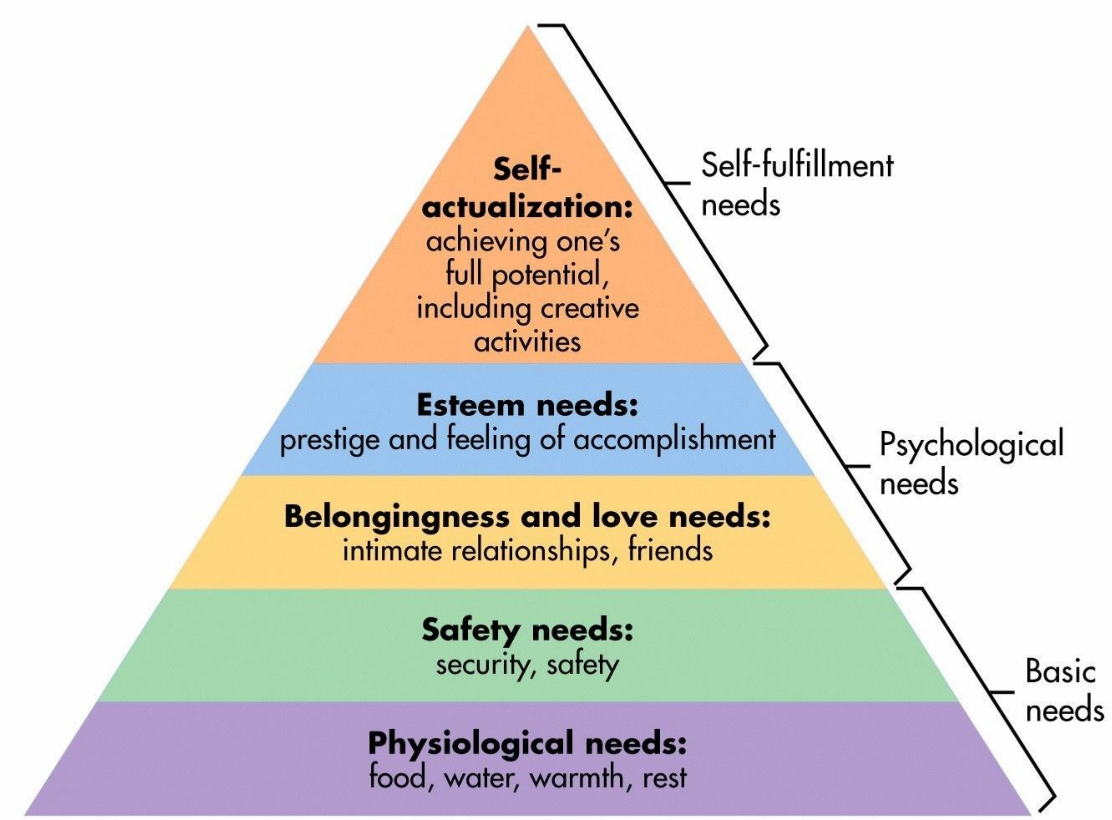


Figure 3 Maslow's Hierarchy of Needs

Scarcity/Abundance Common Mindsets	Scarcity		Abundance		
Mindset/Focus	Narrative	Behaviour/Effects	Narrative	Behaviour	Key References
Maslow level 1	I am hungry, thirsty, cold, tired	Anxiety, attentional bias and disproportionate focus on threat, crisis orientation, reduced cognitive capacity and executive control	I'm OK. I have enough to survive.	productive efforts to address long term survival requirements	Kaufman, 2020
Maslow level 2	I am not safe, secure	anxiety, Disproportionate focus on safety security needs	I am safe, secure	productive efforts to address long term safety and security requirements	Kaufman, 2020
Maslow level 3	I am not loved/connected, I have no friends	Social Anxiety, apathy, remain in isolation	I am loved, connected, I have friends	balanced efforts to address long term social requirements	Kaufman, 2020

Figure 4 Scarcity and Maslow

2.3.Priming

The aforementioned study (Mullainathan and Shafir, 2013) illustrated that the most subtle priming techniques could have profound effects on our mental mindsets and cognitive capabilities. Priming occurs because the prime stimulus or action makes the content and subsequent cognitive processes more accessible, potentially influencing all stages of information processing: attention, comprehension, memory retrieval, inference, and response generation (Forster and Liberman, 2007; Wyer, 2008). The priming stimulus can be subliminal: brief and not easily detectable to the individual who is exposed, or supraliminal: detectable by the individual. Daniel Kahneman, in his cognitive science research on system 1 (autonomic) and system 2 (conscious) thinking, describes priming as a process that affects our associative machine. Psychologists think of the associative machine as a vast network of memories in which each idea is linked to many others. Priming one idea or concept will activate many others, all happening concurrently and mostly at a subconscious level, like a ripple of waves on a pond, initiated by one idea that will activate through a small part of the vast network of associative memory (Kahneman, 2011).

A simple example used to illustrate the concept of priming involves simple word priming. Given the work fragment SO_P, you are more likely to complete the word as SOUP rather than SOAP if you have been recently exposed to the word EAT. The opposite would happen if you were most recently exposed to the word WASH. This is known as a priming effect. With the word EAT in your mind, myriad food-related concepts and words will be activated and made more readily available to your conscious mind. Priming is not restricted to just concepts or words. It can also affect physical behaviour, motivation, goal attainment, emotion, and mood. In Figure 5, Janiszewski and Wyer present a model of the content priming that demonstrates how different nodes are linked, in most cases, bi-directionally. This model presents four different types of content priming (Semantic, Goal, Affective and Behavioural). Semantic priming initiates an idea, whereas goal priming may stimulate a behaviour towards a specific goal. Affective priming is focused on emotion and will make these related states and feelings more accessible, which in turn, can prime related emotional concepts. Behavioural priming may prime actions like mimicry or physical responses to cognition or emotion (Janiszewski and Wyer, 2013).

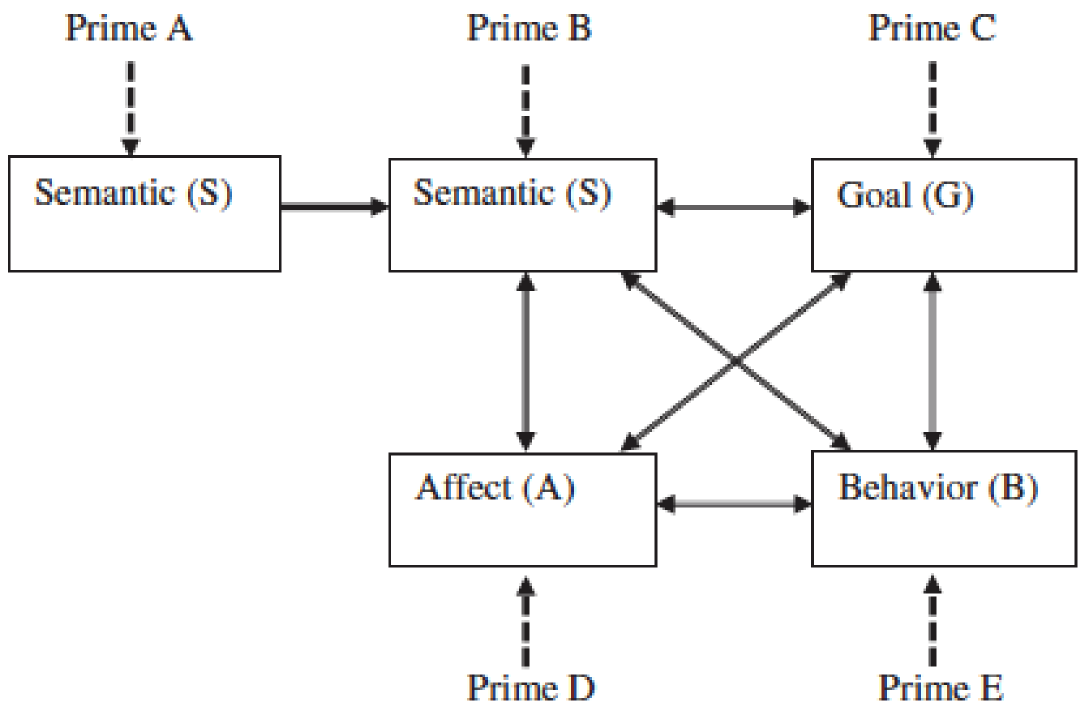


Figure 5 Associate Priming

In our educational context, we define priming more generally to include any intentional action or stimulus, either cognitive (relating to cognition) or affective (relating to emotion), that strives to improve the student-learning mindset. There are other salient features of cognitive priming that underlie the subtle and profound nature of these processes:

The ideomotor effect is an example of priming that initiates action from an idea. In a classic experiment by John Bargh and colleagues dubbed "The Florida Effect", one group of students was primed to create sentences with words related to the elderly. Words like Florida, balding, forgetful, gray or wrinkle were used to prime the concept of old age. The second part of the experiment involved walking to another room to complete a second task. The actual experiment was a deception. The intent of the study was to compare the time to walk to the second room to the groups not exposed or primed by the elderly concepts. As predicted, the elderly primed groups walked much slower, exhibiting a significant behavioural priming effect (Bargh et al., 1996). This change in behaviour, resulting from primed ideas, is an ideomotor effect.

The reciprocal nature of priming suggests that these ideomotor effects can go both ways. In a reverse study of the elderly cognitive priming concepts, a German researcher performed the opposite sequences of actions. Participants were asked to walk around the room at roughly one-third of their normal walking pace. As predicted, the concept of the elderly stereotypic words was more readily recognized in a subsequent task, indicating that stereotypes can be activated simply by stereotypic movements (Mussweiler, 2005). A similar reciprocal priming study compared the effect of various facial configurations on affective responses. The study determined that simulating a smile by placing a pencil sideways in the mouth made Far Side cartoons seem funnier. Conversely, facial configurations of a frown, achieved by placing a pencil in the mouth pointing outwards, reduced the affective response. In short, the cartoons were seen as funnier while in a smiling position (Strack and Stepper, 1988). This finding lends great credence to the concept that acting in a specific manner can invoke a corresponding emotion and to age-old wisdom that suggests we smile if we wish to be happy.

2.3.1. Supraliminal Priming

The supraliminal nature of priming suggests that the most effective priming is related to content that is activated above the conscious level (greater than 500 milliseconds) but below conscious awareness, not unlike the concept of "sleight of hand" used by magicians. A post questionnaire to the ideomotor aging study presented above asked students if they suspected that their test activities influenced their thoughts or actions in any way. Participants unanimously concluded that the study had no impact on their subsequent thoughts or actions, even though the slower walking results of the primed participants were significant (Bargh et al., 1996).

Why is this important? These subconscious priming processes can be so subtle that they threaten our self-image as conscious and autonomous agents and authors of our own actions (Kahneman, 2011). The corollary to this insight; these processes can also be powerful tools to effect positive changes in very subtle, unobtrusive ways. To gain further insight into priming effects, we reviewed other methods used to induce varying mental states and perceived capabilities. A 2010 study highlights the potential of using the most subtle priming techniques for both positive and negative effects. The study, "A versus F: The effects of implicit letter priming on cognitive performance", primed participants in a supraliminal manner to determine the effect on academic performance (Ciani and Sheldon, 2010). The manipulation came in the form of a Test Bank ID code, in which participants were prompted to view and write on each page of their test. The ID code started with either A or F. Participants were randomly assigned to either A or F groups. The research findings confirmed that students were vulnerable to evaluative letters presented before a task confirming that subconscious processes are affected by subconscious priming. Those students primed with the letter A saw an improved academic performance, and those primed with the letter F saw an impaired performance.

2.3.2. Music Priming

In Robert Cialdini's recent book, "Pre-suasion" (Cialdini, 2016), he presents a compelling case for the priming effects of music in a retail environment. A 1997 study (North et al., 1997) tested in-store music effects of specific musical pieces related to countries of origin and purchases of wine. To test this, four different types of French and German wine were displayed equally prominently in a supermarket drink area over a two-week period, changing location occasionally but maintaining equal positioning. The wines were similar in price and degree of dryness. Over the two-week period, French accordion and German Bierkeller music played intermittently. Interestingly, when French music played, 76.9% of the bottles of wine sold in the area were French wine. When German music played, 73.3% of the bottles of wine sold in the area were of German origin. When respondents were asked whether they thought the music influenced their choice of wine, most felt that there was little or no effect. This study supports the subtle yet powerful effect of supraliminal (conscious but not aware) priming.

2.3.3. The Power of Nature Priming

Daily nature walks have also been shown to prime happiness and positive affect (Capaldi et al., 2014). In fact, the power of simple natural views was illustrated in a 1984 study based on recovery records from a suburban Pennsylvania hospital (1972, 1981). In this study, patients with a view of a hospital window of outside natural environments saw considerably faster rates of recovery than those with no window view (Ulrich, 1984).

Nature exposure has been shown to improve physical and psychological well-being, but its impact on social behaviour has also become increasingly important, particularly within collaborative, team-oriented learning environments. In a 2016 study, participants were tested on their social behaviour prior to entering a large urban park compared to participants in the after condition. To test the nature impact, researchers purposely, though meant to appear accidental, dropped a glove from their tote bag as participants were either entering or leaving the park. The "helping rate" for those leaving the park was far greater than for those who were entering the park, suggesting a positive prosocial effect created by this nature exposure. Most recently, University of Waterloo researcher Colin Ellard suggests that new methods of measuring affective, cognitive, and physiological states in VR are consistent with the real-world effects and our affinity with vitality at every level (Ellard, 2020). Ellard suggests that these effects can be experienced in exposures as brief as 50 milliseconds. This concurs with the work of Daniel Kahneman, "Thinking Fast and Slow" (2011), and Adam Alter's treatise on both the profound psychological effects discussed in *Drunk Tank Pink* (Alter, 2014) and the effects on nature to reset our minds and bodies (Alter, 2013).

2.3.4. Priming Positive Affect

Conscious supraliminal activities that improve mood or mental states demonstrate a positive impact on information organization and creativity. In a 1987 study (Isen et al., 1987), positive affect (elevated mood) was induced in study participants by viewing a few minutes of a comedy film or by receiving a small bag of candy. Another group received neutral stimuli, while two more groups engaged in physical exercise meant to represent affective arousal. In performing two tasks that required creative ingenuity, the positive-affect groups, primed with candy or funny movies, saw improved performance, while the control groups and exercise groups saw no performance increase. There is also evidence of the longer-term effects of frequent positive affect. In a 2005 UCR study, "The Benefits of Frequent Positive Affect: Does Happiness Lead to Success?", the researchers demonstrated that happiness is associated with and precedes successful outcomes and may have a causal relationship with many of the desirable characteristics related to success (Lyubomirsky et al., 2005). Another insightful study that used rituals to affect positive self-perception also demonstrates the impact of priming affect. This 2016 study by Alice Brooks and colleagues demonstrated that executing rituals prior to critical experiences can be used to decrease anxiety while increasing perceived self-control and overall performance (Brooks et al., 2016).

2.3.5. The Power of Repeated Exposure

Psychologist Robert Zajonc created several studies that demonstrated that mere repeated exposure to a word, concept, or image will enhance positive affect related to the initial stimuli and will even extend to similar or related concepts. He argues that this is a feature of most living organisms whose survival prospects are better served by avoiding novel stimuli (Zajonc, 1968; Monahan et al., 2000). As such, this evolutionary trait may create implicit biases that predispose us to stereotypical thinking that might be perceived as racist, xenophobic, and averse to that which is not familiar (Zajonc et al., 2001).

This is also how norms are created. Consistent, repeated exposure to ideas or information induces cognitive ease, regardless of the moral value or veracity of the information. Eventually, the process will condition us to familiarity and enhanced positive affect related to these concepts. Celebrity culture is similarly based on this concept, as McMaster University's Larry Jacoby and colleagues illustrated in his paper, "Becoming Famous Overnight" (Jacoby et al., 1989), with long-term priming effects of name exposure. This human predilection for familiarity enables positive feelings for those concepts most exposed over other alternatives (Zajonc et al., 2001). This repetitive media exposure to people, places and things similarly creates cognitive ease, good feelings, and norms that are based on idealized worldviews. These embedded worldviews most often profile the most fortunate: the wealthy, beautiful, provocative, and successful.

2.3.6 Priming Self-Perception

Changing the context of people or environments can also have a significant effect on reducing anxiety and improving cognitive performance. The Proteus Effect posits that as we change our digital self-representations, these self-perceptions can change our behaviour (Yee and Bailenson, 2007). In a 2018 study (Banakou et al., 2018) of participants embodied in a VR character, researchers demonstrated that virtually "Being Einstein" allowed participants to perform better on cognitive tasks compared to the control normal body group. Both Einstein and control group results were compared with prior cognitive abilities. This research confirms earlier non-VR priming studies from the 1990s. Supported by multiple stereotype studies performed by Bargh, Chen, and Burrows (Bargh et al., 1996) and a further study at the University of Nijmegan (Dijksterhuis and Van Knippenberg, 1998), it is generally concluded that priming a stereotype or trait leads to overt behavioural changes.

2.3.7 Debiasing and Stereotype Threats

Similar research in the area suggests a potential impact of the embodiment of different skinned participants. A 2013 study (Peck et al., 2013) tested participants in an Implicit Association Test (IAT) three days prior to and after the embodiment process. The study demonstrated a reduction in implicit racial bias, particularly for dark-skinned embodied conditions. This offers promise for bridging inter-racial barriers but could also provide a cognitive lift to those vulnerable to stereotype threats. Stereotype threat is a psychological state where apprehension about a negative stereotype may disrupt or diminish cognitive and academic performance within that group.

A 1995 study (Steele and Aronson, 1995) showed that African American minority groups were vulnerable to negative stereotypes related to scholastic ability, and the mere salience of the stereotype could impair performance. Similarly, a 1998 study on the effects of stereotype threat on women's math performance suggested that stereotype threat may underlie gender differences in advanced math performance (Spencer et al., 1999). Further research also suggests that, by priming positive stereotypes or eliminating the saliency of potentially negative stereotype cues, threats could be reduced, and cognitive performance improved (Rudman et al., 2001; Blair, 2002; Sassenberg and Moskowitz, 2005). VR solutions that allow us to design and control environmental variables may help mitigate these stereotype threats but also offer further positive priming effects.

Priming activities can also have a positive impact on our inherent negativity bias (Ito et al., 1998). A 2014 study focused on cognitive priming and the positive interpretation of daily events, demonstrated the potential to prime abundance thinking by creating positive visual imagery in advance of daily activities. A within-subjects experiment of 214 college students practiced a goal-oriented mental imagery technique and/or to-do list techniques on alternate days. On mental imagery days, students were far more likely to report a sense of accomplishment, ease, coping, and positive affect compared with to-do list days. While the to-do list management techniques were still valuable, it is reasonable to hypothesize that performing the more salient positive visualization effects concurrently would likely result in further improvements (Burke et al., 2014).

2.3.8. Priming and Scarcity

We believe the priming examples discussed above clearly demonstrate the profound effect of the most subtle priming techniques to change feelings, motivations, and self-perceptions and to activate scarcity or abundance mindsets (Mullainathan and Shafir, 2013; Bargh, 2017, Kahneman, 2011).

2.4.Learning Theories and Mindsets

Educational theorists have long considered the interaction of emotional and cognitive factors in learning. Bloom's taxonomy (Bloom et al., 1956 and 1964) is one of the earliest efforts to show that learning is not a purely cognitive task; but includes affective and psychomotor elements. Later, Social and Emotional Learning (SEL) researchers and practitioners developed frameworks for promoting mental health in learners as a part of the learning process (Payton et al., 2000; Conley, 2015). As discussed earlier, we are not differentiating between cognitive and affective priming methods specifically in our review, but rather on our more general priming concept: any action or stimulus intended to improve the student learning mindset. The three principal learning methodologies: Behaviourism, Cognitivism, and Constructivism, all have relevance in various educational contexts today (Ertmer, Newby 1993). We view experiential learning and situated learning as derivatives of constructivism but review them separately.

2.4.1. Behaviourism

Behaviourism learning evolved from the work of early thinkers like Ivan Pavlov and B.F. Skinner, both of whom introduced the concepts of classical and operant conditioning (Skinner 1971; Graham, 1982). Classical conditioning is a type of learning that is based on involuntary stimuli (e.g., scent, sound), whereas operant conditioning focuses on voluntary stimuli and learning because of choice and subsequent reward or punishment. A child choosing to place their hand on a stove is a form of operant conditioning where the child (the operant) chooses a behaviour voluntarily and feels the consequence of that action. The wonderful smell of fresh bread in the air causing a person to crave that bread and/or salivate is an example of classical conditioning, a behaviour induced or influenced by an involuntary external stimulus.

Operant conditioning is used in the therapeutic process of behavioural re-conditioning intended to control thoughts, feelings, and actions, known as cognitive-based therapy (CBT). CBT uses a non-associative learning method called habituation that uses repetitive exposures to reduce stimuli salience. (Thompson, 2009, Wagner, 1979). These techniques aim to diminish fears and phobias in patients. Alternatively, sensitization techniques can be used to heighten sensitivity to stimuli that may predict high-risk scenarios (Thompson, 2009, Wagner, 1979).

Behaviourists offer great insights into aspects of priming that affect our cognitive processes. Classical conditioning theory is the basis for antecedent learning strategies where stimuli are primed or put in place prior to the learning experience to change behaviour. Antecedent strategies may include changing pre-learning or preparatory activities, rituals, or changing the environmental context of the learning environment (lighting, music, seating arrangements, décor) or any potential environmental stimuli that may affect the learner. While initially applied to deal with problem behaviours like autism spectrum disorders (ASD) (Conroy et al., 2005), these antecedent intervention strategies are now targeted more widely and used as a tool for improving academic performance (Kruger et al., 2016; Gyllen et al., 2021).

2.4.2. Cognitivism and Constructivism

Cognitivism is more concerned with the process of learning rather than behaviour. Cognitive Psychology suggests that learning is more than a change in behaviour but is instead mediated by thinking that results in a change in understanding. The learner acquires knowledge and internal mental structures. Learners take on information, store it, and relate it to other ideas, information, and worldviews to be retrieved later when needed. The mental structures or models help make sense of the external world (Johnson-Laird, 2004). Fergus Craik succinctly describes the process and evolutionary value of cognitivism.

"If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and the future, and in every way to react in a much fuller, safer, and more competent manner to the emergencies which face it." (Craik, 1943, Ch. 5, p. 61)

Constructivism extends the previous theories by proposing a more subjective model of learning. With behavioural and cognitive theories, the world is real and external to the learner, whereas constructivism is a function of how the individual creates meaning from his or her own experiences (Ertmer and Newby, 2013). Piaget, a pioneering thinker in cognitivism and constructivism, suggested that learners construct understanding (Piaget, 1966). They do not simply mirror and reflect what they hear or what they read but instead look for meaning, regularity, and order in the events of the world, even in the absence of full or complete information (Bodner, 1986).

Lev Vigotsky, a social constructivist, introduced the social dimension. He proposed that learning is a socially mediated activity with emphasis on the teacher as an expert or scaffolder. He originated the concept of sociocultural learning, describing learning as a social process and the origination of human intelligence in society and culture. He suggests that learning occurs on two levels, first socially and then integrated into the individual's mental structure (Vigotsky, 1978). Furthering Vigotsky's approach, Social Learning Theory posits that we learn socially by observing others (Bandura and Walters, 1977).

2.4.3. Experiential Learning Theory (ELT)

Due to the nature of how priming is woven into our life experiences, of particular interest for our research was the Experiential Learning Theory (ELT). Kolb's Learning cycle is based on a very logical concept: Learning begins with having a concrete experience, followed by a reflection of that experience, then the conceptualization of abstract concepts that incorporates the new insights from the experience with existing conceptual models, and finally, active experimentation of the lessons learned. The cycle continues to repeat as the learner's conceptual worldview is continually refined. See Figure 6.

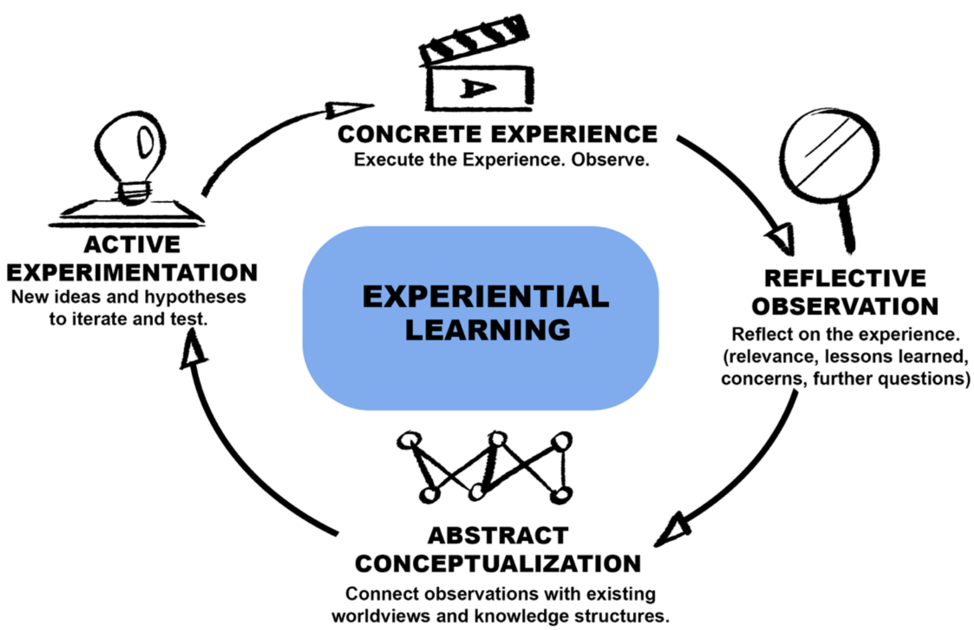


Figure 6 Experiential Learning Theory Cycle

Experiential learning theory provides a more holistic model of experiential learning (Kolb 1984). The theory presupposes the following:

- Learning is best achieved as a process: a continuing reconstruction of experience.
- All learning is relearning.
- Learning requires the resolution of conflicts between different views.
- Learning is a holistic process of adaptation to the world.
- Learning results from synergetic transactions between learners and the environment.
- Learning is the process of creating knowledge.

It should be noted that while the learning experience, conceptualization of abstract concepts and experimentation are all critical components of learning, perhaps the most critical element in the experiential model is the concept of reflection, often dismissed in favour of the need for action or doing. In a study called, *Learning by Thinking; How Reflection Aids Performance*, DiStefano and his colleagues demonstrated this in a dual-process theory model of learning by doing vs. learning by doing plus reflection. While the subjects appeared to be doing less, they were achieving more and dramatically outperformed the control group, shedding further light on the power of reflection as a learning mechanism (DiStefano et al., 2016).

An early forerunner in the field of experiential learning was Edgar Dale. Dale's Cone of Learning metaphor intended to convey that knowledge retention depends on multiple modalities, with some modes of learning having a more progressive impact than others, as represented by the widening base (Dale, 1946). Building on Dale's original model, a revised model is presented in Figure 7 (Bruner, 1966; Dale, 1969). The specific percentages have never been validated, but the metaphor remains a valid representation of the value of these modalities in the ELT process (Dwyer, 1978; Bruner, 196**6**).

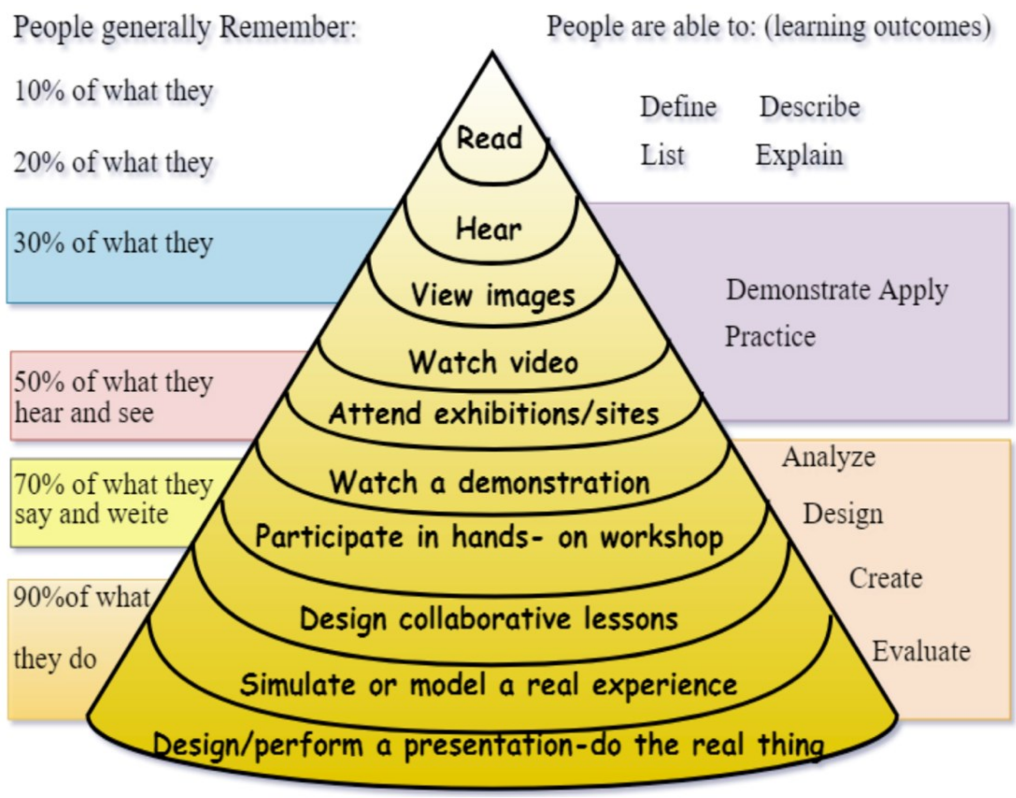


Figure 7 The Cone of Learning

2.4.4. Situated Learning Theory (SLT)

Building on the experiential framework, SLT advocates for learning within a community of practice and within a specific situation (Brown et al., 1989; Lave and Wenger, 1991). Within a situated environment, learners can see, hear, do, and feel the experience resulting in higher retention, as suggested in the Dale's cone of experience in Figure 7. The critical challenge of experiential and situated learning is attaining the proper context and frequency of access to relevant workplace experiences. These situated experiences can be scarce in many communities of practice and require considerable training resources enabling the student***s*** the opportunity to try, fail, and gain feedback from experts. Cooperative college and university placement programs like the University of Waterloo in Ontario, Canada, are so committed to this model of learning that most programs seek to combine experiential/situated experiences with academic courses on a 50/50 basis after the first year, extending the actual length of most degree programs (uwaterloo.ca, 2022). Sadly, since the onset of COVID-19, the availability of situated placement opportunities has diminished, and students have struggled to gain social context and work-based relationships.

Based on SLT requirements, technology solutions that improve access and frequency to relevant situated environments and social contexts could induce confidence through better understanding, increase motivation to try something new and ultimately improve academic performance. For example, placing a student within an animation studio could alleviate emotional concerns like anxiety or low self-confidence with proper context and amplify the understanding of an animation-related idea or concept. Further, given this improved understanding, the student may increase their willingness to participate in the creative process.

Stephen Krashen's Affective Filter (AFH) hypothesis with second language learning (SLA) advocates for creating learning experiences that reduce affective filters that inhibit learning. Key filters of AFH were anxiety, motivation, and self-confidence. Reducing anxiety while increasing motivation and self-confidence has proven very effective in second language learning acquisition (SLA). (Krashen, 1983). SLA is not that different from situated learning in that major progress occurs once embedded in the cultural environment. Hence, like SLA, creating SLT experiences may offer a fertile substrate where priming interventions to reduce these affective filters could improve academic performance.

2.4.5. Learning Mindsets

Learning mindsets can have a considerable effect on academic performance. Growth Mindset (GM) research suggests that if children believed that their intelligence and academic success were malleable, organic, and in the process of growing (growth mindset), they progressed and achieved greater success than those students who believed that their intelligence was "predetermined" (fixed mindset), and they were not in control of those variables (Dweck, 2008). Growth mindset is characteristic of abundance thinking, whereas fixed mindsets are clearly a form of scarcity thinking. Dweck has furthered this research to indicate that disciplines like math, long considered the domain of the few, can be mastered simply by employing a growth mindset (Dweck, 2010). While growth mindsets are indicative of perceived control over academic achievement leading to more persistence and a willingness to embrace challenges, self-efficacy can be considered a related theory. Self-Efficacy Theory (SET) was defined by Albert Bandura as the belief in one's ability to succeed at a particular task or challenge (Bandura, 1977). With SET, the willingness to embark on more significant challenges is indicative of a confidence level in one's ability to cope with the strain, incumbrances, and potential failure of the given challenge. Like growth mindset, high self-efficacy represents abundance thinking, whereas low self-efficacy is indicative of a scarcity mindset.

2.4.6. Summary of Learning Theories and Mindsets

We know that scarcity thinking can have a disruptive influence on the learning cycles, and while we know that improved emotional states can have a positive impact on performance, there is little evidence of proven solutions that improve learning mindsets in post-secondary institutions (Paunesku et al., 2015). Learning models like ELT, SLT, and mindset theories like GM and SET show great promise by identifying critical thought paradigms that affect learning mindsets and engagement. The embedded perception that resources are finite and outside of one's control can cause apathy, fear of failure, and fear of negative evaluation. By priming the awareness that intelligence levels and academic success are not predetermined and are within the control of the student, an attitude of abundance can be promoted, leading to an eventual growth mindset (Dweck, 2008). Similarly, priming self-efficacy can improve willingness to take risks and improve academic performance (Bandura and Schunk, 1981; Dweck, 2008). Antecedent interventions that affect environmental stimuli (lighting, décor, environments, artifacts) may also become viable preparatory and motivational strategies if augmented with technology that affords student customization, personalization, and situated learning simulations. (Kruger et al., 2016).

2.5. Technology Solutions

In a recent post-secondary study from Kent State, technology and social media consumption were positively correlated to anxiety and negatively correlated to GPA performance (Lepp et al., 2013). While there is evidence to suggest that technology usage may be a contributing factor to anxiety, negative mindsets, and reduced academic performance, the corollary may also be true; that technology solutions can offer mitigating effects to student mindset challenges and performance. In our technology research, we identify four key technologies that have demonstrated the potential for improving student learning mindsets. VR, Video Games, and Artificial Intelligence solutions are already showing great promise and proving valuable in myriad application domains (Slater and Sanchez-vives, 2016; Fish et al., 2018), while biometrics are also beginning to be deployed personally and increasingly in therapeutic contexts (Sano and Picard, 2013).

2.5.1. Virtual Reality

Virtual Reality (VR) is considered a subset of a more general concept, Extended Reality (XR), a term that includes VR, Augmented Reality (AR), and Mixed Reality (MR). VR is defined as images and sounds created by a computer that seem almost real to the user that can affect them by using sensors (Oxford Dictionary, 2019). Central to the concept of VR is the quantifiable concept of immersion and the more subjective idea of "presence" or the feeling of "being there" (Slater, 2009). Based on these immersive possibilities and the ability to create a sense of presence, VR is an ideal environment to create scenarios that evoke different forms of conscious and unconscious awareness. Within a restricted domain, VR can provide a blank canvas to allow us to create and control an environment and diminish distractions from other real-world influences (Slater and Sanchez-Vives, 2016).

As a technology substrate, VR offers unique design and psychological affordances needed for realistic simulations, interactions, presence, and immersion (Shin, 2017; Steffen et al., 2019; Slater, 2009). VR provides the facility to design realistic, situational contexts: environments, artifacts, and avatars (Slater and Sanchez-Vives, 2016). The need to create custom physical environments to prime the learners would be very difficult and costly, if not impossible, without the use of VR. One realistic, high-quality VR learning environment could easily be created for less than $100,000 USD and accessible on the Internet from almost anywhere in the world. The real-world creation would cost millions of dollars per installation and would only be accessible in one geographic location.

With VR, designers can create learning spaces that are more conducive to specific learning objectives while "designing out" potential anxiety-inducing barriers. In a 2013 study, 3D Virtual Environments (3DVE) were used to test the effects of supraliminal priming on creativity (Bhagwatwar et al., 2013). The results showed that when teams created ideas in the primed 3DVE environments, they created more ideas, and the ideas were of higher quality than in the neutral, non-primed environments.

Ellard (2020) also suggests that the groundswell of interest in incorporating multi-sensory research for the interior and urban landscape design is driven, in part, by emerging technologies such as immersive VR, that allow us to create convincing simulations of built or natural settings, approaches that would have been previously impossible. While this research does not test specific cognitive performance effects as in Mullainathan/Shafir scarcity research (Mullainathan and Shafir, 2013), it does suggest that the positive psychological effects are transferrable between virtual and real-world environments and could be a powerful design tool for both real and immersive domains. Proving a desired emotional response in VR could save many iterations of real-world space designs and ensure efficacy prior to breaking ground. The same data could also inform the design of more elaborate immersive spaces.

There is also growing evidence to suggest that VR may offer perceptual advantages that could not be acquired in the real world. As discussed in section 2.3.6 (priming self-perception), participants embodied in an iconic VR (Albert Einstein) performed better on cognitive tasks compared to the control normal-body group, suggesting that the design of avatars in the environment also presents opportunities to elicit positive psychological effects that improve cognition (Banakou et al., 2018). A 2021 study comparing wayfinding behaviour and spatial knowledge acquisition in VR compared to real-world environments found that while wayfinding results were comparable, spatial knowledge was processed differently between real and immersive mediums. While visual information was more efficiently processed in the real world, searching for visual information was more effective within immersive environments (Weihua et al., 2021).

An interesting 2019 study from Tokai University in Japan tested game scores within a VR-based archery game following a 10-minute meditation using the *Muse* meditation headset (choosemuse.com). While there was no direct linkage to cognition, they observed improved game scores for all categories (Beginners + 275%, Intermediate, +107%, Experts +17). The game did, however, test hand-eye coordination and reaction times. Furthermore, after completing these activities, all participants reported feeling recharged to continue their daily activities (Asati and Miyachi, 2019).

Most research suggests that mindfulness does offer position psychological value, even with shorter sessions (Goleman and Davidson, 2017, Asati and Miyachi, 2019), but derives more benefits with prolonged practice. (Mrazek et al., 2014) In fact, there is evidence that meditators derive sustained neuropsychological effects such as improved theta band activity in the right hippocampus, an area associated with memory processes (Lardone et al., 2018). However, there does not appear to be empirical research linking improved cognition over just one session, suggesting that sustained practice is required to improve cognition. A recent study of brief mindfulness meditation techniques for one session of 25 minutes (Guided Mediation, SHAM Meditation (no guidance)) observed positive effects on mood and heightened mindfulness but failed to observe any effect on attention and working memory, suggesting little or no effect on cognition (Johnson et al., 2013).

VR is also proving valuable in many other cognitive domains. There is growing empirical evidence suggesting that Virtual Reality Exposure Therapy (VRET) is becoming a viable, mainstream treatment alternative for phobias and various anxiety-related disorders. Efficacy rates for VRET are comparable to other forms of in vivo (real-world exposure) Cognitive Based Therapy (CBT) (Carl et al., 2019). CBT is a structured, goal-oriented form of psychotherapy that helps people learn how their thoughts, attitudes, and beliefs relate to the emotional and behavioural reactions that cause them difficulty. While CBT uses in vivo exposure techniques to diminish fears or negative thought patterns, VRET offers the possibility of creating an environment to face those fears that might otherwise be too costly or inaccessible.

One VRET study followed the use of automated psychological coaching therapy using immersive VR for the treatment of fear of heights. The VRET solution showed considerable improvement over the control group, an improvement that was sustained in subsequent follow-ups (Freeman et al., 2018). With regular CBT, exposing a patient with fears such as heights or insects to tall buildings, flying, or even spiders, can be costly and/or unsafe. With a VRET process, as presented in Figure 8, the patient iteratively faces increasing levels of exposure until the fear is extinct.

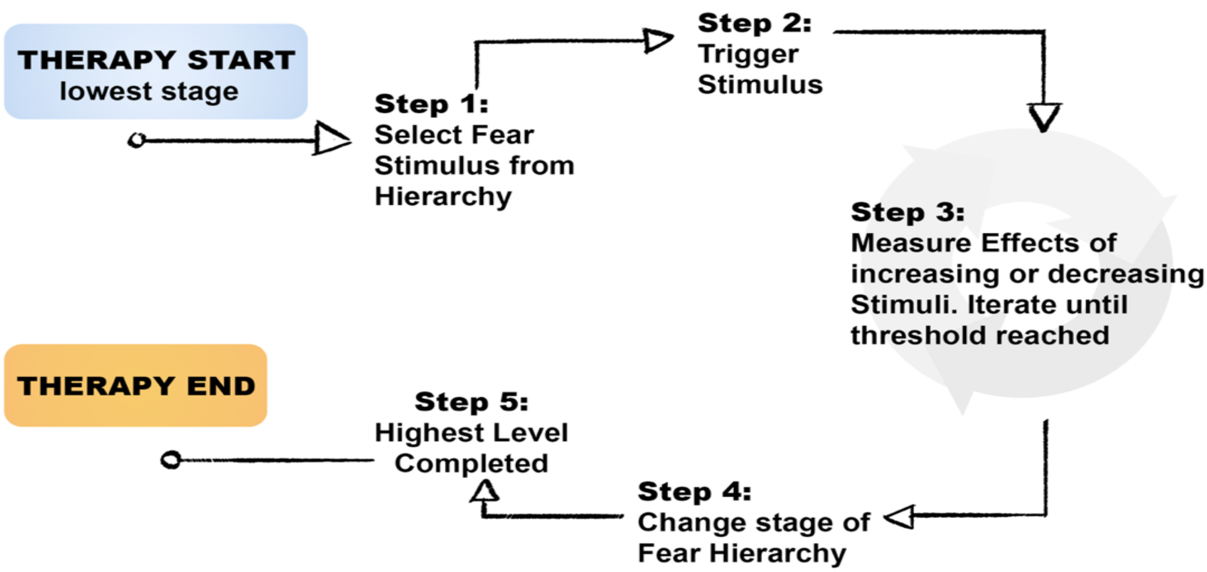


Figure 8 VRET Fear Extinction Cycle

There are also attentional affordances available in VR environments that can offer therapeutic and pain reduction benefits (Malloy and Milling, 2010). A 2000 study on the use of VR as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures, researchers demonstrated that when burn victims were immersed in a distracting VR environment, they reported 35-50% reductions in the pain incurred during the wound care process. (Hoffman et al., 2000). The researchers theorized that with less attention available to the real-world pain due to the attention required for the VR distraction, there was a direct reduction in perceived pain.

Beyond priming affordances of custom and personalized VR environments (Shin, 2017; McGowin et al., 2021), characters and avatars offer further advantages. Avatar embodiment techniques that offer participants the opportunity to inhabit custom personas of other races or cultures show great promise in reducing stereotypes, low self-perception, and negative academic performance associated with stereotype threats (Peck et al., 2013). Further, existing research indicates VR effects on reducing anxiety (Camara and Hicks, 2019), and improving academic performance and student experiences (Liu et al., 2020; Yu et al., 2018).

Any technology solution must be scalable, customizable, and facilitate personalization. The choice of VR offers the potential to combine VR procedural and simulation capabilities with AI/ML to allow educators to create customizable experiences with priming interventions personalized to the specific learner.

To that end, VR may also be used as a tool for creating custom learning environments and personalized antecedent conditions, allowing autism spectrum disorder (ASD) students to experience customized environments with varying conditions while being in the same learning space with the general student population (Kruger et al., 2016). This capability could afford special needs teachers the tools to mitigate the emotional challenges of their students and improve academic performance, but could be more generally applied (Conroy et al., 2005). For example, with the agency to control light, sound, visual perspective, personal embodiment, and other environmental variables, these antecedent personalization capabilities could be applied as cognitive elixirs to the general student population for emotion regulation and improved academic performance.

2.5.2. Computer Games

In popular culture, we associate games with being fun and escapist, which can seemingly diminish the potential positive impact of this technology. Today's games, particularly serious games, are far more complex and may contain positive pedagogies at various levels of play. (Gamage and Ennis, 2018). Immersive worlds and simulation logic can allow educators to provide more realistic simulations that represent the learning context that they are attempting to convey. Games can be complex learning environments with the potential to mediate emotion and various cognitive processes.

A 2006 research paper (Buckley, Anderson 2006) focusing on non-violent video games argues that video games are used in simulations in almost every facet of business or education and are utilized as teaching tools in simulations ranging from elementary schools to military bases. Even corporations like *McDonald's* use video games in the employee training process, while medical establishments like the *Mayo Clinic* use video games to train residents.

According to Self Determination Theory (SDT) (Ryan et al., 2006), games lead to motivation for three reasons: competence, autonomy, and relatedness, all of which are primarily intrinsic motivators that can positively affect learning (Gee, 2003; Johnson, 2005). Furthermore, VR games have been shown to induce the sense of overall presence through the feeling of being within the virtual world (physical presence), by experiencing emotions as deeply as in the real-world (emotional presence), and by feeling a part of the narrative (narrative presence) (Lombard and Ditton, 2000).

The SDT pyramid is presented in Figure 9.

Figure 9 The Self Determination Theory (SDT) Pyramid

Behaviourist theories focus on extrinsic motivators and would be relevant to games that focus on scoring, measuring, and providing intermittent rewards that may be useful in the process of inducing positive affect. Game researcher Nick Yee's reference to popular role-playing games like "Everquest" as "Skinner boxes" (nickyee.com, Yee, 2001) is a recognition of the connection and relationship to "Skinner boxes", reward and punishment testing environments for lab rats, used in the study of operant conditioning. (Skinner, 1971).

Nick Yee also sheds a slightly varied insight into an empirical model of player motivation in online games that is inclusive of both intrinsic and extrinsic motivators (Yee, 2007). He categorized ten motivation subcomponents that fell under one of three categories: Social, Achievement, and Immersion. His findings are presented in Figure 10. While both the Yee and the Ryan/Deci models provide different lenses, they do present a consistent theme. Some of the achievement motivators (e.g., Game Mechanics) would relate to competence, the social motivators to relatedness, and the immersive motivators to autonomy.

Achievement	Social	Immersion
Advancement Progress, Power, Accumulation, Status	**Socializing** Casual Chat, Helping Others, Making Friends	**Discovery** Exploration, Lore, Finding Hidden Things
Mechanics Numbers, Optimization, Templating, Analysis	**Relationship** Personal, Self-Disclosure, Find and Give Support	**Role-Playing** Story Line, Character History, Roles, Fantasy
Competition Challenging Others, Provocation, Domination	**Teamwork** Collaboration, Groups, Group Achievements	**Customization** Appearances, Accessories, Style, Color Schemes
		Escapism Relax, Escape from RL, Avoid RL Problems

Figure 10 Gaming Motivations (Yee, 2007)

Beyond being motivational tools of engagement, games can have a direct impact on participants' mental states and performance. In a 2012 study, "Sparking Creativity: Improving Electronic Brainstorming with Individual Cognitive Priming", researchers demonstrated that supraliminal priming, a process where users are aware of the priming but not of the intent, did result in more creativity (Dennis et al., 2012). Members of brainstorming teams exposed to priming in web-based computer games generated significantly more ideas and of better quality than the neutral primed control group.

Games have been demonstrated to have therapeutic effects that can aid in reducing dependence on Selective Serotonin Reuptake Inhibitors (SSRI) anti-depressants. One of the most compelling examples of this was demonstrated in a 2018 study called Zombie's verses Anxiety: An Augmentation Study of Prescribed Video Game Play Compared to Medication in Reducing Anxiety Symptoms (Fish et al., 2018). In comparing two groups suffering from symptoms of anxiety, one group was prescribed one medication, plus casual video game (CVG) play, four times per week for 30-45 minutes for one month. The control group was prescribed a traditional two-medication regimen for controlling symptoms of S-Anxiety and T-Anxiety. (State and Trait Anxiety). Trait anxiety generally describes a personality characteristic rather than an ephemeral state of anxiety. State anxiety is anxiety related to an anticipated threat or fear. Results demonstrated that the CVG/one medication combination under a prescribed condition significantly reduced S-Anxiety symptoms and moderately reduced T-Anxiety, compared to the medication-only control scenario.

The study applied flow as a theoretical framework, and participants claimed to have achieved flow immediately after 30 minutes of gameplay, which occurs only in the absence of anxiety (Csikszentmihalyi, 1997). Csikszentmihalyi's flow theory, referenced in the study, is illustrated in Figure 11. These findings are significant and suggest that gaming interventions may offer non-invasive and cost-effective companions or alternatives to medications.

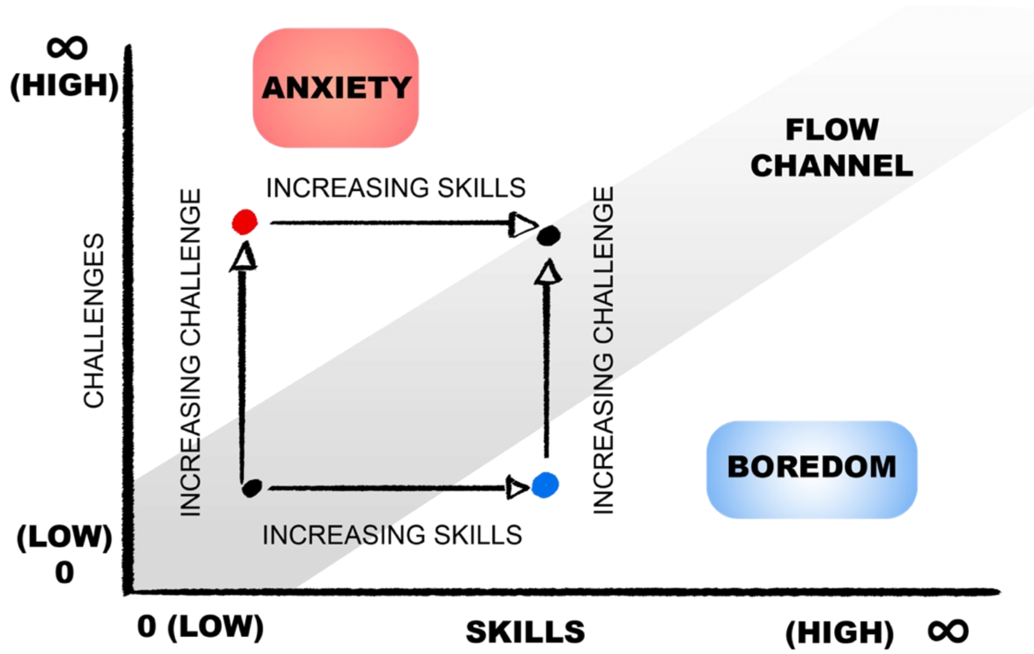


Figure 11 Finding Flow (Csikszentmihalyi, 1997)

Gaming solutions have also been shown to improve working memory and, consequently, cognitive capacity. The results from this 2017 study revealed that the extent of daily gaming activity was related to the enhancement and speed of the most demanding level of working memory task (Moisala et al., 2017). A further study on the effect of anxiety levels on learning performance found that digital game-based learning was beneficial to high anxiety learners while there was a negligible effect for learners with low anxiety (Yang et al., 2018). Finally, video games do provide a substrate for supraliminal priming effects, as they are activities of which we are conscious (exposure greater than 500 milliseconds) yet unaware of their effects. This is amplified if an elevated suspension of disbelief or heightened sense of presence is achieved (physical, emotional, narrative) (Lombard et al., 2000; Ryan et al., 2006).

2.5.3. Artificial Intelligence (AI)

AI-based Intelligent Virtual Agents (IVA) and other forms of social and learning avatars show great promise within the learning environment and will become powerful personal educational resources as they become more intelligent and more affect-aware (Shvo et al., 2019). The VRET fear of heights study referenced above clearly demonstrated that the animated avatar virtual coach yielded better results than the other chosen methods of treatment by the control group (Freeman et al., 2018). Considering the expense of qualified psychotherapists, the availability of a VR fear training solution using a virtual coach offers the prospect of higher accessibility and affordability to the public.

Similarly, a 2018 review of social robots for education showed that they could be effectively used in educational settings to increase cognitive and affective outcomes. Much of the positive learning effect was attributed to their physical presence (Belpaeme et al., 2018). Interestingly, some of the challenges of physical robots alluded to in the study could be avoided by simply using animated AI characters in VR. Nonetheless, as researchers continue to hone the interplay between personality, motivation, emotion, and mood, IVAs will become far more engaging and useful in learning environments (Shvo et al., 2019). Further to this, as AI personal agents like Siri, Alexa, or Google become mainstream tools for myriad information processing and personal management tasks, it would seem logical that various emotion management modules, as in the virtual coach above, would become applications built on these AI platforms much as various personal management tools are made available as smartphone apps today.

Combining AI with VR offers unique possibilities. While affective learning was once hailed as the panacea of human development and has been slow to realize these expectations (Picard et al., 2004), current VR implementations with high-fidelity immersive virtual spaces and customizable computational platforms are nearing ubiquity and offer the prospect of scalable priming interventions aimed at emotion regulation and academic optimization that can be personalized uniquely to each student and refined using AI and ML algorithms for cognitive optimization (Picard, 2000).

2.5.4. Biometrics, Wearables, and Smartphone Apps

There is growing evidence that personal technologies can help manage emotional states and prime learner engagement. In a 2018 study called "There's an app for that: The impact of reminder apps on students' learning and anxiety", a homework suite planner app facilitated student organization and time management leading to more completed assignments, lower anxiety, and greater overall learning satisfaction (Simmons et al., 2018).

Biometrics combined with machine learning algorithms are becoming valuable tools for data acquisition and analysis, providing high degrees of personalization and situational customization. In a 2015 study (Sano and Picard, 2013), researchers analyzed 30 days of data collected from wearable sensors and surveys to predict mood, happy or sad, from daily behaviours and previous sleep history. Neutral interactions and total academic hours were shown as differentiators between happy and sad groups, while the machine learning analysis resulted in a 70-82% prediction accuracy when using one to five nights of previous sleep analysis. These results were clearly not accurate enough to suggest the use of this technology in behavioural prompting. Still, the acquisition of this data could provide a valuable input stream for improved analysis and understanding of a students' individual propensities and vulnerabilities. Smartwatches and other biometric wearable devices (e.g., Fitbit, Apple Watch) already provide real-time feedback on ECG, heart rate, and, in some cases, blood pressure allowing the user to monitor data and set alerts and notifications as desired. These tools and the availability of personal health data can be used to improve personal health awareness and anxiety management.

One of the more interesting apps was a cognitive priming app that is used to achieve cognitive bias mediation for attentional biases for negative or anxiety-ridden people. Stressed out individuals, by their very mental state, will notice negative cues, faces, and events far more frequently than positive. With attentional bias, what is focal is causal, and for that reason, a negative state of mind will notice more negative imagery. A literature review in 2018 (Zhang et al., 2018) reviewed several commercial apps focused on cognitive bias modification, concluding that there has been very little validated scientific study regarding these applications, but there appears to be some promising content. One such app mentioned combatting negativity bias was SPOT Smile.

The SPOT Smile app (apkpure.com), available as an APK (Android Package Kit) or standard android file type, does one simple thing. It presents several screens, nine squares at a time. On each screen, the users are asked to pick out the smiling face. As in most games, speed and accuracy are rewarded, but the real intent of the game is to prime the individual into a positive affective state by finding the smiles. This attempt at cognitive bias modification is the type of simple daily game that could offer a positive lens for those so challenged. More academic study and validation are required in this area, but the general trend and thinking are promising.

Finally, anxiety management drugs and related consumables are big businesses, and although there is proven value in these techniques, they fall outside of the scope of this paper. It is important to note, however, that quite often, a combination of technology and medical solution can provide effective means of reducing the pharmaceutical portion to lower levels, reducing side effects, and achieving the anxiety management objective (Fish et al., 2018).

2.5.5. Technology Affordances

Each of these platforms offers unique affordances that can be useful educational tools to be deployed alongside priming initiatives. Games can capture attention and engagement in custom worlds that induce flow and reduce anxiety. VR offers powerful attentional control mechanisms by affording new custom worlds where distractions can be minimized, and specific priming nuances can be built into the design of these virtual worlds. Antecedent intervention strategies could benefit from the custom design capabilities of these environments, avatars, and special effects. In doing so, participants may experience various learning challenges as iterative scenarios in realistic environments in a manner that is more situationally relevant and personal. Data acquired through biometric sampling can be mined with machine learning algorithms to provide actionable insights that are delivered through AI guidance. For example, AI can be used as a tool to increase awareness of students' emotional states. This awareness may help facilitate interventions or dynamic customization of environmental factors like lighting to reduce anxiety.

In summary, VR, Gaming, AI, and Biometrics are technologies that have all shown promise in addressing the challenges of scarcity mindset management and academic performance improvement. While these technology solutions work independently, it is most logical to assume that the aggregate effect of these technologies could create a much greater impact. The combination of VR as a customizable computational technology using biometrics to track key physiological responses offers the prospect of scalable priming interventions that can be personalized and delivered uniquely to each student, and refined/improved using AI and ML. A high-level summary of technology affordances relevant to priming is presented in Figure 12.

Unique Affordances to Facilitate Cognitive Priming	Technology Solutions				
Affordances/Unique Capabilities	VR (MR)	AR	AI/Machine Learning	Biometrics	Games
Attentional Control	filters out external world and other distracting elements and facilitates intentional attentional control. Real time Heads up Displays (HUD)	fails to filter out external influences and fully direct attention	procedural ability to invoke actions and interventions based on changing situational variables	Data monitoring and notifications provide information for real-time interventions	Attention capturing, engaging with possibilities of achieving flow state
Environmental Design & Control (Customization and Cues)	Customizable with ability to induce positive affect, creativity, calm, etc ...	augmentation with lower customizability of real world environments.	real-time data sampling and learning enhances customization process and cue elicitations	Real-time data monitoring can provide valuable information to enable AI/ML dynamic contexts.	Gaming environments can be designed for intention using supraliminal priming to effect specific goals.
External Avatar Design & Control	Ability to create anti stereotype representation and specific desired representations	enables authentic character interaction within real world context	real-time data analysis can facilitate dynamic designs and changing contexts.	Real-time data monitoring can provide valuable information to enable AI/ML dynamic contexts.	Custom or dynamic avatars can facilitate powerful priming effects and behavioural changes
Avatar Embodiment (Proteus Effect)	Customizability enables more emmersive role playing with greater feelings and empathy	Limited	real-time data analysis can facilitate dynamic designs and changing contexts.	Real-time data monitoring can provide valuable information to enable AI/ML dynamic contexts.	Custom or dynamic avatars can facilitate powerful priming effects and behavioural changes
Experiential Simulation & Learning (e.g VRET)	Customizable, procedural and repeatable to enable iteration and more effective experiential learning	enables enhancement and augmentation of real world contexts. Fewer iterative possibilities with less control	real-time data analysis can provide relevant feedback and actionable insights to improve subsequent iterations	Real-time data monitoring can provide valuable information to enable AI/ML dynamic contexts.	Games can be designed as experiential simulations enabling high engagement and enhanced learning
Presence (Authenticity) - Suspend Disbelief	As more immersive qualitative experiences improve so also does perceived authenticity and suspension of disbelief	Limited	Use of IVAs can be used to augment authenticity, engagement and feeling of presence.	Limited	Combined custom environments with high engagement result in authentic feelsing of presence
Private or Scalable Social Platforms	Enables privacy of personal experiences with IVAs or within human social group	Enables privacy of personal experiences with less capable social platform	IVAs and customizable NPCs can enhance private experiences.	Limited	Private or Scalable platforms enable custom experiences as required
Points Rating based on 1 point per square (Green - 1, Gold = .5, Red = 0)	7/7	2/7	6/7	5/7	7/7

Figure 12 Technology Affordances

2.6.Insights and Findings

We have posited that anxiety, cognitive biases, and negative mindsets are an aspect/symptom of scarcity thinking, a thought process that appropriates cognitive bandwidth and diverts focus to the perceived insufficiency at the expense of more relevant processes like learning, causing a negative impact on academic performance. A summary of the most critical learning, priming, and technology insights, followed by a proposed aggregate insight that brings the research insights together.

2.6.1. Summary of Learning Theory and Mindset Insights

Learning is best achieved as a process: a continuing reconstruction of experience (Kolb, 1984) and the ELT cycle offers a fertile substrate where priming interventions to reduce affective filters (Krashen, 1983) could improve academic performance. The ELT process can provide timed trigger points where various priming interventions may be activated (Kolb, 1984). Such guided priming can lead to increased motivation, better situational context, and ultimately better learning outcomes. Situated Learning Theory (SLT) (Lave and Wenger, 1991) recognizes the value of social and contextual experiences within a community of practice. Based on SLT, technology solutions like VR that improve situational contexts should induce confidence through better understanding and increase motivation to engage in more challenging activities with better understanding resulting in improved academic performance.

Inducing positive affect can result in better information organization, improved creativity, and better academic performance (Ashby and Isen, 1999; Isen et al., 1987). Recent research into learning mindsets suggests that priming motivation and self-confidence can increase performance through improved GM (Dweck 2008). Albert Bandura's SET similarly draws causal connections between self-efficacy and academic performance, suggesting that finding methods to prime self-efficacy would have lasting academic effects (Bandura and Schunk, 1981; Bandura, 1993). While mindset interventions have been proven to work, scalability remains an issue/limitation (Paunesku et al., 2015).

2.6.2. Summary of Key Priming Insights

Priming causes exposure and availability of new ideas into the associative network of memories. Optimal priming effects manifest through the experiences, environments, and people in a supraliminal manner, with influence that can affect behaviour, cognition, motivation, and evaluation (Bargh et al., 1996). These priming effects can be profound, changing our cognitive capacity and executive function (Mullainathan and Shafir, 2013). Priming virtual environments have been shown to increase creativity and performance. (Bhagwatwar, 2013, Dennis et al., 2012). Repeated exposure to a stimulus without negative consequences will induce cognitive ease, familiarity, liking, and positive affect, which has been shown to increase creativity and academic performance (Zajonc, 1968).

2.6.3. Summary of Key Technology Insights

VR presence capabilities continue to improve and blur the line between real and imagined realities. Increasingly, immersion technology improvements create powerful experiences that are realistic, believable scenarios that can suspend disbelief and provide a powerful priming substrate for these experiences. Studies have shown that priming through creative environments can increase creativity (Pena et al., 2013; Pena et al., 2009). Avatar designs and avatar embodiment techniques can also be useful tools to mitigate racial stereotypes and biases, providing a cognitive lift for those vulnerable to stereotype threats. (Chang et al., 2019). We also learned that CVGs can potentially prime positive affect, flow experiences, and provide a healthy alternative to medication (Fish et al., 2018; Csikszentmihalyi, 2000). Gaming solutions have been shown to increase working memory, which increases cognitive availability and performance. The combination of VR as a customizable computational technology using biometrics to track key physiological responses offers the prospect of scalable priming interventions that can be personalized and delivered uniquely to each student, and refined/improved using AI and ML.

2.6.4. Interdisciplinary Insights and Research Gaps

Research tells us that to address the problem of student academic performance, we must focus our efforts on eliminating scarcity thinking (which includes anxiety) in favour of more positive abundance thinking to improve mental states and learning mindsets. Deploying supraliminal priming methods is clearly the solution. Behavioural psychologists like Bargh, Zajonc, Isen, and Ashby have shed insights on a powerful tool with the capacity to affect cognitive capacity and executive control (Bargh, 1996, Mullainathan and Shafir, 2013). The research also suggests that there are many other ways of reducing scarcity with priming methods. These include inducing positive affect, mental mindset conditioning (meditation), custom environment design, attentional control strategies, motivational messaging, and many others. The most proven and validated research studies appeared to be related to priming positive affect (Isen et al., 1987; Ashby and Isen, 1999), mental mindset conditioning (Mrazek et al., 2014; Hafenbrack et al., 2013; Goleman and Davidson, 2017) and improving environmental context (Bhagwatwar, 2013; Pena and Blackburn, 2013; Yu et al., 2018).

Another aspect of the process of applying priming tools is the timing, and the ELT process offers timed trigger points where priming interventions may be activated (Kolb, 1984). Inducing positive affect or conditioning the mind for an educational event would best occur just before the concrete learning, like a preparatory experience prior to the learning event. But ELT cycle emphasizes the importance of ongoing “priming” in various forms. While motivation and reflection can be important aspects of this ongoing process, SLT suggests that the learning context is also of significant importance.

VR offers specific affordances (realism, immersion, presence, and interactivity), in addition to general programmability, customization, and scalability of digital technology, that suggest it may be particularly useful to implement the above priming methods. VR can also be combined with other technologies such as games and AI to potentially provide more effective priming. We aim to investigate how these leading priming methods related to positive affect, mental mindset conditioning, and environment context can transfer to digital domains, especially VR. While studies in the physical world have clearly shown that priming can have a positive effect on improving mindsets, cognition, and academic performance, there is little evidence of the transferability of these effects to the digital realm, particularly VR. Some general questions to be answered include the followings:

- Can priming techniques transfer to a digital realm like VR?
- If transferable in general, what types of priming strategies and methods are most effective, and how and when should they be applied?
- What is the real value of VR immersion and presence in our proposed interventions?

3. Theoretical Framework

To answer our research questions, we opted to break up the challenge into a two-phased approach. We then followed with a reflective approach to expand our theoretical model. Phase one focused on the basic idea of priming positive mental mindsets to reduce scarcity thinking and its implementation using VR, while phase two sought to extend our understanding of priming strategies by testing context but also considering the effect of the digital environment (particularly immersion).

3.1. Phase One

Phase one research activities intended to validate the core premise that our priming strategies are transferable and "do work" within the digital realm to reduce scarcity thinking (anxiety inclusive) and increase cognitive availability measurable by academic performance improvements. We focused on preparatory priming interventions as they are a very common type of priming (Dennis et al., 2012, Gyllen et al., 2021), and we expected them to have more noticeable effects. Based on our literature review (Chapter 2) and the main goal of preparing learners prior to the learning activity, we proposed to study two methods that have been generally successful in non-digital formats: positive affect priming through playing games (Brom et al, 2016), and mental relaxation through meditation (Mrazek et al., 2014).

Games have been shown to increase positive affect and creativity (Denis et al., 2012; Brom et al., 2016), motivation (Ryan et al., 2006), feeling of flow (Fish et al., 2018), increase working memory (Moisala et al., 2017), and improve academic performance (Yang et al., 2018). Meditation has also been proposed as a means of calming the user and preparing for other activities (Mrazek et al., 2014; Roquet and Sas, 2018; Goleman and Davidson., 2017; Huberty et al., 2019). It has also been argued that meditation may have limited effects on academic improvements (Conley, 2015), while other studies observed the positive academic effects attributable to meditation (Mrazek et al., 2014). Hence, we thought it would be helpful to investigate its effectiveness in the VR format.

In phase 1, the Studies 1a and 1b were a pilot and a larger scale investigation into the effect of preparatory priming trying to answer our first research question:

RQ1: Do preparatory experience primes intended to increase cognitive bandwidth and increase academic performance transfer to VR? While there are many possibilities to explore, we will focus on two key activities.

a. Using VR Gaming as a preparatory prime to increase cognitive bandwidth and academic performance.
b. Using VR Meditation as a preparatory prime to generate a calm mindset to increase cognitive bandwidth and academic performance.

3.2. Phase Two

Phase two seeks to extend our understanding of priming strategies by testing context but also to consider the effect of the digital environment (particularly immersion). We start with investigating context-oriented priming. The reason for this choice is two-fold:

- We find the context (environment) particularly suitable for VR implementation and investigation as we can use the virtual environment to simulate various situated learning contexts (Slater and Sanchez-Vives, 2016; Slater, 2009)
- While we expect other priming methods related to priming longer-term positive mindsets or studying the impact of reflection to require more complicated investigations and longer time periods to assess. As such, we find their proper evaluation beyond the scope of this proposal. But we found it helpful to consider other methods for future deployment.

Both studies in Phase 2 use a common learning activity (a short animation course) followed by a series of content and UX questions. Participants view these courses within varying situated contexts in both immersive and non-immersive environments. With these tests, we answer our remaining research questions:

RQ2: Extending our core premise into a specific VR learning context, how effective is context-oriented priming in custom VR environments to increase cognitive bandwidth and academic performance.

a) Using custom-designed situated learning environments and subject matter artifacts to create an effect that increases cognitive bandwidth and academic performance.
b) Which digital environments are most effective toward achieving our desired goals? Specifically, is there a performance difference between immersive and non-immersive VR environments?

The Approach: The literature review insights offered guidance as the basis of our strategy when designing a VR solution to address scarcity mindset. These guidelines include:

- Focus priming interventions on activities that induce positive affect, generate calm or improve learning mindsets (Isen et al., 1987; Mrazek et al., 2014; Dweck, 2008)
- Exploit the capabilities of VR to create and simulate customized situated learning scenarios and experiences that would otherwise not be viable. (Bhagwatwar, 2013)

- Deploy priming methods in a supraliminal manner to be most effective by minimizing conscious awareness and maintaining presence (Bargh, 2017; Slater, 2009).
- Provision for repetitive exposure techniques to create ease with unfamiliar concepts and facilitate the iterative requirements of the ELT cycle (Kolb, 1984; Zajonc, 1968).

3.3. The Priming Process

To address scarcity thinking in an educational environment, a proactive strategy was required to challenge the thoughts that preceded or occurred within the context of that experience. As such, our first step was to propose a priming model that used what was learned about priming effects, a process to systematically induce thoughts and create cognitions that affect emotions, mental mindsets, and ultimate learning outcomes. Presented in Figure 13 is an example of an educational priming process.

Based on our research on priming and cognition, we knew that the most subtle action or idea could induce a wave of cognitions and associated thoughts (Bargh, 2017; Kahneman, 2011). Those thoughts (positive or negative), in turn, create similar emotions that trigger a mindset (scarcity or abundance) that will affect subsequent learning, behaviour, and academic performance (Mullainathan and Shafir, 2014; Dozois et al., 2006). Neutral primes would likely induce neutral or non-negative emotions in line with Robert Zajonc's theory of mere exposure (Zajonc, 1968) and ultimately induce a positive mindset effect results due to repetitive exposure and increased familiarity. That said, we chose to focus on studying the priming effects within one experience, as a longitudinal study on the effects of repetition was beyond the scope of this research. Acknowledging that priming is a subtle, ephemeral process, further study to determine the longer-term accumulative or degenerative effects would be a valuable contribution to the research. Based on the work of Robert Zajonc (19670), we hypothesize that longer-term priming effects would be cumulative and positive, but further research is necessary in this area.

The priming process presented in Figure 13 refers to positive thoughts and emotions but may not be reflected in the conscious feeling of the individual. In fact, as we have seen in the North study (North et al., 1997), for example, participants were unaware of the effect of the priming. Similarly, being within a realistic situated learning environment may not necessarily elevate emotional state but may still achieve desired priming effect. It is also important to note that there are many methods of eliciting positive mental mindsets or emotions. While the generation of positive affect has been shown to improve creativity and overall performance (Isen et al., 1987) and meditation has been shown to calm the mind and improve long-term focus (Mrazek et al., 2014), there are many other methods that could be used. Other possible examples are presented in Appendix K.

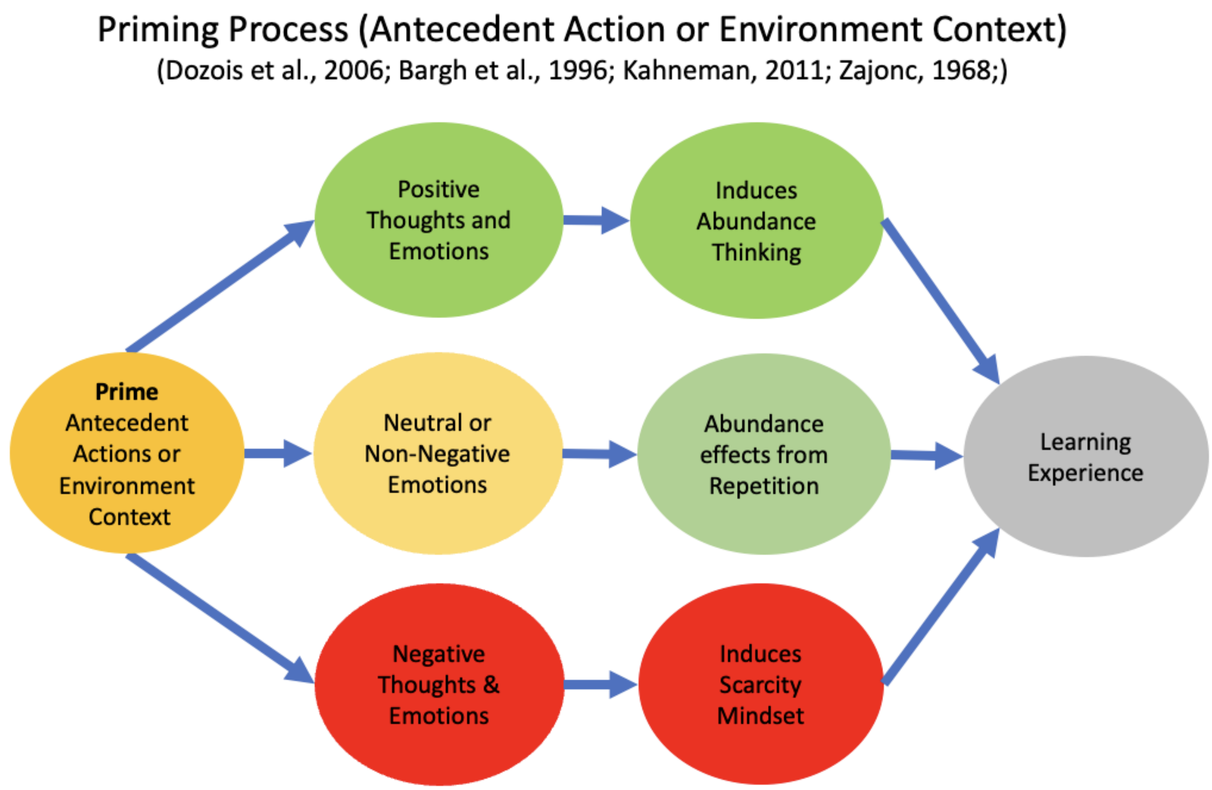


Figure 13 Priming Example

3.4. Priming Abundance Strategy

Building on the understanding of the priming process, we based our strategy on designing intervention methods that could transform scarcity mindset thinking into abundance mindset thinking. As such, this strategy framework could provide the basis for a technology platform to reduce student anxiety and increase cognitive bandwidth. A concept diagram is presented in Figure 14. The transformational process presented in the middle section of Figure 14 represents the ongoing priming research and proposed interventions used to transform scarcity thinking with limited cognitive capacity (red) to a more optimal learning state of abundance mindset thinking, as indicated by the increased size of the rectangle (green) indicating increased cognitive bandwidth. This is not to say that every priming intervention method would concurrently change all scarcity mindset afflictions. In fact, even addressing one facet of a negative thought pattern like reduced negativity bias or priming the transition to a Growth Mindset could increase cognitive bandwidth.

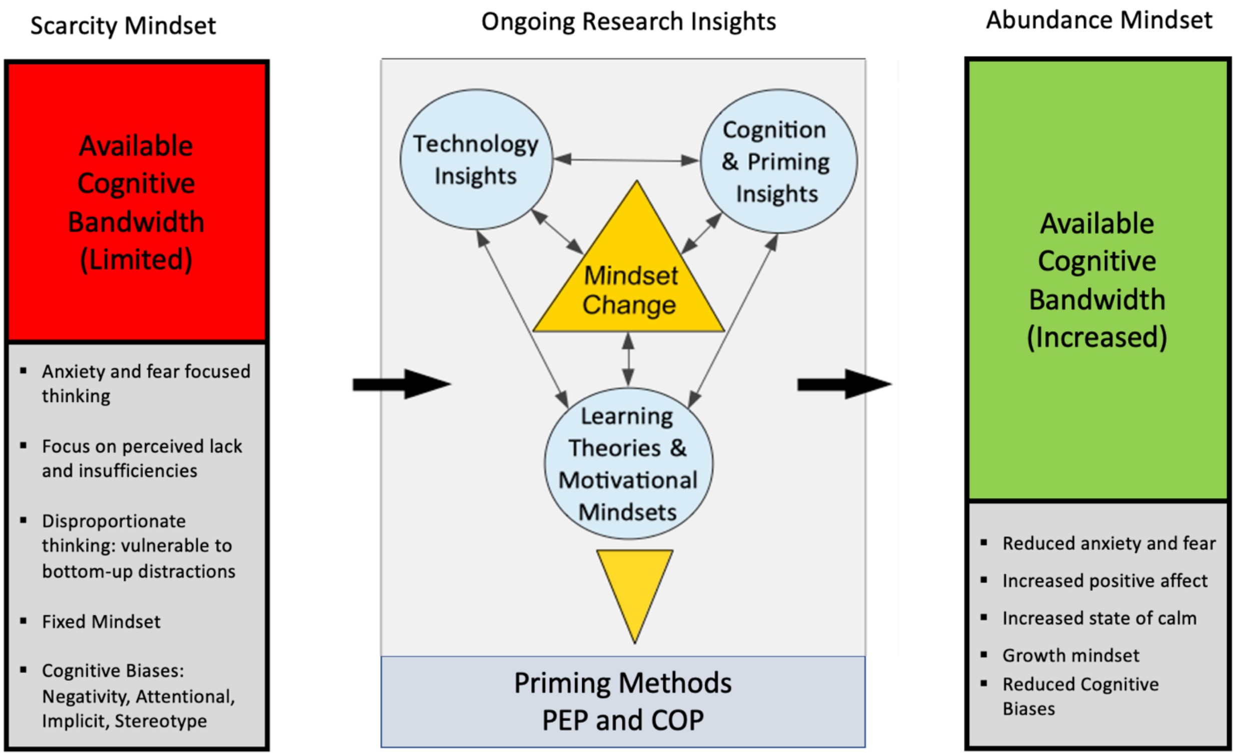


Figure 14 Framework for Transforming Scarcity to Abundance Thinking

The research in Chapter 2 suggests that different mindset challenges be addressed with different techniques. For example, inducing a state of calm would be better achieved with a slower-paced meditative activity, while inducing positive affect or striving to create flow experiences would best be achieved with video games.

The middle diagram in Figure 14 presents the first two priming strategies we used to create positive learning effects and facilitate improved emotional learning. Initially, we focused on preparatory (early) interventions and context-oriented interventions,

- PEP - Pre-Learning or Preparatory Experience Prime
- COP - Context Oriented Prime

Preparatory Experience Priming (PEP) represents the most common form of priming as it is usually executed prior to the educational experience or activity (Dennis et al., 2013; Gyllen et al., 2021). Context Oriented Priming (COP) strives to create a realistic and positive environmental context based on situated learning theories (Brown et al., 1989; Lave and Wenger, 1991).

An example of a PEP would be a short game, nature walk, or funny video. A COP could be a custom-designed creative environment that allows the student to feel more creative, an awe-inspiring mountain scene, the sound of a stream, characters/avatars, visual effects, or literally any element within the context of an environment. For our research, we focus primarily on the context of custom-designed environments.

While our research proposes iterative interventions throughout a learning experience, we focused initially on proving one case within an accepted educational framework. The PEP, for example, would be applied just before the concrete experience within the ELT cycle diagram in Figure 15, whereas the context priming would occur during the concrete experience phase.

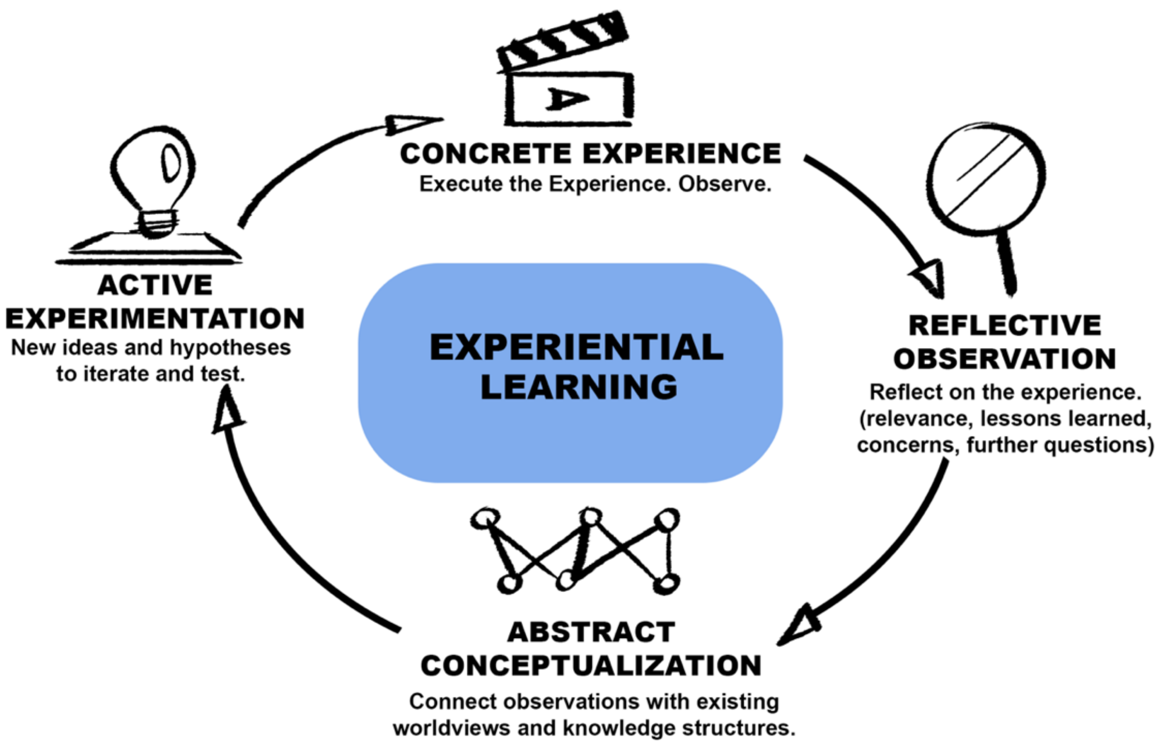
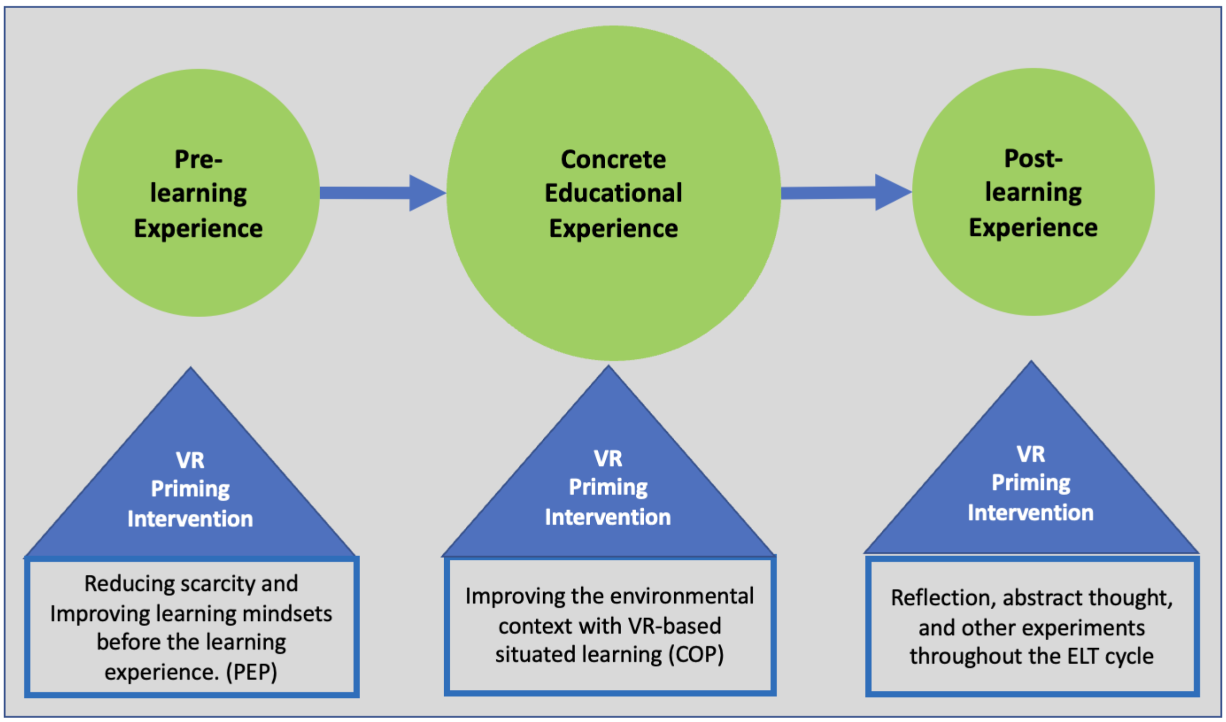


Figure 15 ELT Learning Cycle

3.5. VR Implementation of Priming Interventions

With our initial strategic framework determined, we required a technology substate to test our proposed priming process. We chose VR to facilitate the possibilities and customized scenarios that might not be possible or viable otherwise. Further, the psychological affordances of presence and immersion that lead to high fidelity, realistic, immersive experiences have been shown to create profound supraliminal priming effects (Yu et al., 2018; Pena and Blackburn, 2013), and this was a key element of our strategy.

The VR implementation of priming interventions allowed us to address the research requirements that exploit our key interdisciplinary insights. Further, this VR technology solution could provide the basis for a scalable platform to improve learning mindsets and increase cognitive bandwidth on an ongoing basis. A concept diagram is presented in Figure 16. The PEP and COP methods are positioned within the pre-learning and concrete educational experiences. The model also provisions for future possible priming interventions after the concrete learning experience and within the full cycle.



(Mullainathan and Shafir, 2014; Fish et al., 2018; Bhagwatwar et al., 2013; Lave and Wenger, 1991)

Figure 16 VR-Based Priming Interventions

In concert with our priming strategy, we will focus our technology implementation on preparatory interventions that precede the learning experience and context-oriented interventions that create custom environments to prime situated learning effects. Hence, we will implement the following priming methods as presented in Figure 16:

- Pre-Learning or Preparatory Experience Priming (PEP) Interventions
- Context Oriented Priming (COP) Interventions

The VR-based priming interventions intend to create positive emotions that induce abundance thinking to improve emotional learning. As discussed in literature review (Chapter 2), there are many ways of inducing positive emotions and improving learning mindsets. Some of the examples that may be considered for potential priming interventions within our proposed VR-based intervention strategy include:

- positive affect inducement (Isen et al., 1987)
- mental conditioning/meditation (Goleman and Davidson, 2017; Huberty et al., 2019)
- motivational messaging (Ryan et al., 2006)
- Mere repeated content exposure (Zajonc, 1968)
- Attentional controls (Eysenck et al., 2007)
- Relaxation techniques (Conley, 2105)
- Customized environments or avatars (Banakou et al., 2019; Peck, 2013)
- Gorgeous aesthetics (Norman, 2004)

For our research studies, we built the prototype testing product on the following Oculus Quest VR hardware platform. This hardware platform was used for all studies (1a, 1b, 2a, 2b) with varying content and software applications. Based on the study requirement to create high fidelity, realistic experiences that were mobile and self-manageable (due to COVID-19), we chose to use the Oculus Quest as the user participant testing device. The current specifications presented below allowed for sufficient immersive quality, degrees of freedom, and battery capabilities. The Quest fully untethered device could deliver a cost-effective ($399 CDN, 2020), fully mobile experience that simplified the user experience and minimized the technology headaches associated with tethered computer infrastructures (e.g., HTC VIVE PRO, Oculus Rift). See Figure 17. Later, participants were able to use the Oculus Quest 2, which presented an identical interface with slightly improved technical specifications.

Figure 17 Oculus Quest

The Oculus Quest Product Specifications

- Display panel: OLED.
- Display **resolution**: 1440 x 1600 per eye
- 72Hz refresh rate.
- Qualcomm Snapdragon 835 processor.
- 4GB RAM.
- Lithium-ion battery with 2-3 hours of playtime, depending on what you are playing.
- 6 degrees of freedom head and hand tracking.
- Two touch controllers.

Using local wi-fi, games, course content, and priming content would be available on-demand for pre-loading Android Package (APK) files to be used with specific scenarios. (e.g. text ads, images, videos).

To meet our specific research requirements, we needed to create or buy a series of content experiences to be used within the research studies. While we may not have been able to control the UI fully, certain VR games and tools offer specific properties that proved very useful for our priming needs and would be very difficult for us to create at a comparable quality level within the PhD study timeframe. Details of these design choices are discussed in the following chapters (4 and 5).

3.6. Research Studies

We executed three-phase research to investigate and improve our proposed framework:

Phase 1 (Study 1a and Study 1b) tested our strategic priming model for preparatory primes (PEP). To determine whether PEPs were effective, we tried to answer our first research question to determine if priming interventions worked and were transferable to the digital realm. Two PEP methods were used: VR Gaming in study 1a and both VR Gaming and VR-based Meditation in study 1b. We used a test of cognitive performance to determine the priming effect of PEP in both cases.

Phase 2 (Study 2a and Study 2b) evaluated the effectiveness of COP, our other key priming method in the strategic priming model. We studied COP for both IVR (Study 2a) and DVR (Study 2b). While phase 1 studies used a standard cognitive test as the pre/post-activity assessment tool, Studies 2a and 2b used a VR classroom as the COP environment with a short course on animation and a follow-up test as the base activity.

Phase 3 (Post Study Reflections) reflected on the research insights to improve our theoretical design and suggested some best design practices and an improved theoretical model to accommodate more informed strategic iteration and additional priming strategies. Throughout these studies, we used the VR priming intervention framework and a variety of VR tools described in Chapter 4, followed by the description of the studies in Chapters 4 and 5. In our reflection, we proposed a more comprehensive priming model called Cyclical Priming Methodology (CPM) and renamed the technological implementation: Virtual Reality Educational Priming (VREP).

4. Research Phase One

In this chapter, we briefly review the theoretical framework and our technical approach for phase one research (studies 1a and 1b) that addresses the viability of our core premise. In study 1a, we performed a preliminary test for viability, focusing on Research Question 1a (VR games as preparatory priming). Study 1b intended to fully validate our core premise; that VR-based preparatory priming interventions do work. It extended the priming scenarios to include VR-based meditation to induce calm prior to an educational event and added more participants and study details.

4.1. Brief Theory Overview

Phase one focused on the basic idea of priming positive mental mindsets to reduce scarcity thinking and its implementation using VR. We focused on our preparatory priming interventions (PEPs) as they are a very common type of priming (Dennis et al., 2012, Gyllen et al., 2021), and we expected them to have more noticeable effects. Based on our literature review (Chapter 2) and the main goal of PEP (preparing learners prior to the learning activity), we proposed to study two methods that have been generally successful in non-digital formats: positive affect priming through playing games (Fish et al., 2018), and mental relaxation through meditation (Mrazek et al., 2014).

Due to the experience of both the research team and others, VR implementation and evaluation of these two forms of preparatory priming were feasible. This meant that these two options were not only interesting examples but also relatively easy to test, which made them the best candidates for our studies. As discussed in Chapter 2, there are many other forms of priming, such as subliminal ones (Elgendi et al., 2018), and interventions to prepare students, such as cognitive/behavioural plans and bodily relaxation (Conley, 2015). However, due to our limited scope, we could not investigate more of these methods and chose games and meditation as good candidates for this study, leaving others to future research. Our studies used a VR game and a VR meditation app as the priming tools, both with immersive VR, Oculus Quest, Head-Mounted Display (HMD) device. Because the full study involved a considerable design and administration challenge, particularly during the COVID-19 pandemic, we decided to break up our phase one process into two studies: a preliminary and a full study. The first study was intended to be a smaller (10+ participants), informal process to determine if the prospects of our thesis were promising prior to launching into a full 50+ participant study.

Upon validating the viability of the core premise from this preliminary study, we proceeded to the larger (50+) participants with custom-designed VR Environments to answer the following research questions identified in the gap analysis. In phase 1, the Studies 1a and 1b were a pilot and a larger scale investigation into the effect of PEP, trying to answer our first research question:

RQ1: Do preparatory experience primes (PEP) intended to increase cognitive bandwidth and increase academic performance transfer to VR? While there are many possibilities to explore, we will focus on two key activities.

4. Using VR Gaming as a PEP to increase cognitive bandwidth and academic performance.
5. Using VR Meditation as a PEP to generate a calm mindset to increase cognitive bandwidth and academic performance.

4.2. Common Material

To answer these questions, Study 1a used one preparatory priming method (game), and Study 1b used two (game and mediation) and compared them with a no-prime case. These formed our independent variables. The studies used anxiety and cognitive bandwidth, before and after priming, as measurements (dependent variables). In this phase, we used the cognitive bandwidth as a proxy for the learning potential. The required tests for these measurements are listed in Section 4.2.4 and the appendices for both studies.

The author was the designer of the VR application framework and prototypes with artistic and technical assistants for improving software designs and assets. The VR-based priming intervention technical framework provides a technology solution that allows us to create a learning experience with supraliminal priming interventions seamlessly interwoven into the overall experience. As such, the technology solution had to facilitate supraliminal priming (conscious but little or no awareness of the intention by the participant).

The VR-based priming intervention framework, presented in the previous chapter, identifies 2 initial priming strategies: Preparatory Experience Prime (PEP) and Context Oriented Prime (COP). The PEP priming strategy required the VR experience to be presented prior to the educational activity/challenge. Based on research related to the positive affect inducement capabilities of games (Dennis et al., 2012; Fish et al., 2018; Yang et al., 2018), we opted to use a popular VR-based video game called *Beat Saber,* whereas the VR meditation solution required us to build a custom app (discussed in more detail in the meditation section below).

4.2.1. Common Software applications

For data management, software development, environment designs and avatar creation, we have opted to use several unique software tools due to their strengths, familiarity, and our past experiences:

- Campus VR software platform (Campus-vr.com)
- Gaming – Unreal Engine (UE) 4.24
- Scripting Programming UE 4.0 - Blueprint with C++
- API Interface Languages – Python, SQL with JSON
- Video Editing – Adobe Premiere Pro
- Environment modelling – Autodesk Maya 2019
- Avatar creation – Maya, Autodesk Generator
- Sideloading VR software - www.sidequestvr.com
- Custom avatar design software - www.iclone.com
- Results, analysis, and data visualization - Microsoft Excel
- iclone 7.0 software with motion capture system – www.iclone.com
- Perception Neuron Motion Capture – www.neuronmocap.com.
- Google Forms – www.google.com/forms/

4.2.2. Gaming

We chose to use VR gaming as a tool to prime positive preparatory experiences (PEP). This choice is based on the demonstrated potential of video games to improve the player's emotional state (Fish et al., 2018; Yang et al., 2018). While the research team could have developed a game for testing, there were suitable games already available that served our purpose. One such game that demonstrated that appeared to have priming possibilities was *Beat Saber*. The *Beat Saber* game provided a fully immersive flow game experience that had been described as both invigorating and fun. Further, the feelings of immersion and presence were well executed on the Oculus Quest. A visual of the game is presented in Figure 18.

Figure 18 Beat Sabre Game

4.2.3. Meditation

We used meditation as another intervention to improve the emotional state and increase awareness and mental abilities (Mrazek et al., 2014). The meditation app was a custom-designed, guided meditation application inspired and informed by the CALM app with recent research on mindfulness app evaluations (calm.com; Roquet and Sas, 2018; Goleman and Davidson., 2017; Huberty et al., 2019). While we would have preferred a market-ready, off-the-shelf VR meditation application such as *TRIPP VR* (now available on the Oculus platform), there were no such applications available on the Oculus store in 2019, nor were we able to locate a fully immersive, untethered VR application that would meet our needs. As such, we chose to build. The app was designed by the author, created with the help of VR developers from *Toonrush* (toonrush.com), and built upon the *CampusVR* software platform (campus-vr.com) using Unreal Engine 4.24.

The app was sideloaded onto the Oculus Quest HMDs using the Sidequest VR program (www.sidequestvr.com). As the participant enters the meditation space on a lofty mountaintop above a large body of water, they are met with beautiful nature sounds (waves, wind, and birds chirping), and after 15 seconds, a voice-guided meditation commences. The guided meditation is very simple, focusing primarily on noticing the beautiful scenery and bringing attention to the breathing process. The meditation process lasts for 5 minutes, at which point participants are asked to take off the headset to begin the next step. Images of the custom Meditation app are presented in Figure 19.

Figure 19 The VR Meditation App

4.2.4. Measurement Tests

During the Phase 1, we used the following measurements and tests:

1. Short-form State Trait Anxiety (STAI) – an anxiety self-assessment questionnaire (Marteau et al., 1992) – See Appendix C.

2. University of California Matrix Reasoning Test (UCMRT) - Cognitive Reasoning Test (Pahor et al., 2019) – See Appendix D.

3. User Experience (UX) questionnaire related to the Meditation and Gaming Experience – See Appendix E

4.2.5. Dealing with Data and Anonymity

All published data will be anonymous, referring only to participant numbers. The data will be stored on a password-protected laptop computer for the duration of the project and until the full completion of the intended published paper. The consent forms and all other paper test documents will be scanned and maintained in a folder on a password-protected laptop computer. All documents that contain personal information (signed informed consent forms, etc. …), including the code key, will be kept separate from the de-identified coded data to avoid re-identification. All summary results logged in spreadsheet format (XLS) will be maintained in a folder on a password-protected laptop computer.

The master list will be an Excel spreadsheet document. It will contain the participant numbers only, which relate to the specific data set. Should participants wish to withdraw within a week, they can only do this by providing the participant number that they were assigned for testing. This master file will be maintained with all other files and results, both scanned or digitized, on the same password-protected computer. All digitized data will be backed up offline for possible future research on the same topic and stored indefinitely.

4.3. Study 1a

4.3.1. Overview

Study 1a was our pilot experiment. It was conducted while we were developing our ideas and helped motivate and establish the main point of VR-based interventions. The study hypothesized that priming in VR would improve academic performance, and while somewhat informal in nature, it was primarily intended as a validation for the main experiment (Study b). The independent variable was the test case (prime vs. no prime). Our study employed a within-subjects design with two dependent variables: the anxiety level and cognitive bandwidth test performance deltas between prime and no prime test cases. To determine pre-test anxiety, students answered a short-form version of an anxiety questionnaire called the State Trait Anxiety Inventory (STAI) (Marteau and Bekker, 1992).

To determine if there were any improvements in performance attributable to the priming activity, the control condition (baseline score) was achieved by participants first completing version A of a test called the University of California Matrix Reasoning test (UCMRT), a nonverbal ability test to measure abstract problem-solving ability (Pahor et al., 2019). This specific test was not a direct test of academic performance. However, we felt that it would indicate cognitive bandwidth changes that may suggest available cognitive capacity that could be used in learning or other cognitively challenging activities, in line with Mullainathan and Shafir's scarcity studies (Mullainathan and Shafir, 2013).

This test was followed by our priming activity, playing five minutes of a popular VR-based video game called *Beat Saber*. After the priming activity, a different version (different questions/same format) of the UCMRT (version B) was administered. While we considered comparing the VR-based priming activity to a between-subjects priming activity outside of VR, we felt that the empirical research for non-VR based interventions through gaming had already been established (Fish et al., 2018; Yang et al., 2018; Moisala et al., 2017) and our focus would be to determine if VR environments, with all of their inherent affordances and advantages not possible in real physical settings could prove effective.

Our research intent was twofold; 1) to determine if the VR gaming prime delivered prior to a cognitively challenging event would show promising statistical results towards improving cognitive bandwidth and warranting a more comprehensive study, and 2) to determine whether there was a relationship between anxiety levels and performance improvements. While versions A and B of the UCMRT test were sufficiently unique (different questions), we did expect a practice or learning effect between the two versions of the test, but with only ten participants, we felt we could get more data with a simple within-subjects experiment and elected to defer the mitigation of learning effects to the full experiment (Study 1b). In study 1b, we provision to the mitigation of learning effects and provide a more details statistical analysis.

4.3.2. Participants

Ten non-paid participants (6-female, 4-male) ranging from 18-50 years of age were provided with food and refreshments, and then asked to participate in an informal test of our VR gaming and testing process. This activity was intended as a preliminary study to establish our process and gain an early sense of statistical validation.

4.3.3. Material

Participants were provided with an Oculus Quest VR system for the gaming activity and a 2019 IPAD Pro for the testing activities. All participants used systems with the exact same system specifications. The gaming software used for the priming activities was the *Beat Saber* Demo game on the Oculus Quest, while the IPAD Tests were performed with the University of California Matrix Reason Test (UCMRT) app (See Appendix D). The UCMRT, like the Raven's Progressive Matrices test, is considered an unbiased test of fluid intelligence, a test that requires no previous knowledge of language or cultures. The questions are all based on visual pattern recognition. While the previous scarcity study to test cognition, referenced in Chapter 2 (Mullainathan and Shafir, 2013), used the Raven's Progressive Matrices test (considered an industry standard for psychologists), this was not available to us without a licensed psychologist, which would have caused considerable expense and logistical challenge. The UCMRT, created by the University of California Riverside, was designed as an academic alternative to the Raven Progressive Matrices test. The specific app, downloadable from the Apple App Store, was called "Recollect the Study" (Pahor et al., 2019) and is only made available to the academic research community. The participants were also asked to complete a short form State Trait Anxiety Inventory (STAI) (Marteau and Bekker, 1992) questionnaire to determine their pre-game levels of anxiety (See Appendix C).

4.3.4. Procedure

Our study employed a (1x2) within-subjects design with one independent variable (gaming prime) and two dependent variables: the anxiety level and cognitive bandwidth test performance improvement between prime and no prime test cases. The control condition was achieved by participants completing version A of the UCMRT prior to the priming activity and then version B of the UCMRT after the priming (game) activity.

We commenced the procedure in an informal social environment. All participants were excited about playing with the VR technology. The Oculus quest VR headset provides a user experience (UX) tutorial for general VR navigation, while *Beat Saber* provides a demonstration tutorial of the game. As such, most participants learned all they required for the study within 5-10 minutes of practice. The practice session included helping the participant fit the headset comfortably and navigate the menus to initiate the *Beat Saber* game. The researcher was able to view the progress on the screen as the Oculus VR Unit was set to Cast onto a large screen TV. Once all participants were comfortable with the technology, we discussed the process with the group. The process involved taking a 10-minute cognitive test, playing the game (the priming activity) and then taking a similar version of the test afterward. We then initiated the process as indicated in the steps below.

1. Participants were asked to complete an STAI test prior to the activity. The test was composed of 6 questions that correlated to the full STAI. The test captured direct and reverse coded answers between 1 and 4 with a maximum possible score of 24 points. Consistent with the long-form version, higher anxiety levels were above the mid-point: 12 points (Marteau and Bekker, 1992).
2. Participants were presented with the first UCMRT (version A). The time to complete the exercise was 15 minutes; 5 minutes to complete pre-test training examples, and 10 minutes to complete 23 questions. (Pahor et al., 2019)
3. After roughly 1 hour, participants commenced the VR game experience. Once comfortable with the VR headset and software, they were asked to proceed with 2 plays of the *Beat Saber* demo game. This process took just over 5 minutes to complete.
4. After completion of the VR Gaming activity, within 5 minutes, participants were given the second UCMRT (version B, same test format, all different questions)

4.3.5. Results

Using a one-tailed t-test, we compared the pre-game and post-game cognitive test performances. The t-statistic (2.37) greater than 2.0 suggests sufficient magnitude, while the P-value of .02 indicates a significant difference.

UCMRT Short Test of Cognitive Reasoning							
User	Test Pre Prime	Test Post Prime	Prime Delta	Anxiety Q	t-Test: Paired Two Sample for Means		
P1	14	13	-1	10		Aft Prime	Bef Prime
P2	7	9	2	10	Mean	14	11
P3	11	15	4	15	Variance	15.11	37.11
P4	3	8	5	15	Observations	10	10
P5	5	14	9	15	Pearson Correlation	0.76	
P6	5	14	9	9	Hypothesized Mean Difference	0	
P7	11	14	3	15	df	9	
P8	17	20	3	10			
P9	15	13	-2	10			
P10	22	20	-2	12	t Stat	2.371	
					P(T<=t) one-tail	0.021	
Mean	11	14	3	12.1	t Critical one-tail	1.833	
Low Anxiety		LA	11				
High Anxiety		HA	19				
Note: All STAI scores under 12 are LA, all scores above 12 are HA							

Figure 20 Cognitive and Anxiety Results

4.3.6. Discussion

The sample size (10) for this preliminary study to assess the viability of the premise was low, but the results were promising (See Figure 20). This study was a first step to assess the viability of our VR-based priming intervention strategy, the priming process, and the use of VR technology to increase cognitive availability. The results were in line with existing research on positive affect priming through playing games (Fish et al., 2018) which can help with better cognitive operation. It suggests that non-digital interventions can be applied in digital form where there are more flexibility and programmability. While we suspected a practice effect was contained within the overall statistics, the results were sufficient to suggest further research. To build on what we had learned, there were additional factors to consider for subsequent studies.

While at first glance, higher anxiety scores appeared to be related to higher test performance improvements, this could also have been related to a practice effect or confidence gained by more anxious individuals. Hence, for future tests, delta in anxiety levels could provide us with more insight. As such, for the full study, we planned to assess anxiety before and after priming activity to assess whether there had been a change because of the experience.

While the University of California researchers suggested that the learning effects of the UCMRT would be minimal, and with a completely different set of questions in Test A versus Test B, it may not have factored in the familiarity and comfort level with the process itself and the technology. To that end, subsequent studies should alternate the order of the prime and no prime scenarios to further reduce potential learning effects due to general process familiarity and general practice effects. Further, test participant order should be randomized to eliminate any possible grouping effect. Given the small sample size and the informal nature of the study, we did not relate anxiety levels to performance data.

In summary, while the pilot study was preliminary, the results were encouraging and warranted further investigation to determine if the VR gaming application could serve as an effective prime to improve cognitive availability while offering potential anxiety-reducing benefits for those afflicted with scarcity mindset issues.

4.4. Study 1b

4.4.1. Overview

As discussed at the start of this chapter, the abilities of video games and meditation practices to increase cognitive bandwidth and academic performance have been both suggested and contested in some literature (Mrazek et al., 2014; Conley, 2015). As such, our research intent is twofold. Given that Meditation and Games have been shown to have potential in other digital and non-digital contexts to reduce anxiety and increase cognitive bandwidth (not necessarily correlated), and given the promising prospects of study 1a, we hope to determine 1) whether these priming methods do work within fully immersive VR environments and 2)

their relative efficacy. Beyond our twofold research intent, we were curious to gain more insight into the emotional and performance aspects of these priming methods.
We define our research hypotheses as follows.

H1a. VR Meditation can reduce anxiety levels (scarcity mindset).
H1b. VR Meditation can increase cognitive bandwidth.

H2a. VR Gaming can reduce anxiety levels (scarcity mindset).
H2b. VR Gaming can increase cognitive bandwidth.

H3a. VR Gaming will be more effective than VR meditation for reducing anxiety.
H3b. VR Gaming will be more effective than VR meditation for increasing cognitive bandwidth.

Based on these hypothetical research questions, we designed a mixed-method experiment with two independent variables: (A) priming method (game vs. meditation) and (B) priming condition (prime vs. no prime). Participants were divided into two groups based on variable A and were asked to complete both options of variable B (prime and no prime conditions for both game group and meditation group participants). This allowed us to not only compare the effects of two priming methods but also compare this effect with the no-prime condition for the same participants. The 2x2 design resulted in a mixed-method (between and within-subjects) research study. The dependent variables (measurements) for each of the four cases were anxiety levels as measured by STAI and cognitive bandwidth improvements as measured by the UCMRT.

4.4.2. Participants

The user study was performed with 56 participants between the ages of 17 and 48. 46 of the participants were university students (S) while 10 were not students (NS) but identified as lifelong learners, 30 participants identified as female, 26 as male. (N=56, F=30, M=26, S=46, NS=10). They were randomly divided into two groups corresponding to games and meditation priming, with 30 and 26 members, respectively. The group sizes were not equal due to some assigned participants who did not finish the experiment and could not be replaced later due to logistic limitations. Participants were paid $30 CDN or given a Tim Horton’s Gift Card of equivalent value.

4.4.3. Material

All participants were provided with an Oculus Quest VR headset, as described in Chapter 3, for the gaming and meditation activity and a 7th Generation IPAD for the cognitive testing. All headsets and tablets had the exact same system specifications, as presented in Figure 9. We considered the guidelines presented in Chapter 3 for selecting and/or designing our VR-based interventions. We particularly focused on the first guideline; creating virtual worlds and experiences that induce positive affect and calm the mind.

The software used for the game priming activity was the *Beat Saber* Demo game (www.beatsaber.com) on the Oculus Quest HMD. The app was, and still remains, one of the more popular applications on the Oculus Quest VR platform, mostly due to the "fun factor" and its ability to generate positive affect. Further, recent research suggests that negotiating in 3D spaces may have positive cognitive effects (Raichlen and Alexander, 2017) and *Beat Saber* activities require visual and timing acuity within a 3D environment to achieve the tasks. The process was very simple and lasted 2 minutes and 35 seconds. The participants use their *beat saber*s to slice oncoming blocks and circles in an optimal manner while energetic music plays in the background. We requested users play the demo round twice for a total of 5 minutes and 10 seconds, then put down the headset for the next activity.

The Meditation app was a custom-designed guided meditation application inspired and informed by the CALM app and recent research on mindfulness app evaluations (calm.com; Roquet and Sas, 2018; Goleman and Davidson., 2017; Huberty et al., 2019). As discussed, in Chapter 3, given the limitations of availability on the Oculus Quest platform, we opted to build the application. The app was built upon the Campus VR software platform and sideloaded onto the Oculus Quest HMDs using the *SidequestVR* program (www.sidequestvr.com). As the participant enters the meditation space on a lofty mountaintop above a large body of water, they are met with beautiful nature sounds (waves, wind, and birds chirping), and after 15 seconds, a voice-guided meditation commences. The guided meditation was very simple, focusing primarily on noticing the beautiful scenery and bringing attention to the breathing process.

The meditation process lasted for 5 minutes, at which point participants were asked to take off the headset to begin the next step. While we considered testing for a longer period of time, we chose a 5-minute interval for the following reasons;

- We preferred a short experience that a student might be able to do prior to class.
- We chose a time limit comparable to the gaming experience (5mins, 10 seconds).
- Research suggests that 5-minute meditation sessions can be effective (Krygier et al., 2013) and viable prior to classroom sessions (Ishikawa et al., 2020).

- Recent successful meditation products have also demonstrated success with 5-minute sessions. (choosemuse.com).

Harvard neuroscience researcher Sara Lazar talks about the value of short meditation sessions when time is short. (choosemuse.com/blog/the-benefits-of-a-5-minute-meditation).

"When most people hear the word "meditation," we can sometimes conjure up the image of zen masters with decades of experience. But while research suggests long-term meditation has its benefits, you don't need to spend hours to see them. In fact, all you need to get started is a spare 5 minutes." (Sara Lazar).

Our study required us to measure changes in two factors: anxiety levels before/after priming activities and cognitive bandwidth before/after priming activities. We elected to measure anxiety around priming activities to minimize potential test anxiety and to determine the effect attributable to the priming activity. The anxiety was measured subjectively and using a self-reporting questionnaire based on an approved shortened version of the STAI. We chose the approved shortened version (6 questions) to maintain the flow of the experiment. We used UCMRT to objectively measure the cognitive bandwidth. Like STAI, the UCMRT cognitive test was a shorter version of the industry-standard Raven's Progressive Matrices (RPM) test but designed for academic research. The UCMRT presented 23 multiple-choice visual puzzles that were answered in a multiple-choice format within a 10-minute time limit. The front-end UCMRT application was presented on a 7th generation IPAD, and the data was collected on the University of California Riverside's backend cloud-based server. The app, downloadable from App Store or Google Play Store, is called "Recollect the Study" and is only made available to the academic research community.

4.4.4. Procedure

Given the limitations caused by the COVID-19 social distancing requirements, we designed a study that could be performed independently by participants in their homes. To enable the process, our apparatus was dropped off and picked up at participant sites by the research team. Proper disinfection rules were followed between each device use. Each participant was provided with the hardware, software, and user guide explaining the process and was given up to 48 hours to complete the study. While we suspected that more time between test activities would be optimal to "come down" or eliminate any residual post-test emotional effects, and, considering there was no research available for the duration of VR-based testing effects, the researchers felt that an hour should be enough time for participants to return to their regular emotional state of mind. As such, we asked participants to permit one hour minimum between tests.

Because our within-subjects study required two separate tests, one after the prime condition and one after the no prime condition, we wanted to mitigate the possibility of any learning or practice effect, whether through the specific test or the process itself. As such, we interlaced the priming process to alternate between the first test event and the second test event. Once our participants were confirmed, we randomized the list and slotted them sequentially into one of four conditions prior to proceeding.

Meditation – Prime, Test1, Wait, Test 2
Meditation – Test 1, Prime, Test 2
Game – Prime, Test1, Wait, Test 2
Game – Test, Prime, Wait, Test 2

Therefore, for both the game and meditation priming, there were two possible scenarios. Scenario 1 performs the priming activity first; hence the no prime test to establish baseline will be the second UCMRT, whereas scenario 2 performs the priming activity second. Hence the first UCMRT will serve as the no prime baseline test. See below.

Scenario 1 (Prime First)

- Sign consent form
- Fill out anxiety questionnaire 1 (Before)
- Complete 5-minute VR Experience (Game or Meditation)
- Fill out anxiety questionnaire 2 (After)
- Complete first UCMRT
- Wait minimum of 1 hour
- Complete the second UCMRT
- Complete UX Questionnaire

Scenario 2 (Prime Second)

- Sign consent form
- Complete the first UCMRT
- Wait minimum of 1 hour
- Fill out anxiety questionnaire 1 (Before)
- Complete 5-minute VR Experience (Game or Meditation)
- Fill out anxiety questionnaire 2 (After)
- Complete the second UCMRT
- Complete a UX questionnaire

A random code was given to each participant and entered in all steps to allow tracking and connecting the participant data anonymously.

4.4.5 Results

Quantitative Data

We performed a 2x2 experiment design with two independent variables, each with 2 two values. Our first variable (A) determined the game vs. meditation participant groups and was between subjects. The second variable (B) determined prime vs. no prime measurements for the same participants within each group. This experiment design resulted in four sets of measurements and required a mixed model, so we ran a 2-factor ANOVA with one repeated measure for both anxiety and cognitive score data to see if there was any significant difference in between-subjects and within subjects-data.

These measurements were done for both cognitive bandwidth (objective) and anxiety (subjective). They were all continuous data and had a normal distribution. This allowed us to use parametric methods such as ANOVA.

The ANOVA results suggested that priming was effective for anxiety, with both methods performing with an insignificant difference from one another. On the other hand, for the cognitive tests, while priming was overall effective, there was a difference between the two methods.

The ANOVA results are shown in Figures 21 and 22. We can see that for both anxiety and cognitive bandwidth, ANOVA shows a significant difference along variable B (prime vs. no-prime), while variable A (game vs. meditation) only has a significant difference for anxiety. Figure 23 presents the Mean and Standard Deviation (SD) results for both conditions and both methods. Looking at the mean values in Figure 23, we can assume that games were successful while meditation was not (for cognitive test). This means that all hypotheses were supported except for H1b (meditation improves cognitive bandwidth) and H3a (games are more effective than meditation for anxiety).

Anova Summary (2 rows X 2 columns)					
A = groups: the between-subjects variable delinated by the rows					
B = the repeated-measures variable delineated by the columns					
Source	SS	df	MS	F	P
Between Subjects	945.86	55			
A	90.26	1	90.26	5.7	0.0205
Subjects within A	855.6	54	15.84		
Within Subjects	285	56			
B	116.04	1	116.04	37.07	<.0001
A X B	0.15	1	0.15	0.05	0.823907
B X Subjects within A	168.81	54	3.13		
Total	1230.86	111			

Figure 21 Self-Assessed Anxiety Scores from Short STAI

Anova Summary (2 rows X 2 columns)					
A = groups: the between-subjects variable delinated by the rows					
B = the repeated-measures variable delineated by the columns					
Source	SS	df	MS	F	P
Between Subjects	2015.42	55			
A	52.91	1	52.91	1.46	0.0205
Subjects within A	1962.51	54	36.34		
Within Subjects	520.5	56			
B	58.58	1	58.58	7.31	<.0001
A X B	29.38	1	29.38	3.67	0.823907
B X Subjects within A	432.54	54	8.01		
Total	2535.92	111			

Figure 22 Cognitive Test from UCMRT

Statistical Results	Meditation Priming		Game Priming	
UCMRT Scores	Prime	No Prime	Prime	No Prime
Mean	12.3846	12.0385	12.0333	9.6333
Standard Deviation	4.6740	4.7030	0.5843	4.1893
STAI Anxiety Scores	Post Prime	Pre Prime	Post Prime	Pre Prime
Mean	8.6923	10.8077	10.5667	12.5333
Standard Deviation	1.4301	2.7389	3.3185	2.9564

Figure 23 Mean/SD of anxiety and cognitive test scores

To support ANOVA results for our key area of study (academic performance), separate post-hoc paired t-test comparisons for meditation and gaming cognitive test scores demonstrated significance indicating a positive improvement in test scores due to VR game priming (P=.0008), but no significance was observed indicating no positive improvement in test scores due to VR meditation priming (P=.34). See Figure 24. Comparing directly between delta scores of meditations vs. gaming for an increase in cognitive bandwidth observed a significant increase as presented in Figure 25 (P=.03). The two-tailed comparison was slightly over (P=.06) but with a strong one-tailed P-value in both direct prime vs. no prime conditions and comparing with both T-test and the ANOVA test, and a strong T-value approaching 2.0 (P=1.89), we would argue for a significant result, suggesting that gaming was more effective than meditation.

A similar test for anxiety showed significance for both games and meditation, with P values of .02 and .01, respectively. A further T-test comparing deltas of prime vs. no-prime between VR Meditation and Gaming for anxiety reduction yielded no significant difference (P=.41). Overall, the T-Test did not provide us with any new and helpful insight. We used a two-tail test in all these cases to allow for detecting any significant differences in either direction.

t-Test: Paired Two Sample for Means	Meditation Priming		Game Priming	
	Prime	*No Prime*	*Prime*	*No Prime*
Mean	12.38	12.04	12.03	9.63
Variance	21.85	22.12	27.17	17.55
Observations	26	26	30	30
Pearson Correlation	0.59		0.7	
Hypothesized Mean Difference	0		0	
df	25		29	
t Stat	0.413		3.499	
P(T<=t) one-tail	0.34		0.0008	
t Critical one-tail	1.708		1.699	
P(T<=t) two-tail	0.17		0.0015	
t Critical two-tail	2.06		2.05	

Figure 24 Cog. Bandwidth – (Prime vs. No Prime)

t-Test: Two-Sample Assuming Unequal Variances	*Delta Meditation*	*Delta Games*
Mean	0.346	2.4
Variance	18.235	14.11
Observations	26	30
Hypothesized Mean Difference	0	
df	50	
t Stat	1.897	
P(T<=t) one-tail	0.031	
t Critical one-tail	1.676	
P(T<=t) two-tail	0.063	
t Critical two-tail	2.009	

Figure 25 Comparing Cog Bandwidth Deltas Games vs. Meditation

To distribute the practice effects, we did interweave the baseline testing of the UCMRT by placing the no prime conditions alternately as the first or second test. Accordingly, scenario two should experience a practice increment effect, while scenario one should experience a practice deficit resulting in lower overall numbers compared to scenario two. Both VR meditation and VR gaming did experience the predicted difference between scenarios, as presented in Figure 26. In both gaming and meditation, the "prime second", scenario two numbers scored considerably higher than the "prime first", scenario one numbers.

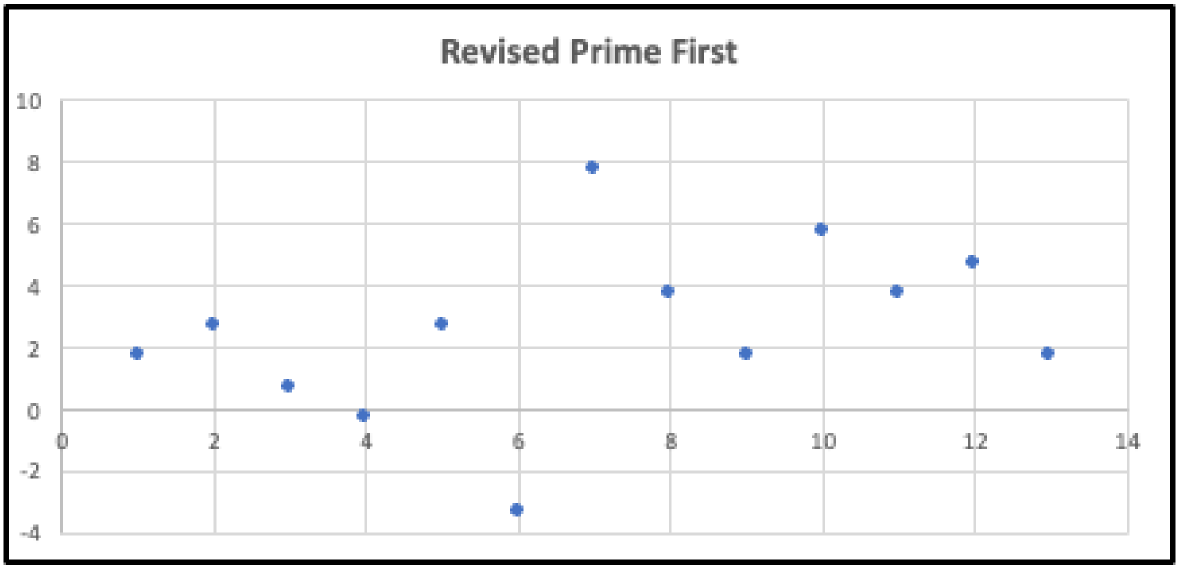
As mentioned above, there was no statistical significance observed with UCMRT between prime and no prime conditions with VR meditation, but there was with VR gaming. As such, we will focus further analysis on assessing practice effects for gaming deltas. VR gaming deltas do show a positive weighted mean average even before we adjust for the practice effects.

Comparing Practice Effects			
Gaming UCMRT Performance Deltas		Meditation UCMRT Performance Deltas	
Scenario One Prime First (13)	Scenario Two Prime Second (15)	Scenario One Prime First (12)	Scenario Two Prime Second (12)
1	-1	-4	1
2	3	-5	4
0	0	1	4
-1	-1	1	1
2	4	2	0
-4	8	-5	2
7	3	0	-2
3	4	-2	-4
1	-1	-2	4
5	2	1	4
3	4	-4	5
4	5	1	-1
1	9		
	3		
	3		
24	45	-16	18
Weighted Mean Average	33.75	Weighted Mean Average	1
Overall Score Difference	21	Score Difference	34
Difference per Sample	0.75	Difference per Sample	1.42
Note1: We eliminated one outlier from each group			
Note2: Weighted mean average between Prime First and Prime Second			

Figure 26 Prime First (scenario 1) and Prime Second Deltas (Scenario 2)

Considering we are dealing with very small sample sizes; we can analyze the scatter plot to see if it makes sense visually. See Figure 27. After we adjust each score for up or down accordingly (.75) for an estimated practice effect, the revised scatter plot presents the VR gaming UCMRT scores for both scenarios.

In both scenarios, most of the numbers are clearly distributed above zero with strong distribution between 1 and 4 positive delta points. There are outliers in both cases, but the overall trends appear consistent.



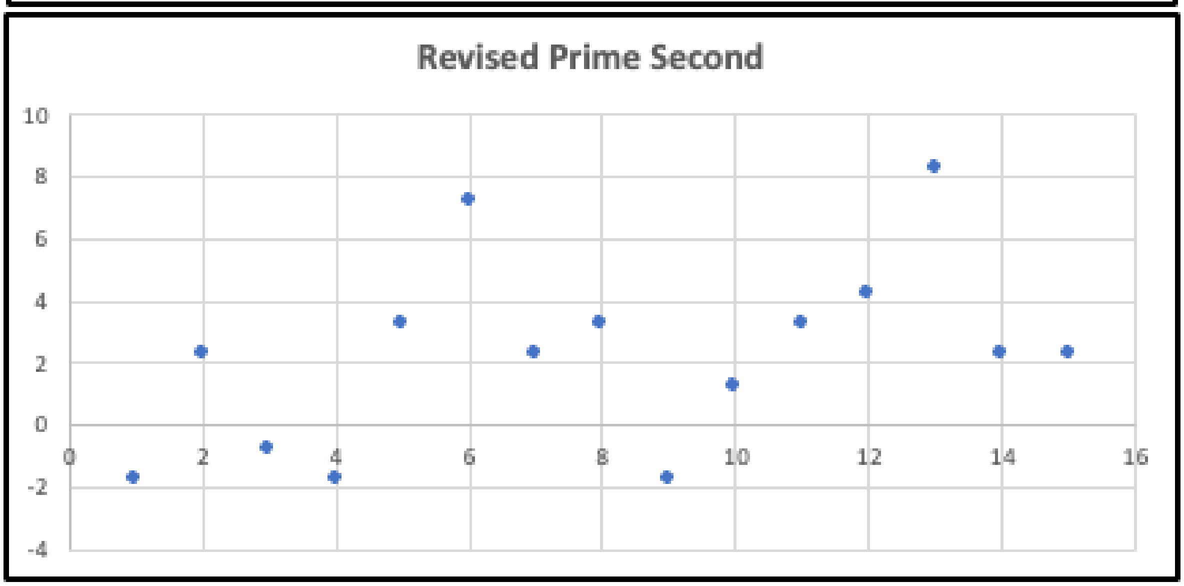


Figure 27 Scatter Plots for Scenarios 1 and 2 after adjusting for practice effects

UX Survey

We also conducted a UX survey questionnaire (See Appendix E), with questions to determine previous experience with VR and games. The participants also provided final feedback related to their VR, gaming, and meditation experience, along with their assessment of the experience. While 50 of 56 participants were newbies or very inexperienced VR players, almost 50% claimed to be frequent gamers. 48 of the 56 participants did not meditate regularly or did so occasionally if stressed.

34 of 56 participants felt that the VR priming activities did reduce anxiety in a small or large way, while the remainder felt that there was an effect but nothing significant. Only one participant claimed to have no anxiety reduction at all. 8 of the 56 participants felt some level of discomfort with VR but nothing significant. One person did experience cyber nausea and stopped the experiment. Some of the comments provided by participants were:

- I felt more focused for the second test
- Was fun and made you forget the stress of the test
- Also had more energy.
- Slight motion sickness but nothing terrible.
- Gave me a headache but a great overall experience.
- Found VR very relaxing

Additional Results for Study 1b

To address questions related to anxiety levels and cognitive performance, we tried to determine if higher anxiety participants experienced greater cognitive performance increases than lower anxiety participants, as noted in the 2018 digital game-based learning study (Yang et al., 2018). In Figure 28, we summarize the cognitive performance improvements for both VR Meditation and VR Gaming conditions for both Low and High Anxiety participants. Based on the short-form STAI process, a low/average anxiety level would be any score of 12 or below. A high anxiety level would be any score above 13.

To classify the participants, we used pre-test anxiety levels and broke the participants into two groups, High Anxiety (HA) (scores >= 13+) or Low Anxiety (LA) (scores <= 12). We identified 23 HA and 33 LA participants.

Increase in Mean of Cognitive Performance (UCMRT)			
	VR Meditation Mean Performance Increase (Frequency)	VR Gaming Mean Performance increase (Frequency)	Total
High Anxiety	1.125 (8)	3 (15)	2.39
Low Anxiety	0 (18)	1.8 (15)	0.82
Total	0.36 (26)	2.4 (30)	1.45
Conditions	Calm Mindset Method	Positive Affect Method	

Figure 28 Comparing Cognitive Performance and Anxiety Levels

As presented in Figure 29, we performed a two-sample T-test, assuming unequal variances to compare increased test scores (deltas) between HA and LA participants. While the data suggests that HA participants appeared to benefit slightly more than the LA participants from the VR priming process, we did not observe a significant difference between the two groups (p=.09466).

HA Participants vs LA Participants Delta Test Scores		
t-Test: Two-Sample Assuming Unequal Variances	***High Anxiety Deltas***	***Low Anxiety Deltas***
Mean	2.956521739	0.818181818
Variance	17.31620553	13.65340909
Observations	23	33
Hypothesized Mean Difference	0	
df	44	
t Stat	1.979759227	
P(T<=t) one-tail	0.027003538	
t Critical one-tail	1.680229977	
P(T<=t) two-tail	0.054007076	
t Critical two-tail	2.015367574	

Figure 29 High Anxiety vs Low Anxiety Participant Test Deltas

4.4.6. Discussion and Limitations

Based on the test results, we review our research hypotheses in Figure 30.

H1a. VR Meditation can reduce anxiety levels.
Supported. VR Meditation demonstrated statistically significant anxiety reduction as a result of the priming activity.
H1b. VR Meditation can increase cognitive bandwidth.
Not Supported. VR Meditation did not demonstrate an increase in cognitive bandwidth in the subsequent test.
H2a. VR Gaming can reduce anxiety levels.
Supported. VR Gaming demonstrated statistically significant anxiety reduction as a result of the priming activity.
H2b. VR Gaming can increase cognitive bandwidth.
Supported. VR Gaming demonstrated a statistically significant increase in cognitive bandwidth in the subsequent test.
H3a. VR Gaming will be more effective than VR meditation for reducing anxiety.
Not Supported. There is no significant difference in anxiety reduction between the two methods.
H3b. VR Gaming will be more effective than VR meditation for increasing cognitive bandwidth.
Supported. VR Gaming was demonstrated to be a more effective process for increasing cognitive bandwidth.

Figure 30 Results of Hypotheses

While the anxiety assessment was subjective, participants felt better after the priming exercises (both meditation and gaming) than before. This was to be expected, as existing research suggests that positive affect and mental calm can effectively reduce anxiety. While this may result in better cognitive performance, it was evidently not causal in the meditation scenario. The results answer our general question about the transferability of these methods to the digital realm positively. Upon reflection, the VR meditation activities' limited effect on cognitive bandwidth was unsurprising. Like sports or crafting, meditation is a long-term skill that yields more benefits over time as participants improve and better understand how to apply the process.

Since most of the participants were inexperienced meditators, as discovered in the pre-test discussions, it was unlikely that they would have sufficient skills and practice to gain the full cognitive benefits of meditation in such a short trial. A similar result (no cognitive effect) was observed in a 2013 study of one-time effects on mood, mindfulness, and memory tasks typically associated with cognition. As in our study, where we did observe reduced anxiety levels, the 2013 study also reported mood improvements and elevated feelings of mindfulness (Johnson et al., 2013), but no cognitive improvements.

The academic trials that did observe improved cognition demonstrated benefits over a longer time. For example, GRE reading comprehension scores were increased after a 2-week mindfulness training course (Mrazek et al., 2013). On the other hand, the gaming activities were more ephemeral and generated an immediate elevated state. Further, as in the Isen studies that compared the act of receiving candy, funny videos, exercise, and neutral movies (Isen et al., 1987), exercise did not generate similar positive creativity effects. As such, we theorize that the gaming effect was most likely attributable to increased positive affect.

It should be noted that this study occurred during the first COVID 19 lockdown phase in the spring/summer of 2020, where possible crowding and stress may have impacted the result. For example, even with a VR HMD, meditation activities are better performed in areas that are quiet and private, and this may not have been an optimal arrangement for some. VR gaming, on the other hand, does not depend on quiet spaces and may have been less affected by the COVID lockdown. Further, the STAI anxiety scores were a self-reported measure of anxiety levels and were therefore potentially subject to expectancy biases, where participants might expect to have reduced anxiety because of the priming activity or simply to please the researcher. As most of the participants were remote (no personal contact) and did not know the lead investigators, the "pleasing effect" was likely not an issue. An expectancy bias was possible. Unfortunately, in-person physiological measurements that could have helped mitigate these biases were not possible during the testing period due to COVID 19.

While the Isen et al. study (Isen et al., 1987) referenced in the related work did demonstrate negligible cognitive performance improvements with the arousal/exercise subjects compared to positive affect subjects, future studies could consider the effect and coincidence of positive affect and arousal effects working in tandem. (Isen et al., 1987). The combined effect of arousal and positive affect could serve to amplify the results and should be better understood. We compared these two VR priming methods because they represented different approaches to reducing scarcity thinking and improving learning mindsets. Meditation is a controlled mental conditioning exercise that takes focus and concentration. VR gaming is more ephemeral and intended to generate immediate feelings of positive affect. While we suspect that reduced anxiety contributed to the improved academic performance, it appears that it may not have been sufficient in the meditation case to generate a sufficient effect. We suspect that VR gaming also benefitted from an increase in positive affect, which has been shown to improve cognition in similar studies. (Isen et al., 1987).

Previous literature suggests that users with higher anxiety levels may experience greater cognitive performance increases than those with lower anxiety (Yang et al., 2018). While there appeared to be some improvement, our study did not observe a difference between these two groups. This finding may be due to limited sample size or other specific situations in our study compared to the Yang study, including the game and VR context. Further research is required to verify the potential difference based on anxiety level. To further explore our VR-based priming intervention strategy for future study, it will be critical to test other priming strategies (e.g., context, motivational messaging, and reflective activity) in the future and to prime against varying content scenarios beyond simply cognitive reasoning tests. How does this VR-based priming strategy work for Math, Science, Art, Design, or the Humanities?

Implications and Further Research

Given the performance difference between the video game and meditation scenarios with similarly positive anxiety effects, it would be worth testing for other factors like positive affect in future studies. The Positive Affect Negative Affect Schedule (PANAS) (Watson et al., 1982) could be used as a subjective assessment of affect in future studies. Newer biometric -techniques like GSR, gaze analysis, and short surveys could also help demonstrate within-subjects priming effects on the brain during future priming studies. Building on the current research, investigating other VR-based tools and techniques for reducing scarcity mindset and optimizing student engagement would make sense. We hypothesized that they would help the transition from a scarcity mindset to an abundance one, although in different ways. Activities like dance, yoga or other physical activities or even less kinetic games like bird watching or similar search and concentration games would be worth exploring as possible candidates for inducing abundance thinking.

This study was limited to simple interventions suitable for pre-learning or Preparatory or Experience Priming (PEP). A full investigation of our priming strategy requires evaluating other intervention techniques, which were the subject of our phase 2. While the next phase of the research, which focused on COPs, was not expected to create a noticeable emotional difference between prime and no-prime participants, we did continue to measure anxiety and further added positive affect to determine if these elements were mediating the performance changes in any way. Further, we wanted to determine if the user experience was relevant to the overall context and, as such, added a more comprehensive UX study. With COPs, the use of supraliminal priming methods was not expected to yield effects that were noticeable to the participants, yet like the priming study testing wine sales against varying cultural music (North et al., 1999) still observed a priming effect.

Finally, in the next studies, we focused on priming effects within IVR and DVR environments which may have similar benefits that need to be investigated in the future. Study 2a focused on assessing various priming influences within immersive VR environments, while the role of immersion was considered for the second phase (Study 2b) in our context-based priming studies in phase 2.

5. Research Phase Two

In this chapter, we briefly review our theoretical background and technical framework for phase two research (studies 2a and 2b) that study the priming effects of context in VR. In study 2a, we study the priming effects of context-oriented priming within custom VR learning spaces. In study 2b, we extend the context of the learning environments to include levels of immersion as we compare the priming effects of IVR and DVR. It is important to note that as in study 1 (a and b), we are not testing or validating the efficacy of VR compared to real-world classrooms; rather, we are testing whether VR supports the priming activities. We have also made an assumption here; based on recent research demonstrating the transferability of psychological effects into 3D virtual environments (Bhagwatwar et al., 2013; Murdoch and Davies, 2017) and the results of Study 1b that VR is a viable medium with inherent advantages (discussed in Chapter 2) to host various priming interventions that would otherwise not be possible in a real-world classroom. The delivery of an asynchronous classroom experience is an example.

5.1. Brief Theoretical Overview

Phase two seeks to extend our understanding of priming strategies by testing COPs but also to consider the effect of the digital environment (particularly immersion). We start with investigating context-oriented priming (COPs). The reason for this choice is two-fold.

- We find the context (environment) particularly suitable for VR implementation and investigation as we can use the virtual environment to simulate various situated learning contexts (Slater and Sanchez-Vives, 2016; Slater, 2009)
- While we expect other priming methods related to priming longer-term mind positive mindsets or studying the impact of reflection to require more complicated investigations and longer time periods to assess. As such, we find their proper evaluation beyond the scope of this proposal. But we found it helpful to consider other methods for future deployment.

As such, we defined two studies for this phase 2:

- Study 2a focuses on COPs within immersive VR.
- Study 2b focuses on COPs within desktop VR.

Studies 2a and 2b, while both focusing on COP, allow us to also investigate the effect of immersion through IVR and DVR. This is an ongoing topic of research within the VR community, and it is important for us to know if immersion has any effect on the performance of priming methods. Both studies in Phase 2 use a common learning activity (a short animation course). They also share the same measurement tools, which are described in 5.5 and presented in detail in the Appendices. These include a learning test based on the animation course (replacing the UCMRT cognitive test in Phase 1), self-reported anxiety (as in Phase 1), UX survey (enhanced from Phase 1), and Positive and Negative Affect Schedule (PANAS), which intends to measure affective improvement as recommended to us by thesis committee after Study 1. While we do not necessarily expect changes to Positive Affect, Anxiety, or UX scores based on our planned phase 2 research, these tests are very easy to administer and may shed additional insights into our priming activities. In Phase 2, we continue with our remaining research questions, each with their corresponding studies:

RQ2: Extending our core premise into a specific VR learning context, how effective is context-oriented priming (COP) in custom VR environments to increase cognitive bandwidth and academic performance.

a) Using custom-designed situated learning environments and subject matter artifacts to create an effect that increases cognitive bandwidth and academic performance.
b) Determining which digital environments are most effective towards achieving our desired priming goals? Specifically, is there a performance difference between IVR and DVR environments?

5.2. Common Materials

The author was the designer of the VR application framework and prototypes with artistic and technical assistants for improving software designs and assets for the VR-based priming intervention strategy. The technical framework provides a technology solution that allows us to create a learning experience with supraliminal priming interventions seamlessly interwoven into the overall experience. As such, the technology solution must facilitate supraliminal priming (conscious but little or no awareness of the intention by the participant).

The VR-based priming intervention strategy framework identifies 2 initial priming strategies: Preparatory Experience Prime (PEP) and Context Oriented Prime (COP). To facilitate and test each of the scenarios in phase one, a customized VR meditation application and the use of existing VR gaming software (*Beat Saber*) intended to calm the mind and induce positive affect respectively were used. The COP priming strategy required the design of custom VR environments for both immersive and non-immersive conditions that could facilitate specific situated learning environments with props and/or artifacts. These custom VR environments were created with the use of an existing virtual university software platform called Campus VR: a virtual, customizable product/service offering designed by the author (www.campus-vr.com) and used in corporate and public post-secondary VR courses.

By designing and/or inserting customized priming interactions into the customized learning environments, the researchers were able to achieve desired priming effects of provisioning for both prime and no prime scenarios.

The VR classroom was a custom-designed VR environment using the Campus VR software platform. The original environments were created with Maya modelling and texturing tools and imported directly into UE Version 4.24. The classroom design was inspired by a popular theatre-style classroom design used by the author/instructor at Ryerson University. The original content model was a green-screened video of the professor, composited into the Campus VR environment and exported as a custom APK. On a subsequent revision, we opted to capture the professor's presentation using a motion capture system (Perception Neuron) and a custom-built avatar (iclone) that was imported directly into the UE 4.0 virtual environment.

The screen share video content was synchronized with the avatar professor to create a feeling of being in a classroom with the professor at the front of the room. Examples of a learning theatre, a learning theatre with animation-related artifacts and a customized animation studio (student and teacher views) are presented in Figures 31 and 32.

The animation studio presented popular movie posters, as would be expected in a typical studio, but these images did not change or cycle throughout the presentation. The VR theatre classroom with artifacts at the front of the class cycled new images above the main presentation screen every 1-2 minutes, as might be expected in a viewing session or online movie experience but did not cycle the images that were on the side/periphery. These images remained static to minimize distraction from the main screen and speaker. A more detailed presentation of the specific priming setup and content is presented in Appendix J.

Upon entering all VR environments, very soft ambient music played in the background as students settled in place, with the core programming (audio and music) commencing shortly thereafter (within 5 seconds). In an informal query of students, most felt it was common to have background music while studying or watching videos online. As this was an asynchronous presentation (like watching a YouTube video), we did include some ambient background music in the design of the experiences. The ambient music did not compete with the core content but filled in small sound gaps in the presentation.

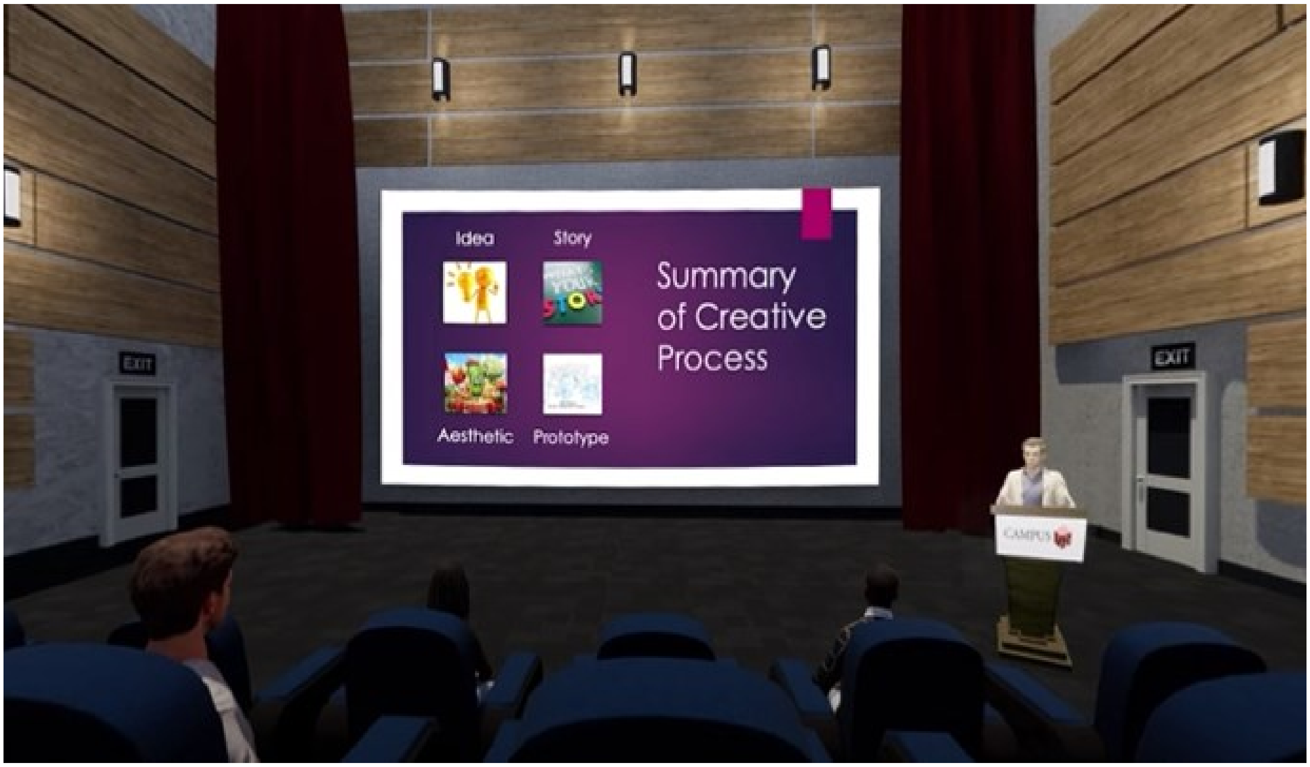


Figure 31 VR Classroom(above) and Classroom with Artifacts (below)

Figure 32 Animation Studio from student view (above) and teacher view (below)

5.2.1. Hardware and Software

As discussed in Chapter 3, the Oculus Quest VR HMD was used for all studies (See Chapter 3, Section 3.6. – The VR Computer Hardware Platform).

To meet our specific research requirements, we created content experiences that were used within the research studies. As such, we created custom VR courses within 360VR environments. Using local wi-fi, course content and priming content were made available on demand for pre-loading APKs to be used in specific scenarios and for insertions of specific priming content. (e.g., text ads, images, videos). For data management, software development, environment designs and avatar creation, we have opted to use several unique software tools due to their strengths, familiarity, and our past experiences:

- Campus VR software platform (Campus-vr.com)
- Gaming – Unreal Engine (UE) 4.24
- Scripting Programming UE 4.0 - Blueprint with C++
- API Interface Languages – Python, SQL with JSON
- Video Editing – Adobe Premiere Pro
- Environment modelling – Autodesk Maya 2019
- Avatar creation – Maya, Autodesk Generator
- Sideloading VR software - www.sidequestvr.com
- Custom avatar design software - www.iclone.com
- Results, analysis, and data visualization - Microsoft Excel
- Data management - Postgres SQL
- iclone 7.0 software with motion capture system – www.iclone.com
- Perception Neuron Motion Capture – www.neuronmocap.com.
- Google Forms – www.google.com/forms/

5.2.2. Phase Two Tests

To accommodate more qualitative feedback and to allow us to understand the user experience better, we have simplified the testing process to create one Virtual Reality User Experience (VRUX) questionnaire. While the UX focus is not core to our research questions, we felt that we could derive some insight and understanding for future research. This questionnaire will simplify, aggregate, and provision for key design feedback, learning technology assessment, and various qualitative questions that will help inform our design insights. The open-ended questions at the end of VRUX follow a well-established reflection process that motivates the participants to make sense of their experience as an explicit story (what happened) and an implicit story (how they felt/thought about it). In addition to the STAI (Common materials), we added the following tests to be used in both studies 2a and 2b.

- Phase 2: Virtual Reality User Experience Questionnaire – See Appendix F
- Content Test - Measuring Learning Impact - Appendix G
- PANAS Positive Affect Negative Affect Schedule (Watson, Clark, and Tellegen, 1988) – Appendix H.

5.2.3. Dealing with Data and Anonymity

All published data will be anonymous, referring only to participant number. The data will be stored on a password-protected laptop computer for the duration of the project and until the full completion of the intended published paper. The consent forms and all other paper test documents will be scanned and maintained in a folder on a password-protected laptop computer. All documents that contain personal information (signed informed consent forms, etc…), including the code key, will be kept separate from the de-identified coded data to avoid re-identification. All results summary results logged in spreadsheet format (XLS) will be maintained in a folder on a password-protected laptop computer.

The master list will be an Excel spreadsheet document. It will contain the participant numbers only, which relate to the specific data set. Should participants wish to withdraw within a week, they can only do this by providing the participant number that they were assigned for testing. This master file will be maintained with all other files and results, both scanned and digitized, on the same password-protected computer. All digitized data will be backed up offline for possible future research on the same topic and stored indefinitely.

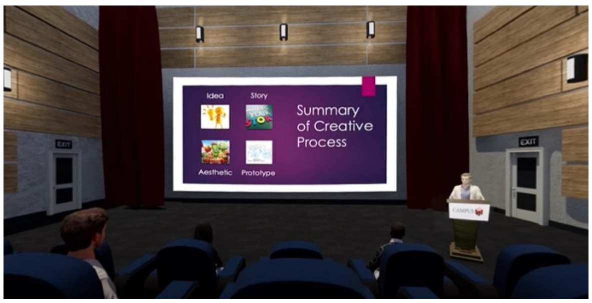
5.3. Study 2a COP with Immersive VR

5.3.1. Overview

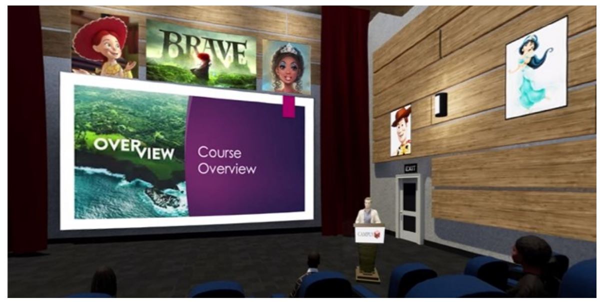
The study, a between-subjects test with one independent variable (Priming context), explored the effectiveness of context-oriented priming (COP) within the ELT cycle. We designed a 27-minute immersive VR course based on the creative process of making an animated movie. Participants were divided into three groups with two prime conditions and one no prime condition. The priming conditions were selected based on the theories such as Experiential Learning (Kolb, 1984) and Situated Learning (Brown et al., 1989; Lave and Wenger, 1991) that emphasize the role of realistic environments in learning. In both prime conditions, we felt that we could create situated learning and abundance priming effects by being "in the role"; immersed in a realistic context that would help students engage by feeling part of a relevant creative experience.

Our no prime environment was a VR classroom theatre based on an existing real-world university classroom. The same VR classroom theatre, when augmented with artifacts and iterating popular animation artifacts, served as our first prime environment. An animation studio that simulated a real-world animation setting was our second prime environment. See Figure 33.

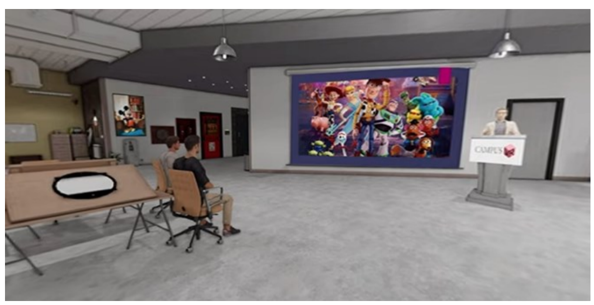
The study used three dependent variables (academic score, user experience, and affective improvement). We also asked several qualitative UX questions that may shed insights into potential effects on motivation, self-confidence, and myriad other influences. Academic score was our main subject and represents the learning effect of the context. It was measured through a short test after the course.



VR Classroom Theatre (No Prime)



VR Classroom Theatre w Artifacts (Prime 1)



Animation Studio front (Prime 2)

Figure 33 Prime and No Prime Conditions

In summary, for Study 2a, the three test conditions were as follows:

1. No Prime – VR Theatre Classroom
2. Prime One – VR Theatre Classroom with iterating visual artifacts
3. Prime Two – VR Animation Studio

There is no research evidence suggesting that context can improve the VR user experience, and based on current understanding (North et al., 1999), we expect that the effect of context is less noticeable to participants. Still, we measured the subjective user experience (UX) satisfaction through a survey to investigate any possible effect. Anxiety and positive affect were also measured using a pre and post-course short-form State Trait Anxiety Inventory (STAI) (Marteau et al., 1992) and Positive Negative Affect Schedule (PANAS) (Watson et al., 1988) surveys, respectively. The STAI measured changes in self-reported anxiety levels while the PANAS changes in both positive and negative affect. The test and the surveys are described in Section 6.5 and in the Appendices.

Based on anticipated priming and situational learning effects, we investigated the following hypotheses:

H1: (a) Prime conditions (both) will improve academic performance over the no prime condition. (b) There will be no significant difference between the two priming contexts.

H2: (a) Prime conditions (both) will improve subjective assessments of UX results compared to the no prime scenario. (b) There will be no significant difference between the two priming conditions.

H3: All three conditions will improve affective state, as it has been shown in our previous work that enjoyable VR experiences can decrease anxiety.

5.3.2. Participants

The study was performed with 51 participants over three conditions (2 prime, 1 no prime, 17 in each condition). Most participants were existing university students in Ontario, Canada, with a balance of adult lifelong learning students with an interest in exploring VR educational technology. Due to COVID restrictions, some of the students (foreign students) were living remotely in other countries. The participants, upon acceptance, were randomly placed in one of three groups corresponding to priming or non-priming scenarios. Participants were paid $20 CDN (via e-transfer) upon completion of the course and the post-seminar questionnaires.

5.3.3 Materials

Participants were provided with an Oculus Quest or Quest 2 VR HMD that automatically loaded the necessary testing software (APK) to the registered participants from the Oculus App Lab developer module. Testing and questionnaires were completed on personal computers or mobile tablets within a standard browser.

The 27-minute seminar "The Creative Process of Making an Animated Movie" was presented in an audio-visual format on a large screen with the professor, an experienced animation creator/producer, located behind the podium. The content consisted of charts and videos that described the creative process, including sections related to the idea, story structure, characters, aesthetics, prototyping, and key creative roles. Popular movie examples were first analyzed (*The Lion King, Monsters Inc*), a new movie idea was presented and walked through each stage of the process to demonstrate how to approach the problem from scratch.

Experiential learning theorists might advocate for a more participatory role in the learning process, but this content is not a hands-on process or skill. This subject matter (digital storytelling) within the community of practice (an animation studio) facilitates peripheral participation in the manner presented in this VR seminar. An expert producer, creator, or showrunner would share ideas and examples while the student writers or interns attend the creative sessions, observe, and listen. The process becomes more collaborative over time, but earlier stages of creative projects typically focus on dispensing information to create a common understanding of the process, culture, roles, and key creative challenges.

To properly isolate and measure the specific context priming effect of the VR environments independent of other priming or ad hoc teaching influences, we opted to create a very simple, predictable teaching format; a lecture presented as a pre-recorded, non-interactive experience. The multiple-choice questions (20) related directly to the content presented in the seminar. Certain questions (15) required the student to apply what they had learned from the theory, while others (5) challenged the student to choose solutions that applied what they had learned from the new movie idea presented. Presented below are two examples; the first, a theory question based on story structure, and the second, an applied question based on a new idea provided. The full content questionnaire is presented in Appendix G.

As discussed in 5.2 (Common Materials), the animation studio used popular movie posters, as would be expected in a typical studio. However, these images did not change or cycle throughout the presentation. The VR theatre classroom with artifacts at the front of the class cycled new images above the main presentation screen every 1-2 minutes, as might be expected in a viewing session or online movie experience but did not cycle the images that were on the side/periphery. See Appendix J for details.

Example Question 1:

Joseph Campbell suggests that the "Hero's Journey" represents myths and rituals that are typically associated with the following in most cultures.

A. Battles between good and evil
B. A story to explain nature and cosmic events
C. The initiation process
D. None of the above.

Example Question 2:

Parallel Parker is a universe hopping animated hero with a big job; to save the world. Based on your new insights, what would make a good logline for our new Parallel Parker movie?

A. Parker is young and fearless and with the help of her intergalactic friends, she is destined to save the Universe.

B. A stressed-out pre-teen, whose main skills are avoiding school and binge-watching TV suddenly realizes that she, along with her cosmic alter egos, must stop an evil supervillain intent on stealing all that is good from the universe.

C. A super villainy interdimensional entity decides to wreak havoc on the universe by sucking up all the positive energy, leaving the rest of the universe to slowly rot.

D. A young, reluctant girl is faced with the decision of her life. Stay home and chillaxe or get off her butt and save the world. When the chillaxing thing goes wrong, she's forced to save the world instead.

The UX survey was not core to our research questions. However, we felt we could glean insights toward future research and design activities, and it was not a major imposition to ask participants to spend an extra 5 minutes providing UX feedback. Nonetheless, the UX survey consisted of 22 questions related to the qualitative aspects of the experience and a further 6 questions related to feelings of presence. The STAI questionnaire presented six multiple-choice questions related to anxiety levels, while the PANAS presented 20 questions in a multiple-choice grading format to assess positive and negative aspects of mood. Example UX questions are presented below. The full UX questionnaire is presented in Appendix F.

The VR environment was easy to use. (5-point Likert scale)

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Other examples (5-point Likert scale)

- The VR experience was well organized.
- I liked the overall idea/theme of the learning environment.
- I found the VR experience engaging
- I would use the VR learning environment again.

An example from the SUS Presence Questionnaire.

Please rate your sense of “being there” in the virtual environment on a scale of 1 to 7, where 7 represents your normal experience of being in a place.

5.3.4. Procedure

Given the limitations caused by the COVID-19 social distancing requirements, we designed a study that could be performed independently by participants in their homes. To enable the process, our apparatus was dropped off and picked up at participant sites by the research team. Proper disinfection rules were followed between each device use. Each participant received a unique participant code which was used to link the pre-seminar and post-seminar questionnaires and results. Participants were also provided with a link to a website **www.toonrush.com/vrtest** which provided the following information.

- Short Video Guide
- Consent Form
- Pre-Post Test Surveys (STAI and PANAS)
- Post Seminar VR User Experience Survey
- Post VR Seminar Content Test

Upon completion of the short video guide (a 2-minute explanation of the process and surveys/tests that we expected the participants to complete). Upon completion of the consent form, participants were asked to complete a short STAI and PANAS survey, then proceed to the immersive VR seminar within the HMD. The VR experience was available as a browser-based immersive 360 video or an app that was loaded automatically onto the VR headset using the Oculus App Lab software distribution function. Upon completion of the seminar, participants returned to the website to complete the post-seminar STAI and PANAS surveys, a multiple-choice test related to the seminar content, and both UX and Presence Questionnaires.

5.3.5. Results

We had a 1x3 experiment design with one independent variable (Priming condition – prime vs. no prime) and three dependant variables (academic performance, UX satisfaction, and affect). After reviewing the outlier data, we opted to eliminate the highest value from each of the three conditions to avoid skewing results based on potentially contaminated data. These high values occurred for academic scores and were more than twice the average. They came from participants who were very familiar with the subject. Hence our sample size was reduced to 16 participant inputs per condition. With an equal number of participants (16), we first conducted a single factor ANOVA test for academic scores and data samples.

After confirming the significance of mean departure within the conditions (p=.0099), we performed a post-hoc t-test with 2 samples, assuming equal variance. We observed significance in both priming conditions compared to the no prime condition, indicating that participant scores in both prime conditions were significantly higher than in the no prime condition: (prime (artifacts) vs. no prime (P=.0023) and prime (animation studio) vs. no prime (P=.0103)). With T stats of 3.05 and 2.44, respectively (>2.0), we were confident with the results. As hypothesized, participant test scores between the two prime conditions were comparable as no significance was observed between these two conditions (P=.258). Final comparison statistics for both priming conditions (VR theatre classroom and Animation studio) compared to no prime conditions are presented in Figures 34 and 35, while comparison statistics for the prime conditions are presented in Figure 36.

Academic Score Comparison		
t-Test: Two-Sample Assuming Equal Variances	***VR Classroom Theatre with Artifacts - Prime***	***VR Classroom Theatre - No Prime***
Mean	11.938	9.688
Variance	4.8625	3.829
Observations	16	
Pooled Variance	4.346	16
Hypothesized Mean Difference	0	
df	30	
t Stat	3.053	
P(T<=t) one-tail	0.0024	
t Critical one-tail	1.697	
P(T<=t) two-tail	0.0047	
t Critical two-tail	2.04	

Figure 34 VR Classroom w Artifacts (Prime) vs. VR Classroom (No Prime)

Academic Score Comparison		
t-Test: Two-Sample Assuming Equal Variances	***VR Animation Studio - Prime***	***VR Classroom Theatre - No Prime***
Mean	11.438	9.688
Variance	4.396	3.829
Observations	16	16
Pooled Variance	4.113	
Hypothesized Mean Difference	0	
df	30	
t Stat	2.44	
P(T<=t) one-tail	0.0104	
t Critical one-tail	1.697	
P(T<=t) two-tail	0.0204	
t Critical two-tail	2.04	

Figure 35 Animation Studio (Prime) vs. VR Classroom (No Prime)

Academic Score Comparison		
t-Test: Two-Sample Assuming Equal Variances	***VR Classroom Theatre with Artifacts - Prime***	***VR Animation Studio - Prime***
Mean	11.938	11.438
Variance	4.863	4.396
Observations	16	16
Pooled Variance	4.269	
Hypothesized Mean Difference	0	
df	30	
t Stat	0.6573	
P(T<=t) one-tail	0.258	
t Critical one-tail	1.6973	
P(T<=t) two-tail	0.516	
t Critical two-tail	2.04	

Figure 36 VR Classroom w Artifacts (Prime) vs. Animation Studio (Prime)

UX Feedback

From our original survey questions, we identified seven questions that analyzed the subjective elements of the VR course experience. While UX feedback (based on a Likert scale of 1 to 5) on qualitative aspects of the experience was positive and the category averages suggested a positive effect for priming, we did not observe significance, in either case, comparing the primes to the no prime condition. Similarly, both PANAS and STAI observed positive changes, most likely because of the immersive VR experience, but we did not observe significance in either case comparing the primes to the no prime condition. The average presence results (based on a 7-point Likert scale) for all conditions were strong (>5). The UX, Affect and Presence results are presented in Figures 37, 38, and 39.

UX Feedback on the Quality of the VR Experience

Question	Artefacts	Studio	No Prime
Helped me Learn	3.6	3.3	3.5
Was Easy to Use	4.4	4.5	4.1
Was Well Organized	4.5	4.6	4.2
I liked the theme	4.3	4.2	4.1
It was engaging	4.0	3.8	3.6
It was fun	3.8	3.9	3.8
I would do it again	4.3	4.1	3.8
Average	4.1	4.1	3.9

Figure 37 Summary of Questions

Affective Results			
Average STAI Scores	**Pre Course**	**Post Course**	**Anxiety Reduction**
Prime Artifacts	9.8	9.2	0.6
Prime Animation Studio	10.5	9.4	1.1
No Prime	9.9	9.1	0.8
Average	10.1	9.2	0.8
Average Positive Affect	**Pre Course**	**Post Course**	**Positive Affect Increase**
Prime Artifacts	28.7	29.1	0.4
Prime Animation Studio	26.2	27.7	1.5
No Prime	27.9	29.9	2.0
Average	27.6	28.9	1.3
Average Negative Affect	**Pre Course**	**Post Course**	**Negative Affect Reduced**
Prime Artifacts	11.3	11.1	0.2
Prime Animation Studio	13.2	10.9	2.3
No Prime	12.3	11.7	0.6
Average	12.3	11.2	1.0
Net PANAS Effect	**Pre Course**	**Post Course**	**Net PA/NA**
Prime Artifacts	40.0	40.2	0.2
Prime Animation Studio	39.4	38.6	-0.8
No Prime	40.2	41.6	1.4
Average	39.9	40.1	0.3

Figure 38 Affective Results (STAI and PANAS)

Presence Results for Immersive Conditions			
Prime Artefacts	**Prime Studio**	**No Prime**	**Average**
5.6	5.5	5.1	5.4

Figure 39 Main Presence Questionnaire Score (scale of 1 to 7)

UX Commentary Feedback

There were dozens of comments that validated designs and/or recommended improvements to the VR experience overall. As expected, very few were specific to the elements of the priming environments. A sample of the more salient comments is presented below.

- Felt real and engaging
- When in VR classroom, you feel totally immersed
- The lack of any interaction made it feel closer to watching a Youtube video, reading a book or watching a virtual conference.
- Seemed like a better version of an online classroom, but without the other people in your class
- Far better than wearing a mask for 2 hours trying to hear what your prof is saying.
- Like a movie theatre.
- It reminds me of the university setting but with the elimination of the anxiety.
- The content was engaging enough that I didn't need to think much about being in VR
- When focused on the lecture I enjoyed the information and was surprised at how much it felt like a real classroom.
- Felt like I was back in a university class in a lecture hall listening to a professor.
- Course in this format is familiar, like any other course (speaker, ppt, podium, seating students), it was easy to feel immersed
- Not quite real enough though better than zoom
- Sometimes images would distort which reminded me that I was in a virtual space rather than a real one.
- Issues of image resolution and inability to take notes.
- It was distracting as I wanted to look around rather than listen.
- I found myself very tired and not able to focus
- During my experience, I'd repeatedly remind myself that as real as it seems it's merely a virtual world.
- I looked around at the other people from time to time, wondered if they were other participants or just placeholders.

A more comprehensive discussion related to the qualitative aspects of the UX is discussed in the post-study reflection (Chapter 6), with details provided in Appendix I.

5.3.6. Discussion

Hypothesis

H1: (a) Prime conditions (both) will improve academic performance over the no prime condition. (b) There will be no significant difference between the two priming contexts.

H2: (a) Prime conditions (both) will improve subjective assessments of UX results compared to the no prime scenario. (b) There will be no significant difference between two priming conditions.

H3: All three conditions will improve affective state, as it has been shown in our previous work that enjoyable VR experiences can decrease anxiety.

Our hypotheses were designed to test the priming effects of our primed VR environments compared to our no prime condition. In reviewing the first hypothesis, both prime conditions observed significant improvement over the no prime condition indicating the primed VR environments did have a significant positive effect on academic scores. There was no significant difference in test score performance between the two priming contexts. Hence, H1a and H1b are both supported.

In reviewing the second hypothesis (UX), neither prime condition demonstrated significance over the no prime condition. Hence, H2a was not supported. The prime conditions observed no significance between themselves with respect to UX results. Hence, H2b is supported. While we considered the possibility that artifacts and situated learning environments might improve affect, resulting in a better-perceived experience, this was not the case. In all conditions, affect did improve, but there was no significant difference between conditions. This was not surprising based on our understanding of the unconscious nature of priming and consistent with the research (North et al., 1999, Bargh et al., 1996).

There was a great deal of relevant feedback provided through the UX study that will inform future design. In general, it was a very positive experience. Most participants felt a strong sense of presence and were sufficiently engaged in the content. That said, image resolution and blurriness appeared to be a major distraction for some. The result of this reduced immersion was a decrease in the presence effect for some. Striving to eliminate issues of blurriness, aliasing, or any image resolution should be a major focus in future environment and character designs for VR spaces. Part of the challenge here was that one “size does not fit all” with VR headsets. Some participants would have benefitted from optical lenses that were specifically made for visually challenged participants. In a non-COVID study, where participants would have had immediate feedback from researchers, some of the visual issues could have been mitigated on the spot. Interestingly, participants seemed to favour the familiar as several comments lauded the similarity to university lecture halls and the overall university learning experience.

All VR experiences were successful in improving affective state of the participants and so H3 was supported. While the PANAS and STAI surveys did not observe differences between testing conditions we had not specifically theorized one way or another for COPs. We did see an increase in positive affect, reduced negative affect, and reduced anxiety in all conditions. This may have been in part due to the novel nature of immersive VR and the specific application content but there was no effect observed that was directly attributable to the priming activities. The PANAS and STAI are also subjective self-assessment tools and potentially more prone to bias and error with smaller numbers of participants, particularly during COVID where the communication between the participants and researchers was limited. Ideally, to properly assess affect and anxiety levels, an FMRI to monitor brain activity and a molecular imaging solution to measure dopamine release and other neurotransmitter levels should be used while content is observed, and the tests are administered. The result of the main presence question on the SUS questionnaire (Usoh et al, 2000) was positive reflecting comparable perceived levels of immersion for all conditions with an average of 5.4 (of 7).

The results were promising and suggest the potential for adding a new learning optimization tool into the educational technology domain. While the "Being Einstein" VR embodiment experiment (Banakou et al, 2018) observed cognitive performance increases due to immersion within an iconic identity, we were curious whether the same positive feelings and performance improvements could be experienced within realistic environments that could make students feel like animation film creators. If VR environments could prime these abundance feelings in this creative environment, arguably the technology could be applied to many other domains that could benefit many other subjects by creating the feeling of being "in role". While the perspective was VR first person, in this study, we did not include an avatar identity embodiment of an aspirational character as we wanted to determine if environmental context alone would be effective, which it was.

As such, determining the effect of COPs for different subjects of study is a promising area of future research. Would science, math, history, or geography related courses gain more from priming activities than the creative arts? Also, exploring other VR-based priming methods: and the combined effect of deploying multiple methods concurrently.

Finally, as accessibility is critical and not everyone can use a VR HMD, assessing the effectiveness of priming in non-immersive VR spaces could inform the design of new or varying priming strategies. We explore this in our next study; Study 2b.

5.4.Study 2b – COP with DVR

5.4.1. Overview

In our previous studies (1a, 1b, and 2a), we investigated and observed:

- VR-based Preparatory Experience Priming (PEP) techniques like VR Gaming (prior to learning activity) can reduce anxiety and increase cognitive availability.
- The effect of Context Oriented Priming (COP) techniques to increase cognitive availability within an immersive VR environment.

Study 2b expanded on the notion of context from what virtual environment the user "sees" to "what physical context the user has". Whereas Study 2a explored COP effectiveness within a fully immersive VR environment from within the HMD, this study compared the better immersive results from study 2 (VR Theatre Classroom with Artifacts) and the no priming condition (VR Theatre Classroom with no augmentation), but in a non-immersive desktop format: DVR. The study can benefit various teaching and learning activities by priming students to feel "in the role" and through this increased engagement, learn more effectively. This study addresses an active research question in VR (value of immersion) and is easier to do during the pandemic (as opposed to comparing VR with in-person contexts), so we believe it is worth doing.

While we also considered using a 2D Desktop version as another environment comparison, we had limited resources. We instead chose to remain focused on the transferability of context priming and the value of immersion within VR environments.

The design of Study 2b is very similar to Study 2 except for the following differences:

- We are comparing DVR with IVR, so we do not require all COP conditions. Our independent variable (priming context) has only two conditions to reduce the number of required participants.
- We do compare the results of both prime and no prime conditions to their identical environments within IVR, which does treat immersion (IVR and DVR) as independent variables as well.

The study, a 2x2 between-subjects test with two independent variables (priming context, immersion), explored the effectiveness of context-oriented priming (COP) within the ELT cycle. We designed a 27-minute immersive VR course based on the creative process of making an animated movie. New participants were divided into two groups with one prime condition (VR classroom theatre with artifacts) and one, no prime condition (VR classroom theatre with no artifacts). Both new test conditions were executed within DVR environments and compared with the IVR results from Study 2a for prime and no prime conditions using the corresponding classrooms.

The study used three dependent variables (academic score, user experience, and affective improvement). Academic score is our main subject and represents the learning effect of the context. It is measured through a short test after the course. As discussed in study 2a, there is no research evidence suggesting that context can improve the VR user experience, and based on current understanding (North et al., 1999), we expect that the effect of context is less noticeable to the users. Nonetheless, we measured the subjective user experience (UX) satisfaction through a survey to investigate any possible effects. Details of the survey and test are described in Appendix F and G. Anxiety and positive affect were also measured using a pre-course and post-course short-form State Trait Anxiety Inventory (STAI) (Marteau et al., 1992) and Positive Negative Affect Schedule (PANAS) (Watson et al., 1988) surveys respectively. The STAI measured changes in self-reported anxiety levels while the PANAS changes in both positive and negative affect. Based on anticipated priming and situational learning effects, we investigated the following hypotheses:

H1:

a) The DVR prime condition will improve academic performance compared to the no prime condition, as observed in our previous IVR study.
b) Because of the simplicity and familiarity of the process, the DVR prime condition will improve academic performance more than the IVR prime condition. We do not expect a significant difference and have no strong reason in favour of either condition (IVR or DVR) but would like to investigate anyway.

H2:

a) The DVR prime condition will improve subjective UX assessment compared to the no prime condition.
b) Because of the simplicity and familiarity of the process, DVR prime condition will improve subjective UX assessment more than IVR prime condition. We do not expect a significant difference and have no strong reason in favour of either condition (IVR or DVR) but would like to investigate anyway.

H3:

(a) The DVR prime condition will improve affect compared to the no prime condition.
(b) Because of the simplicity and familiarity of the process, the DVR prime condition will improve affect more than the IVR prime condition. We do not expect a significant

difference and have no strong reason in favour of either condition (IVR or DVR) but would like to investigate anyway.

5.4.2. Participants

The study was performed with 68 participants over four conditions (17 in each condition). Most participants were existing university students in Ontario, Canada with the balance of adult lifelong learning students with an interest in exploring VR educational technology. Due to COVID restrictions, some of the students (foreign students), were living remotely in other countries. Phase 2 of this study used data from 34 participants from study 2a representing participant from the best prime solution and the no prime participants. The new participants, upon acceptance, were randomly placed in one of two groups corresponding to prime or no prime scenarios. Participants were paid $20 CDN (via e-transfer) upon completion of the course and the post-seminar questionnaires.

5.4.3. Materials

Participants were provided with a Desktop VR link from YouTube VR36*0* to be viewed on a desktop PC or computer tablet. Similarly, testing and questionnaires were completed on desktop PC or mobile tablets within a standard browser.

The 27-minute seminar “The Creative Process of Making an Animated Movie” was presented in an audio-visual format on a large screen with the professor presenting from behind the podium. The content consisted of charts and videos that described the creative process including sections related to the idea, story structure, characters, aesthetics, prototyping and the key roles. Popular movie examples were first analysed (*Lion King, Monsters Inc.*), then as a scaffolding example (Smolucha and Smolucha, 1989), a new movie idea was presented and walked through each stage of the creative process to demonstrate how to approach the problem from scratch.

Our no-prime environment was a VR classroom theatre, as in Study 2a. The VR classroom theatre, augmented with subject matter artifacts, served as the prime condition, the more successful prime from Study 2a based on the Mean Average of the samples. The prime condition would most likely benefit from a situated learning effect as animated movies are often screened in similar screening theatres to simulate an audience experience. See Figure 40.

Figure 40 No Prime (left) vs. Prime (right)

The multiple-choice questions (20) related directly to the content presented in the seminar. Certain questions (15) required the student to apply what they had learned from the theory while others (5) challenged the student to choose solutions that applied what they had learned from the new movie idea presented. Presented below are two examples; the first, a theory question based on story structure, the second, an applied question based on a new idea provided to the student that builds on earlier examples. The full content questionnaire (all 20 questions) is presented in Appendix G.

Example Question 1:

Joseph Campbell suggests that the "Hero's Journey" represents myths and rituals that are typically associated with the following in most cultures.

E. Battles between good and evil
F. A story to explain nature and cosmic events
G. The initiation process
H. None of the above.

Example Question 2:

Parallel Parker is a universe hopping animated hero with a big job; to save the world. Based on your new insights, what would make a good logline for our new Parallel Parker movie?

E. Parker is young and fearless and with the help of her intergalactic friends, she is destined to save the Universe.

F. A stressed-out pre-teen, whose main skills are avoiding school and binge-watching TV suddenly realizes that she, along with her cosmic alter egos, must stop an evil supervillain intent on stealing all that is good from the universe.

G. A super villainy interdimensional entity decides to wreak havoc on the universe by sucking up all the positive energy, leaving the rest of the universe to slowly rot.

H. A young, reluctant girl is faced with the decision of her life. Stay home and chillaxe or get off her butt and save the world. When the chillaxing thing goes wrong, she's forced to save the world instead.

The UX survey consisted of 22 questions related to the qualitative aspects of the experience and a further 6 questions related to feelings of presence. The STAI questionnaire presented six multiple-choice questions related to anxiety levels while the PANAS presented 20 questions in a multiple-choice grading format to assess positive and negative aspects of mood. Example UX questions are presented below.

The VR environment was easy to use. (5-point Likert scale):

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Other examples (5-point Likert scale):

- The VR experience was well organized.
- I liked the overall idea/theme of the learning environment.
- I found the VR experience engaging
- I would use the VR learning environment again.

An example from the SUS Presence Questionnaire:

Please rate your sense of "being there" in the virtual environment on a scale of 1 to 7, where 7 represents your normal experience of being in a place.

Please note, as per Slater (Slater, 2004), there is little value in comparing presence effects between different mediums of immersion. Nonetheless, we do include the questionnaire to determine if there are any priming effects within the desktop conditions.

5.4.4. Procedure

The study, a between-subjects test with one independent variable (Priming context), explored the effectiveness of context-oriented priming (COP) within the ELT cycle. We designed a 27-minute immersive VR course based on the creative process of making an animated movie. Participants were divided into two groups with one prime condition and one, no prime condition (Figure 39).

Given the limitations caused by the COVID-19 social distancing requirements, we designed a study that could be performed independently by participants in their homes. Each participant received a unique participant code which was used to link the pre-seminar and post-seminar questionnaires and results. Participants were also provided with a Youtube *360VR link for the main seminar content and* a link to a website **www.toonrush.com/vrtest** which provided the following information.

- Short Video Guide
- Consent Form
- Pre-Post Test Surveys (STAI and PANAS)
- Post Seminar VR User Experience Survey
- Post VR Seminar Content Test

Upon completion of the short video guide (a 2-minute explanation of the process and surveys/tests that we expected the participants to complete), participants were asked to complete a consent form and a short STAI and PANAS survey, then proceed to the Youtube 360VR link provided to view the seminar. Upon completion of the seminar, participants returned to the website to complete the post-seminar STAI and PANAS surveys, a multiple-choice test related to the seminar content, and both UX and Presence Questionnaires.

5.4.5. Results

We had a 2x2 experiment design with two independent variables (prime condition, immersion) and three dependant variables (academic performance, UX satisfaction, and affect). While this test only sampled two conditions, we also wanted to test the results against results in Study 2a with the comparable immersive environments. After reviewing the outlier data, we opted to eliminate the highest value from all four conditions (two immersive and two desktop) to avoid skewing results based on potentially contaminated data. These high values occurred for academic score and were more than twice the average. They came from participants who were very familiar with the subject matter. Hence our sample size was reduced to 16 participant inputs per condition, 64 in total. The independent test scores for all four condition groups are presented in Figure 41.

With an equal number of participants (16) we conducted a two factor ANOVA with independent samples to test for differences in academic score (Figure 42). After confirming a significant difference in means between columns (Prime vs. No Prime) (p=.0002), we used a Tukey HSD post-hoc test at (.05) to determine significance for the various combinations. For Tukey test results, see Figure 43. Both IVR and DVR prime conditions compared to their no prime conditions were significant whereas prime IVR compared to prime DVR and no prime IVR compared to no prime DVR were nonsignificant.

Test Results for IVR/DVR Study for 2x2 Anova (Prime Condition, Immersion)			
IVR Prime	IVR No Prime	DVR Prime	DVR No Prime
10	10	11	9
12	8	12	8
12	12	7	11
13	10	10	12
16	10	14	9
13	7	11	9
10	11	9	12
11	10	12	8
13	11	14	9
11	9	10	8
8	10	11	7
16	8	13	11
13	7	15	11
11	7	13	11
13	11	11	6
9	14	11	14

Figure 41 2x2 ANOVA Test Data for Academic Score

Anova: Two-Factor for Independent Samples						
SUMMARY	Prime	No Prime	Total			
IVR						
Count	16	16	32			
Sum	191	155	346			
Average	11.938	9.688	10.813			
Variance	4.863	3.829	5.512			
DVR						
Count	16	16	32			
Sum	184	155	339			
Average	11.5	9.6875	10.59			
Variance	4.133	4.496	5.023			
Total						
Count	32	32				
Sum	375	310				
Average	11.719	9.688				
Variance	4.402	4.028				
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.7656	1	0.7656	0.1768	0.6756	4.0012
Columns	66.0156	1	66.0156	15.2454	0.0002	4.0012
Interaction	0.7656	1	0.7656	0.1768	0.6756	4.0012
Within	259.8125	60	4.3302			
Total	327.3594	63				

Figure 42 Two Factor ANOVA (Prime Condition, Immersion)

Tukey HSD Test [.05]		Rows	HSD(.05) = 1.04	
		Columns	HSD(.05) = 1.04	
Results Table Comparison		Delta Means	Tukey	Result
IVR Prime vs No Prime		2.28	1.04	significant
DVR Prime vs No Prime		1.8	1.04	significant
Prime IVR vs Prime DVR		0.438	1.04	nonsignificant
No Prime IVR vs No Prime DVR		0	1.04	nonsignificant

Figure 43 Tukey HSD Test Results

From our original UX survey questions, we identified seven questions that analysed the subjective elements of the VR course experience (Figure 44). While UX feedback on qualitative aspects of the experience was positive and the category averages suggested a positive effect for priming, we did not observe a significant difference comparing the primes to the no prime conditions. See Figures 45 and 46 for details on PANAS, STAI, and presence. To be conclusive, we performed 2 Factor ANOVA tests with independent samples on both PANAS and STAI deltas with no significant result.

The average presence result for the desktop VR was 4.2 (of 7), with no significant difference observed between conditions. We will not compare the result of the presence questions between immersive and non-immersive conditions as per Slater (Slater, 2004), who suggests that comparing presence variables for varying levels of immersion (e.g., Immersive vs. Desktop) has been shown to yield confusing and often misleading results. As such, we do not compare the results of presence here. Nonetheless, there was no significant difference observed in the comparable UX or affective data between the immersive and desktop conditions.

UX Feedback on Quality of the VR Experience		
Question	**Desktop Artefacts**	**Desktop No Prime**
Helped me Learn	3.2	3.2
Was Easy to Use	4.3	3.8
Was Well Organized	4.2	3.7
I liked the theme	4.2	3.7
It was engaging	3.5	3.2
It was fun	3.5	3.4
I would do it again	4.2	3.6

Figure 44 Summary of UX Questions (out of 5)

Affective Results for Desktop Conditions				
Average STAI Scores		**Pre Course**	**Post Course**	**Anxiety Reduction**
Prime Artifacts		9.6	9.4	0.2
No Prime		9.6	9.6	0.0
Average		9.6	9.5	0.1
Average Positive Affect		**Pre Course**	**Post Course**	**Positive Affect Increase**
Prime Artifacts		30.1	30.0	-0.1
No Prime		27.6	27.4	-0.2
Average		28.9	28.7	-0.2
Average Negative Affect		**Pre Course**	**Post Course**	**Negative Affect Reduced**
Prime Artifacts		11.6	11.1	0.5
No Prime		12.9	12.1	0.8
Average		12.3	11.6	0.7
Net PANAS Effect		**Pre Course**	**Post Course**	**Net PA/NA**
Prime Artifacts		41.7	41.1	-0.6
No Prime		40.5	39.5	-1.0
Average		41.1	40.3	-0.8

Figure 45 Affective Results (STAI and PANAS)

Presence Results for Immersive Conditions		
Prime Artefacts	**No Prime**	**Average**
3.9	**4.5**	**4.2**

Figure 46 Main Presence Questionnaire

Digging further into the qualitative UX data, we did observe a significant positive impact on both motivation and self-confidence through the UX feedback questionnaire comparing prime to no prime conditions. The post-test UX question assessing the priming effect of motivation to participate in creating an animated movie observed significance, in both IVR ($p=.0285$) and DVR ($p=.0242$) scenarios compared to the control conditions. See Figure 47.

Similarly, the post-test UX question assessing self-confidence in their ability to create an animated movie observed a significant difference comparing primes to no prime conditions in both IVR (p=.0067) and DVR (.0282) scenarios (Figure 48).

Motivation to participate in creating an animated movie				
t-Test: Two-Sample Assuming Equal Variances	IVR Prime	IVR No Prime	DVR Prime	DVR No Prime
Mean	4	3.1875	3.56	2.6875
Variance	0.93	1.7625	1.46	1.4292
Observations	16	16	16	16
Pooled Variance	1.35		1.45	
Hypothesized Mean Difference	0		0	
df	30		30	
t Stat	1.98		2.06	
P(T<=t) one-tail	0.0285		0.0242	
t Critical one-tail	1.7973		1.6973	
P(T<=t) two-tail	0.057		0.048	
t Critical two-tail	2.04		2.04	

Figure 47 Motivation on 5-point Scale (A-E)

Self Confidence in your ability to create an animated movie				
t-Test: Two-Sample Assuming Equal Variances	IVR Prime	IVR No Prime	DVR Prime	DVR No Prime
Mean	3.6875	2.625	2.8125	2.0625
Variance	0.7625	1.85	0.9625	0.729
Observations	16	16	16	16
Pooled Variance	1.306		0.846	
Hypothesized Mean Difference	0		0	
df	30		30	
t Stat	2.629		2.3066	
P(T<=t) one-tail	0.0067		0.014	
t Critical one-tail	1.6973		1.6972	
P(T<=t) two-tail	0.013		0.0282	
t Critical two-tail	2.04		2.04	

Figure 48 Self-Confidence on 5-point scale (A-E)

UX Commentary Feedback

There were myriad comments that provided feedback. In general, the immersive conditions from Study 2, seemed to generate more favourable commentary while the presence questions related to the desktop conditions may have confused the participants somewhat. A sample of the more salient comments are presented below.

- It was clear that I was not actually in the environment, but it did still feel like I could interact with and explore the environment.
- Watched on a desktop
- Somewhat, it feels like you are in attendance
- I am not in the virtual environment, I am using it as a medium to access the learning.
- I felt more immersed in the beginning when I was first in the environment and getting to explore it like my own classrooms in the past. However, as my interest in the subject matter waned, I think so too did my level of immersion.

- I think the clicking of the mouse may have reminded me.
- felt real and engaging
- Unlike my classes earlier today, it feels like a I went to a theater like place today.
- Enjoy any type of enhanced learning.
- Interacting with friends and classes online, it felt sort of like a place that my friends could exist in when I'm not seeing them in person.

5.4.6. Discussion

Hypotheses

H1:

c) The DVR prime condition will improve academic performance compared to the no prime condition as observed in our previous IVR study.
d) Because of the simplicity and familiarity of the process, the DVR prime condition will improve academic performance more than the IVR prime condition. We do not expect a significant difference and have no strong reason in favour of either condition (IVR or DVR) but would like to investigate anyway.

H2:

c) The DVR prime condition will improve subjective UX assessment compared to the no prime condition.
d) Because of the simplicity and familiarity of the process, DVR prime condition will improve subjective UX assessment more than IVR prime condition. We do not expect a significant difference and have no strong reason in favour of either condition (IVR or DVR) but would like to investigate anyway.

H3:

(c) The DVR prime condition will improve affect compared to the no prime condition.
(d) Because of the simplicity and familiarity of the process, DVR prime condition will improve affect more than the IVR prime condition. We do not expect a significant difference and have no strong reason in favour of either condition (IVR or DVR) but would like to investigate anyway.

Our hypotheses were designed to test the priming effects of our primed desktop VR environment compared to our no prime condition and to compare the relative effect of immersion. While IVE has the advantages of full immersion and novelty, DVR is more familiar and less complicated. Existing literature is not conclusive on the effect of immersion and superiority of IVR or DVR. So, our research adds to an increasing body of research on the subject. In reviewing the first hypothesis, the DVR prime condition observed significant improvement over the no-prime condition. This is consistent with the previous IVR study Hence, H1a is supported. The DVR prime condition did not improve academic performance more than the IVR prime condition. While we did not expect a significant result, we were curious whether the simpler process might create a better result. Hence H1b is not supported by the data. In reviewing the second hypothesis, the DVR prime condition did not improve subjective UX assessment, nor did the DVR prime condition improve affect more than the IVR prime condition. Hence, neither H2a nor H2b are supported. Similarly, in reviewing the third hypothesis, the DVR prime condition did not improve affect, no did the DVR prime condition improve affect more than the IVR prime condition. Hence, neither H3a nor H3b are supported.

The feedback, while positive and supportive of the experience in the desktop condition did not yield and major insights other than UX commentary that felt functional but not emotional. The feelings of presence in the desktop conditions observed by the SUS Presence Questionnaire (Usoh et al., 2000) were not high; 3.9 (prime) and 4.5 (no prime) with no significant difference observed between conditions.

While these studies are small numbers, we clearly observed that priming worked in all priming conditions in both immersive and desktop environments. There appeared to be no significant difference in affect between prime and no prime conditions in either medium, but we did observe that the effects of priming appeared to be experienced more favourably with immersion compared to desktop environments. The commentary for the immersive participants seemed to be more positive and awestruck when compared to the desktop VR conditions.

Top 3 Desktop VR comments:

- It was clear that I was not actually in the environment, but it did still feel like I could interact with and explore the environment.
- felt real and engaging
- it feels like you are in attendance

Top 3 Immersive VR comments:

- When in VR classroom, you feel totally immersed
- When focused on the lecture I enjoyed the information and was surprised at how much it felt like a real classroom.
- It reminds me of the university setting but with the elimination of the anxiety.

While this did not translate into a learning effect beyond the priming results, research on the affective elements of learning between immersive and desktop conditions warrant further study. It is very possible that the immersive activity served as somewhat of an escape, allowing students to filter out everything from their real-world environments including smartphone interruptions. In the desktop conditions, students remained subjected to influences within their real-world environments, hence it may have felt like less of an escape.

A more comprehensive discussion of the UX results is discussed in the post-study reflection (Chapter 6) with details in Appendix I.

6. Research Reflections

When we started this four-year journey, we were motivated to identify and understand solutions to challenges that we were observing in the university student population; more specifically, scarcity mindset, a self-defeating mode of thinking that appropriates key cognitive bandwidth that students require for learning. While anxiety statistics stimulated our initial interest, our research suggested a more general scarcity context for the mindset we were observing.

While we were not sure why such anxiety was being observed, we were quite certain that simply "turning everything off" was not the answer and if we better understood the context of the problem, we might be able to identify a solution that exploited technology and digital media to create healthier mindsets and better learning outcomes for students. Hence, we embarked on research to understand and frame this problem in a way that we could address it prescriptively with a technology design, methodology, and best practice framework.

6.1. Key Insights

We read across many domains that might affect the student experience: learning theories, cognitive psychology, behavioural economics, and technology innovations that we might apply to a theoretical framework. Our research focused on how students learn, how they think and how they use technology and media. Interestingly, our research revealed that there were already multidisciplinary solutions emerging that were solving similar yet more dire problems. For example, Cognitive Based Therapy (CBT) forerunners were using Virtual Reality exposure therapy (VRET) solutions to address habituation needs of CBT (Carl et al., 2019). Further, there was an increasing recognition of the importance of mental mindsets emerging from the domains of learning theory, behavioural economics, and cognitive psychology (Mullainathan and Shafir, 2013; Dweck, 2008; Kahneman, 2011). Growth mindset, for example is a form of abundance thinking that induces feelings of sufficiency and a perceived potential for academic growth in new learning activities. In sports, there is a phrase that refers to the importance of proactivity: "The best defence is a good offence". Hence, as much as we strive to eliminate scarcity thinking, we could be equally proactive in finding solutions that induce abundance thinking in a systemic, repetitive manner.

Key Reflective Insight One

Expand our Scarcity and Abundance Model to include other proactive strategies that would help induce abundance thinking. Include repetition as a key element to transform the current priming model to an iterative process able to create and test meaningful long-term results. The revised priming model is reflected in section 6.2.

While interdisciplinary dots were already connecting in business and medical domains with VRET and other simulation techniques, what became apparent in 2019 was the improved technological ability of immersive VR to alter perception (self and environment) using priming tools to constructively address student mindset challenges. There is already an emerging field of research aiming to prove the viability of scalable mindset interventions. (Yeager et al., 2016, Paunesku et al., 2015). Immersive VR affords the ability to create scalable, realistic, digital environments and simulations that could affect perception and induce desired abundance or growth mindset effects. Further, these scalable mindset priming interventions can be personalized to specific learners' needs, no different than students with ASD or related learning challenges that require very specific antecedent conditions in their learning environments (Conroy et al., 2005; Kern and Clemens, 2007).

What is more, the profound nature of supraliminal priming offers an effective and non-invasive method of positive intervention: a guiding hand. Hence our VR-based priming intervention model can emerge as an unobtrusive, repetitive, cyclical implementation to reduce scarcity thinking by using priming methods PEP and COP, deployed throughout an educational cycle with proven priming techniques and within VR.

In our first four studies (1a, 1b, 2a, 2b) we tested preparatory priming and context priming validating the effectiveness of the priming effects in both cases. While traditional research suggested that these desired performance effects would prevail, we were unsure of the transferability to these digital environments (both immersive and non-immersive) and within the specific situated learning contexts. Hence these findings were novel. In the PEP case, immersive gaming proved an effective psychological elixir to reduce anxiety and increase positive affect prior to the learning experience. Similarly, the COP case used situated learning environments and subject matter artifacts to prime the desired learning effects in both IVR and DVR that would be expected within a situated learning environment.

While self-reported tests related to anxiety and positive affect did not observe increases compared to no prime conditions, there appeared to be a motivational and self-perception effect. In study 2b (COP/IVR vs DVR), UX questions (5 and 6), while qualitative in nature, observed a difference in self-reported motivation and increased self-confidence to embark on further challenges related to making animated movies compared to no prime conditions. While we did observe a similar effect in study 2 (COP IVR), it was only observed in the artifact prime condition. Nonetheless, this suggests that increased motivation and improved self-confidence might be the mediating emotional variable in situated VR learning environments.

Key Reflective Insight Two

Consider expanding our theoretical model to accommodate priming strategies related to motivation.

Further, while we did experience one iteration in our tests, validating the effectiveness of our context priming within experiential and situated learning environments suggests that we might consider a broader context in this regard as well. Perhaps the proposed iteration requirements (insight one) could be applied directly to the ELT cycle: an iterative process that facilitates concrete learning, reflection, abstract generalization, and experimentation phases of experiential learning. As the VR-based priming process enacts, the cycle continues to repeat as the learner's conceptual worldview is repeatedly reflected upon, reconstructed, and refined.

The ELT cycle can provide timed trigger points where various priming interventions may be activated that may occur before, after, or during the experience. The reflection stage of learning generally follows the concrete learning experiences but may also occur at any stage in the learning journey. Given that reflection is often overlooked or diminished in favour of more "action-oriented" learning (Di Stefano et al., 2016), perhaps we should include a priming strategy that initiates reflective thinking within the ELT process as well.

Key Reflective Insight Three

Consider expanding our theoretical model directly into the ELT cycle and further; exploit a new priming opportunity related to reflection within the ELT cycle.

6.2. Combined Insights for an Improved Model

Given the insights (above), a revised priming model called Cyclical Priming Methodology (CPM) is proposed that accommodates the following key insights. Further, we propose a more specific nomenclature be used for the VR implementation of CPM to describe the VR priming intervention strategy: VR-based Educational Priming (VREP).

- Expand our Scarcity and Abundance model to include more proactive, repetitive strategies to facilitate systematic mindset transformation.
- Based on the promising UX results feedback comparing situated learning environments, deploy priming strategies related to motivation.
- Apply the CPM and VR-based Educational Priming (VREP) directly into the ELT process and include a reflective prime to further exploit the existing ELT cycle.

While traditional priming methods mostly focus on preparatory (early) interventions and context-oriented interventions, the enhanced CPM (Figure 49) proposes the following four unique priming intervention techniques throughout the learning cycle:

- PEP - Pre-Learning or Preparatory Experience Prime
- COP - Context Oriented Prime
- REP - Post-Learning or Reflective Experience Prime
- MOP - Motivation Oriented Prime

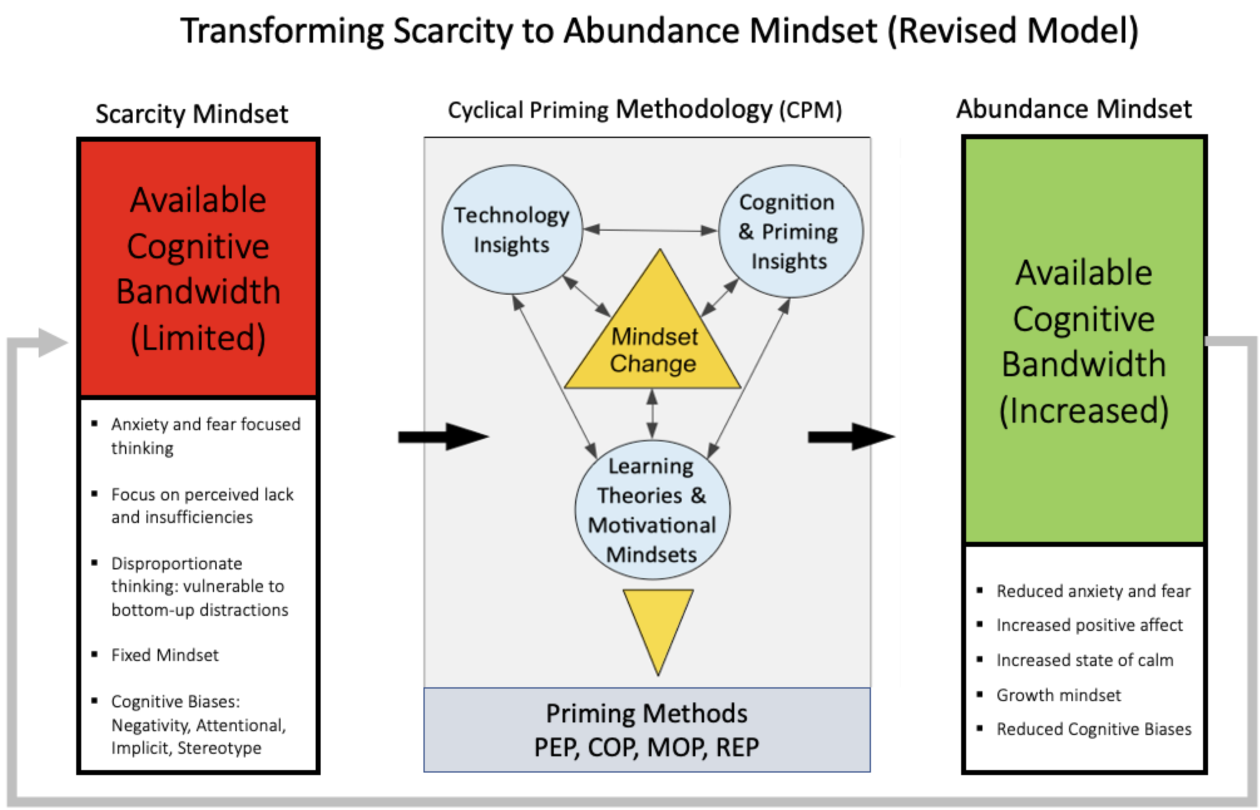


Figure 49 CPM (includes MOP and REP)

PEP represents the most common form of priming that is usually done prior to the many activity (Dennis et al., 2013; Gyllen et al., 2021). We incorporated the other methods to include the entire learning cycle: MOP keeps the learners motivated during the learning activity (Humphreys and Revelle, 1984; Schunk and Pajeres, 2003; Bandura, 1977); REP allows reflection and sense-making after the activity which is an integral part of experiential learning cycle (Kolb, 1984); and finally, COP creates a realistic and positive context which is essential based on situated learning theories (Brown et al., 1989; Lave and Wenger, 1991).

These interventions allow priming throughout the learning cycle. An example of a pre-learning or preparatory experience prime (PEP) might be a short game, nature walk, or funny story. A post-learning or reflective experience prime (REP) might be a prompt that asks the student to consider the relevance to a real-world situation that they may have experienced. The reflective activity could help the student understand the relationship between the learning content and real-world challenges. Motivation Oriented Primes (MOP) would be delivered within the context of the learning experience and could be as simple as a “fun fact” or a motivational suggestion delivered within learning modules as a way of presenting a challenge. A MOP could also be a growth mindset reminder like, “Did you know that 90% of students have rated this module as critical to their development” or a recognition message with stars (e.g., “Hurray, you’ve completed another section, You rock! Only 2 more sections to complete this learning module”). Finally, a Context Oriented Prime (COP) could be a customized situated learning environment, a creative environment that allows the student to feel more creative, an awe-inspiring mountain scene, or the sound of a stream.

If we were to apply these CPM priming techniques (PEP, REP, MOP, and COP) into the ELT cycle (Kolb, 1984) it would be applied as illustrated in Figure 50. Note that the primes are positioned for insertion prior to the actual experience (PEP), during the actual experiences (MOP and COP), and then during the post-experience reflective activity. It should be noted that while reflective experience prime (REP) would initially occur just after the concrete learning experience, the process of reflection can be primed at any time within the ELT cycle: after abstract conceptualization or active experimentation.

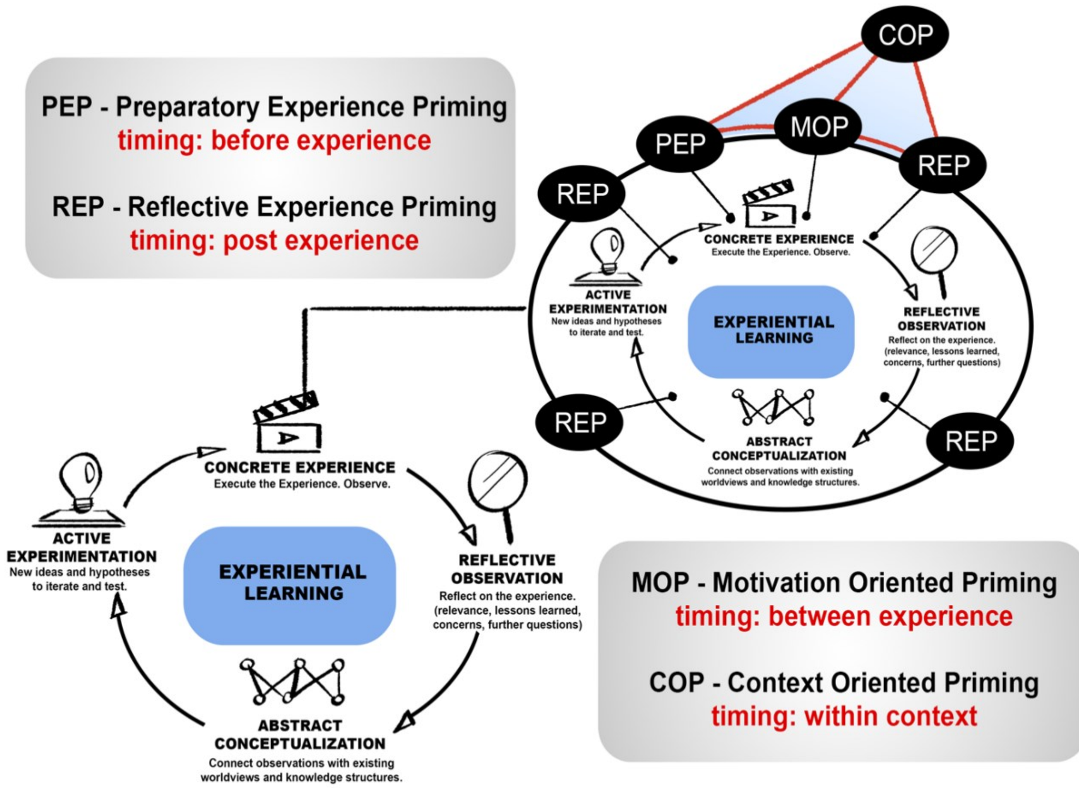


Figure 50 Apply CPM/VREP to the ELT Cycle (Kolb, 1984)

ELT views learning as an iterative process where students continually reconstruct experiences by learning and relearning. Even if cognitive priming strategies ignite only small changes in mental state, if the timing is right, these mental jolts may be enough to improve engagement for the duration of the learning process. These strategic priming interventions, executed within the learning experience, must appear seamless and natural to the student. This will require carefully designed primes and an enabling technology platform.

Enhanced Virtual Reality Educational Priming (VREP)

Finally, The VREP model must be extended to accommodate the additional priming interventions, MOP, and REP. A revised model of VREP demonstrates the applications of PEP, COP, MOP, and REP within a VR world, as illustrated in Figure 51.

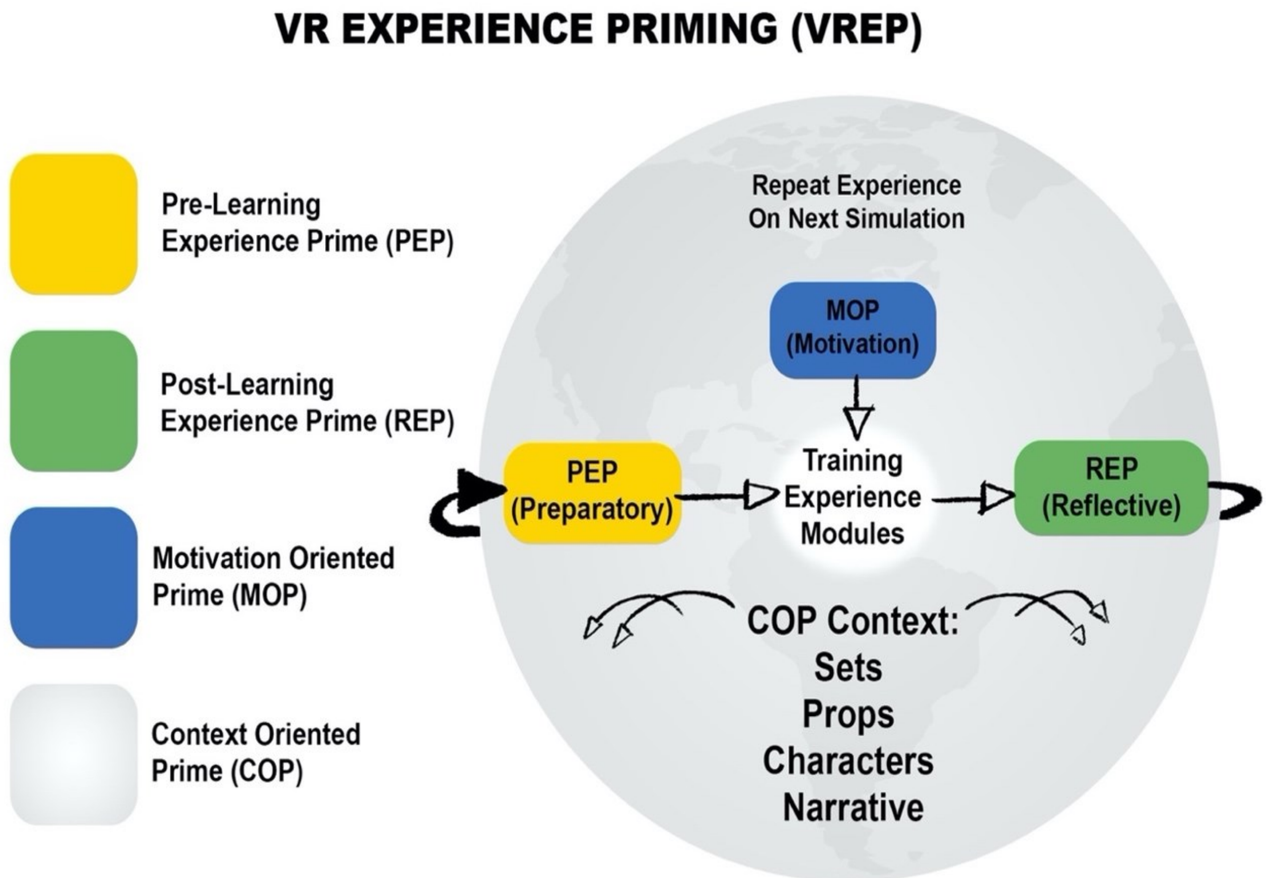


Figure 51 - VREP into the ELT Cycle

6.3. Further UX Analysis

In study 2 (a, b), we expanded the number of UX questions to gain more insight into the qualitative aspects of the experience. The UX questions were made up of qualitative assessments based on Likert scales and text-based answers.

A full summary of the results is presented in Appendix I. Some of the salient insights we discovered follow:

- The overall self-perceived differences in the UX were negligible in most cases between prime and no-prime conditions except for assessments of motivation and self-confidence. This point is discussed in chapter 5 and above (reflection).

- In general, the participant experience was positive, and students felt that the experience of being in a virtual space that simulated or felt like a real university classroom felt calming and effective.
- Concerns raised included the reduced the feelings of presence that were related to blurriness and aliasing. Minimizing these effects are critical to ensuring the viability for this experience for all.
- 73% of participants felt that VR did increase overall engagement (scores of 4, 5, on the Likert 5-point scale)
- 66% of participants felt motivated to learn more because of the VR experience (scores of 4, 5, on the Likert 5-point scale)
- 49% of participants felt motivated to create something because of the VR experience (scores of 4, 5, on the Likert 5-point scale)
- 84% of participants felt that VR was easy to use (scores of 4, 5, on the Likert 5-point scale)
- 68% felt that VR was fun (scores of 4, 5, on the Likert 5-point scale)
- 63% found VR very engaging (scores of 4, 5, on the Likert 5-point scale)
- 33% of participants experienced some level of fatigue or nausea, while 3% experienced more significant fatigue or nausea

6.4. Additional Lessons Learned

In late 2018 and 2019, well into our study cycle, new research studies related to avatar embodiment (Banakou et al., 2018, Banakou et al., 2020) demonstrated the powerful psychological effects on self-perception and academic performance. Interestingly, while being embodied in the Einstein avatar yielded far greater results than the control conditions, the largest effects were attributed to those individuals that tested with lower self-esteem. While changing the context of the avatars fell within our COP methods of priming, we did not have the bandwidth to explore this area. That said, this type of character context-altering strategy could have a very profound effect on self-perception and academic performance for those most vulnerable, with low self-esteem, or stereotype threat. Hence, we recommend further study, but also that we adopt these insights in the design of future VREP models, affording participants more agency and autonomy in using custom avatars that they may feel more comfortable with. This would expand our COP model to include a more comprehensive set of possible priming tools and intervention techniques.

Our research was focused primarily on potential technology interventions within the learning process, and very little consideration was given to content or narrative. This was simply out of scope for our research but incorporating narrative storytelling, gamification, and the use of mystery-solving challenges an area of learning that could weave nicely with our technology and augment the existing VREP model.

Finally, McLuhan's "The medium is the message" is evident with VR technology. Combining VR technology with progressive intervention strategies should create positive results beyond the immediate experiences. VR solutions are already changing the world by improving mental health with VR Exposure Therapy (Carl et al., 2019). We are at the precipice of enabling positive social changes by bringing people from different cultures and geographies together in virtual spaces to learn, interact, and grow. These multi-cultural exposures should contribute to the overall ethos, acceptance, and understanding of each other. This is all very positive and bodes well for thoughtful priming strategies within diverse, globally connected communities.

7. Conclusion

Our research was motivated to find technology solutions to minimize the impact of scarcity thinking (anxiety, negative biases, stereotypes, and negative mindsets) a counterproductive mindset that diverts precious cognitive resources needed for important activities like learning. Through the lens of *Scarcity Mindset*, we conducted a multi-disciplinary literature analysis of innovative ideas in cognitive science, learning theories and mindsets, and technology approaches suited to address the challenges of scarcity thinking.

We identify priming strategies that help transition students to a more positive mental mindset and a theoretical framework called Cyclical Priming Methodology and a VR implementation of CPM called VREP that proposes priming interventions throughout the experiential learning cycle. These intervention strategies focus on student preparation and the context of the learning environment.

Our high-level research questions and our answers were:

- Can empirically demonstrated priming techniques transfer to a digital realm like VR?
    - Yes
- If transferable in general, what types of priming strategies and methods are most effective and how, and when should they be applied?
    - We suggested and successfully tried different preparatory and context primes.
- What is the real value of VR immersion and presence in our proposed interventions?
    - We had mixed results for the effect of immersion.

Finally, were the differences that we observed impactful or meaningful? Yes, we believe they were meaningful and impactful. While we cannot assert conclusively that VR games, VR meditation, or changing the context of the learning environment can improve academic performance, the research suggests that there are most likely positive psychological priming effects and increased cognitive bandwidth available for learning. This is not surprising, as the chosen activities have real-world analogs or examples that consistently make sense. Priming (or preparing one's mind) with a game or deep breathing exercise may be the cognitive equivalent of stretching before a fitness event. Designing a room to elicit positive feelings could be compared to the process of preparing a physical space for a special event (e.g., Halloween, Ramadan, Christmas, Hanukkah, Thanksgiving, etc, …). These comparisons are perceptible, and now, they appear to be transferable to VR.

7.1. Summary of Findings

Our phase one studies (Study 1a and 1b) observed a significant effect in anxiety reduction and increased cognitive bandwidth for VR gaming, and while we did observe a reduction in anxiety for our meditation activities, we did not observe improved academic performance. Hence, we conclude that preparatory priming interventions are transferable to the digital realm but do depend on the specific priming method. VR gaming was more effective than meditation in our goal of increasing cognitive bandwidth and academic performance.

Our phase two studies (Study 2a and 2b) compared three different contexts for an animation course in immersive VR (no prime: plain lecture theatre, prime 1: lecture theatre with animation artifacts, and prime 2: animation studio). For study 2a, we observed a significant difference in both priming conditions compared to the no prime condition. While the mean observed was slightly higher in the animation artifacts condition, there was no significant difference observed between the two prime conditions. Study 2b used the more successful primed environment from study 2a (based on mean as tiebreaker) and compared the IVR and DVR prime with the no prime environment scenarios. We observed significance in academic performance for both the IVR and DVR conditions compared to the no prime conditions.

For study 2a, UX feedback on qualitative aspects of the experience was positive, but we did not observe significance in either case comparing the primes to the no prime condition. Similarly, while both positive affect and anxiety measures observed positive changes most likely due to the immersive VR experience, we did not observe a significant difference in either case when comparing primes to the no prime condition. However, from our UX questions, we did observe an increase in both motivation and self-confidence with the theatre/artifacts prime when compared with the no-prime condition. We did not observe a similar effect with the second prime (animation studio). Hence, we concluded that COP works for increasing cognitive availability but did not decrease anxiety or increase positive affect and the theatre/artifacts environment did increase motivation and self-confidence.

For study 2b, we did observe an increase in both motivation and self-confidence for both IVR and DVR primed environments compared with the no-prime conditions. We also compared the identical prime and no prime environments within immersive and desktop environments to determine if there was any effect attributable to full immersion alone. Neither condition (prime or no prime) observed a significant difference between immersive and desktop VR, suggesting that immersion alone is not the prime determinant of the priming effect.

7.2.Directions of Future Research

We have gained a fair understanding of **"Why"** priming is effective and **"How"** to apply the priming techniques (at least in "analog" situations). But we have yet to gain an understanding of the "Who, What, Where and When, and How Long". Additional research questions beyond the scope of this research but related to these challenges are:

- **Who** are the most sensitive or suitable to the priming interventions? Are these techniques equally impactful to a general student population or does effectiveness vary based on anxiety levels, self-perception, or specific personality types?
- **What** subject matter content is most sensitive and favourable to these priming techniques? Are these techniques best deployed in the context of complex material (e.g., biology or cognitive neuroscience), logic-based, or perhaps sociocultural content (e.g., History, Geography, Anthropology, etc ...)?
- **Where** (in which contexts and environments) are these priming techniques best applied (e.g., nature environments, creative environments, historical settings, specific geographies, or landmarks that evoke emotional responses)?
- **When** is "prime time"? At what point in the learning experience is the most appropriate and effective moment of opportunity? How would we apply these various methods within the ELT cycle? Can we have priming during and after the main task? How frequently should priming be applied?
- Do these priming interventions have a long-term impact? Are they sustainable? We chose to focus on studying the priming effects within one experience, so the effects of repetition were beyond the scope of this research. Acknowledging that priming is a subtle, ephemeral process, further study to determine the longer-term accumulative or degenerative effects would be a valuable contribution to further research.
- Investigating the effect of various types of short games and gameplay features as priming methods (e.g., Cognition, Problem-solving or physical movement in 3D)
- We lack insights into the impact on measurable variables like arousal, valence, agency, persistence, and happiness. What would the impact be on these variables in different classroom scenarios?
- Real-time weather and visual effects could be explored to assess the impact of light, dark, rain, wind, snow and their associated sounds and their impact on mood and other emotional variables.
- Investigating VR-based meditation and the role of agency (guided vs. autonomous) in assessing anxiety levels and perceived self-control (growth vs. fixed mindsets).

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Website – Sideloading VR software apps, www.sidequestvr.com

Website – Textual frequency visualization, www.wordclouds.com

Website – Video Editing – Adobe Premiere Pro, www.adobe.com

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Appendix A – Acronyms

User Tests

- STAI – State Trait Anxiety Inventory
- UCMRT – University of California Matrix Reasoning Test
- VRUX – Virtual Reality User Experience Questionnaire
- WBLT – Web-based Learning Technology Scale
- ANOVA – Analysis of Variance
- FMRI – Function Magnetic Resonance Imaging
- HA/LA – High Anxiety/Low Anxiety
- PANAS – Positive Affect and Negative Affect Schedule

Priming Strategies

- PEP – Preparatory Experience Prime
- REP – Reflective Experience Prime
- MOP – Motivation Oriented Prime
- COP – Context Oriented Prime

Theoretical Models

- CPM – Cyclical Priming Methodology
- VRET – Virtual Reality Exposure Therapy
- VREP – Virtual Reality Experience Priming

Learning Theories

- SDT – Self Determination Theory
- ELT – Experiential Learning Theory
- SEL – Social and Emotional Learning
- SLT – Situated Learning Theory
- GM – Growth Mindset
- SET – Self Efficacy Theory

Technology Terms

- VR – Virtual Reality
- IVR – Immersive Virtual Reality
- DVR – Desktop Virtual Reality
- NIVR – Non-immersive Virtual Reality
- HMD – Head Mounted Device
- APK – Android Package
- AI – Artificial Intelligence

- UE – Unreal Engine
- ML – Machine Learning
- IVA – Intelligent Virtual Agent
- UX/UI – User Experience/User Interface
- CVG – Casual Video Games

Other

- ACHA – American College Health Association
- ASD – autism spectrum disorder

Appendix B – Research Summary

Thesis Study Summary

Studies	Research Intent	Tests	Priming Method	Type of Study	Content	Target Users	Type of Study	Compensation
Phase 1 - Answering the main research question: Does priming work and is it transferrable to VR? Focus on PEP: RQ1a: For VR Gaming; RQ1b: For Meditation.								
Study 1a	Determine impact of VR Gaming experience (PEP) on anxiety reduction and cognitive availability.	Preliminary UCMRT and STAI	Preparatory Experience Priming (PEP)	Within Subjects VR Gaming Prime (PEP) vs No Prime to improve cognitive performance	Beat Sabre Game	Informal test - 10 Participants between 16 and 50.	Within Subjects	no compensation
Study 1b	Compare the impact of VR Gaming vs. Meditation on anxiety reduction and cognitive performance/	UCMRT, STAI, General UX	Preparatory Experiencing Prime (PEP)	Between Subjects VR Gaming and VR Meditation, Within Subjects VR Prime vs No Prime	Beat Sabre Game and Custom Designed VR Meditation App	56 Participants (44 students and 12 non-students)	2x2 Between Subjects and Within Subjects	$30 for 90 minutes
Study 1a: Research Paper: Assessing the Effectiveness of Virtual Reality Gaming to Increase Cognitive Bandwidth and academic performance. Published as short paper AIVR 2020.								
Study 1b: Research Paper: VR-based Student Priming to Reduce Anxiety and Increase Cognitive Bandwidth. Published as Conference paper to IEEE VR March 2021 (Honourable Mention)								
Phase 2 - Assessing the effects of Context Oriented Priming (COP) within Immersive and Non-Immersive VR Learning Environments. Focus on ELT/Situated Learning effects								
Study 2a	Determine the impact of context (COP) priming and situated learning within a Virtual Reality Classroom.	PANAS, STAI, Specific Course Content Test and UX Questions .	Context Oriented Priming	Between subjects VR Prime vs. No Prime Conditions	30 minute VR short courses - How to Make an Animated Movie. IVR	51 Students, 18 Years or older	1x3 Between Subjects	$20 for 60 minutes
Study 2b	Compare the Effectiveness of the optimal immersive priming methods within non-immersive VR environment	PANAS, STAI, Specific Course Content Test and UX Questions	Context Oriented Priming for IVR and DVR	Between subjects immersive vs. non-immersive VR, between subjects VR Prime vs. No Prime	30 minute VR short courses - How to Make an Animated Movie. IVR and DVR views	68 Students, 18 years or older	2x2 Between Subjects	$20 for 60 minutes
Research Reflection	Research Summary: Reflects on the latest literature and research results to improve theoretical model and provide design input to a best practices framework	N/A	N/A	N/A	Reflective Analysis of multidisciplinary research and study results included within the final thesis.	N/A	N/A	N/A
Study 2a: Research Paper: Assessing the Effectiveness of VR Context Priming. Paper presented as Poster Paper IEEEVR 2022, Full Paper submitted to IEEE ILRN in Feb 2022								
Study 2b: Research Paper: Compare the Effectiveness of VR Context Priming in IVR vs. DVR contexts. Full Paper submitted to IEEE ILRN in Feb 2022								
Reflective Research Report included with Chapter 6. Reflective analysis of research and potential improvements and upgrades to theoretical model.								
Proposed Future Research:To assess efficacy of other priming interventions like MOPs, REPs, and aggregate multipriming effect; to study long-term mindset effects on academic performance; to study priming sensitivity to varying academic subjects (e.g. Math, Science, Geography, History, Art, etc...); to study prime effectiveness and sensitivity based on personality types; to study contextual priming effects of avatar embodiment (self and others) towards prosocial behaviour								

Figure 52 Thesis Research Summary

Appendix C – State Trait Anxiety Inventory (STAI - short)

To measure student anxiety levels, we will employ the State Trait Anxiety Inventory (STAI) short test (Marteau et al., 1992). The test is typically 6 multiple choice questions and can be complete within 1 minute. An example test is presented in Figure 53.

A number of statements that people have used to describe themselves are given below. Read each statement and then circle the most appropriate number to the right of the statement to indicate how you feel right now, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	Not at all	Somewhat	Moderately	Very Much
1. I feel Calm	1	2	3	4
2. I am Tense	1	2	3	4
3. I feel Upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Please make sure that you have answered ***all*** the questions.

Figure 53, STAI Short Test

Appendix D – UCMRT

The University of California Matrix Reasoning Test (UCMRT) is an accepted measure of fluid intelligence within the academic community (Pahor et al., 2019). While the Raven's Progressive Matrices (RPM) are often used for fluid intelligence testing (tests the ability to perceive abstract relationships and solve problems independent of previous learning), there were several barriers to using these tests for academic purposes. As a result, we opted to use the University of California Matrix Reasoning Test (UCMRT), a test of comparable effectiveness and able to be completed in less than ten minutes. The left side presents a pattern of shapes as 3x3 matrix, with a blank square asks the test participant to choose the option on the right that would best suit the bottom right empty square and maintain the patter. There is a brief training module to help students understand the testing process and the types of questions. Once the student completes the training module, they are presented with 23 multiple choice questions to be answered in 10 minutes. An example test question is presented in Figure 54.

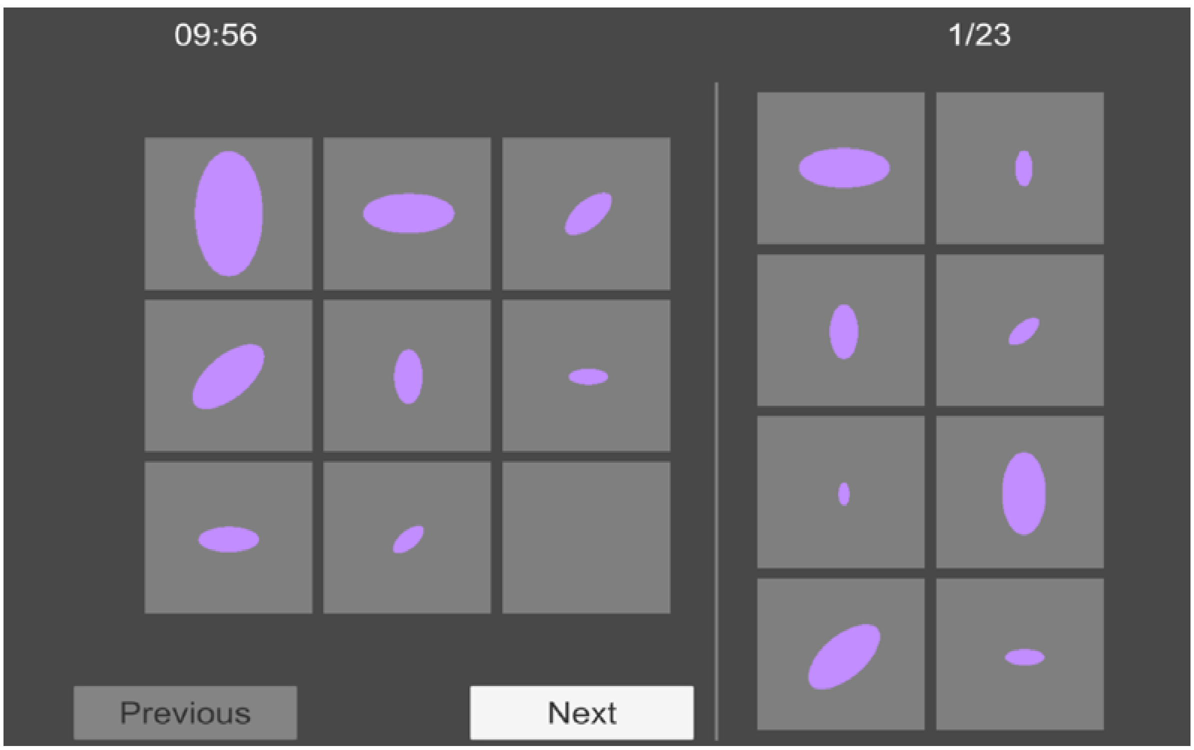


Figure 54 UCMRT Test Question

Appendix E – Phase 1: User Experience Questionnaire

1. How would you characterize your level of experience within a VR Learning Environment?
   A. This is my first opportunity to use VR in a learning context.
   B. I have attended other courses or lectures in VR.
   C. I use VR as learning tool occasionally.
   D. I am very experienced with VR in a learning context.
2. Did the VR Classroom Experience improve your overall interest and engagement with the course material?
   A. Not at all
   B. A little bit but no real difference
   C. Made a small difference
   D. Mae a big difference
3. Did the VR Classroom Experience motivate you to learn more about the subject material?
   A. Not at all
   B. A little bit but no real difference
   C. Made a small difference
   D. Mae a big difference
4. Did you feel any motion sickness, fatigue, or other negative side effects during the VR experience?
   A. Not at all
   B. Yes, but nothing significant
   C. Yes, significantly
   D. Yes, so much I couldn't finish

a) What side effects was it?

6. Other Comments

Appendix F - Phase 2 UX Questionnaire

1. How would you characterize your level of VR experience?
    a. I had never used any type of VR prior to this experience.
    b. I have used Desktop VR prior to this experience but have never used a VR headset.
    c. I have used a VR headset previously (once or twice)
    d. I have used a VR headset often (three times or more)
2. How would you characterize your level of experience with VR Learning Environments?
    a. I had never used any VR environment before this.
    b. I had never used any VR learning environment before this.
    c. I have occasionally used VR learning environments (once or twice).
    d. I have used VR learning environments (three times or more).
3. Did the VR experience increase your overall interest and engagement with the course material?
    a. Not at all
    b. A little bit but no real difference
    c. Made a small difference
    d. Made a big difference
4. Did the VR Experience motivate you to learn more about the subject material?
    a. Not at all
    b. A little bit but no real difference
    c. Made a small difference
    d. Mae a big difference
5. How motivated do you feel to participate in the creation or production of an animated movie?
    a. No interest at all
    b. Small interest
    c. I'm curious but not really motivated
    d. Very interested, I'd like to know more
    e. Absolutely, this is something I would love to do.
6. How confident do you feel in your ability to create your own animated story?
    a. Not confident at all. I will not try.
    b. I think it's doble. I can be persuaded to try.
    c. Not confident but willing to learn and try.
    d. Moderately confident.
    e. Absolutely, I could do this.

7. As a result of the presentation, have you thought about a possible animated story idea?
    a. No
    b. I have the seeds of something but nothing concrete.
    c. The idea is starting to come together
    d. Yes
8. The VR experience helped me learn.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
9. The VR environment was easy to use.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
10. The VR experience was well organized.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
11. I liked the overall idea/theme of the learning environment.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
12. I found the VR experience engaging
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
13. The VR experience was fun.
    a. Strongly Disagree
    b. Disagree
    c. Neutral

    d. Agree
    e. Strongly Agree
14. I would use the VR learning environment again.
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
15. Did you feel any negative side effect such as motion sickness or fatigue during the VR experience?
    a. Not at all
    b. Yes, but nothing significant
    c. Yes, significantly
    d. Yes, so much I could not finish

16. Please describe the environment you experienced.

17. Was there anything unexpected in your experience? Please Explain.

18. Which elements of the virtual environment was more interesting to you?

19. In what ways did the environment supported learning?

20. In what ways did the environment hinder learning?

21. How did you feel when you were in the virtual environment?

22. How did you feel about the learning material?

SLATER-USOH-STEED QUESTIONNAIRE (SUS)

23. Did you have a sense of “being there” in the virtual environment

24. Were there times during the experience when the virtual environment was reality to you?

25. When you think back to the experience, do you think of the virtual environment more as images that you saw or more as somewhere that you visit?

26. During the time of the experience, which was the strongest overall, your sense of being in the virtual environment or of being elsewhere?

27. Do you think the virtual environment as a place in a way similar to other places you've been today?

28. During the time of your experience, did you often think to yourself that you were actually in the virtual environment?

Appendix G – Content Test - Measuring Learning Effect

Upon completion of each course module, the student is presented with 20 multiple choice questions related to the specific content. Each of the test questions is customized based on specific content presented within the course. The test is intended for completion within 20 minutes.

How to Create and Produce an Animated Movie

1. The following is not a critical element of the pre-production creative process.
    a. The idea
    b. The Story
    c. Key Animation
    d. The Aesthetics
2. A **High Concept** can be described as
    a. An old idea with an interesting new spin
    b. An idea that uses technology or science fiction lore to engage the audience.
    c. An idea that is intellectually stimulating and unfolds over the course of the movie.
    d. An easy-to-understand problem or conflict that will capture the interest of potential movie goers.
3. The Pixar 4 Quadrant approach to making movies does not include one of the following strategies.
    a. Making movies the whole family can enjoy
    b. Target young, old, and all genders
    c. All humour needs to be understood and enjoyed by the whole family.
    d. There are multiple layers of comedy.
4. One of the following are features are typically NOT part of the Character's (Hero's) Journey:
    a. The hero is initially resistant to change.
    b. Hero is forced to take up arms and enter an unknown world.
    c. The Hero must use magic to slay the proverbial dragon.
    d. The hero grows because of their journey.
5. With an Institutionalized movie genre
    a. The hero must adapt to a new environment
    b. The movies are normally about groups
    c. There is a sacrifice made at the end
    d. All of the above.
6. Which one of the following is **NOT** considered a *Save The Cat (Snyder, 2005)* movie genre?

    a. Monster in the house.
    b. Out of the bottle.
    c. The Heroes Journey.
    d. Institutionalized.
7. This character archetype is a visionary but can be single minded and lack practical skills
    a. The Ruler
    b. The Sage
    c. The Creator
    d. The Hero
8. This character archetype can be proud and overconfident at times but will rise to meet the challenge.
    a. The Lover
    b. The Explorer
    c. The Hero
    d. None of the above
9. A producer is mainly responsible for:
    a. Managing day-to-day financial transactions.
    b. Making sure directors, writers, and production personnel follow proper procedure.
    c. Overseeing the creative, technical, and business aspects of a production
    d. All of the above.
10. A director is mainly responsible for the following:
    a. The visual blueprint and all final film stock.
    b. Making sure everyone on the set is happy and content.
    c. Evoking an emotional response from the audience.
    d. All of the above.
11. The following is not a function of the Animation Writer(s).
    a. Managing the blueprint of the character journey.
    b. Guardian of story structure.
    c. Coming up with high concept ideas.
    d. Translating the script to a visual story.

Please answer based on your best understanding of the *Save the Cat* *(Snyder, 2005)* movie genres as presented. Here's a logline, what's the genre?

12. On the verge of wasting away with a horrible foster family, an awkward orphaned boy discovers he's a wizard and sets off to attend a magic school; but when an attempt is made on his life, he must finally prove his worth before the most, evil

wizard of all time gets his hands on a powerful totem that could bring about an end of the magic world. (Harry Potter and the Sorcerer's Stone)

   a. Rites of Passage.
   b. Dude with a problem.
   c. Superhero.
   d. Golden Fleece.

13. A Lion cub crown prince is tricked by a treacherous uncle into thinking that he has caused his father's death, and he flees into exile and despair only to learn in adulthood that identity and responsibilities are here where they started. (*The Lion King*)
   a. Monster in the House.
   b. Buddy Love.
   c. Rites of Passage.
   d. Superhero.
14. Jealousy leads a vein queen to threaten the life of a beautiful young princess, who flees into the woods where she is befriended by the seven dwarfs. When the queen, in disguise tricks her into eating poisoned apple, the girl is thought dead and preserved in the glass coffins until a prince awakens her with love's first kiss. (*Snow White and the Seven Dwarfs*)
   a. Rites of Passage.
   b. Dude with a problem
   c. Buddy Love.
   d. Golden Fleece.
15. Parallel Parker is a universe hopping animated hero with a big job; to save the world. Based on your new insights, what would make a good log line for our new Parallel Parker movie?
   a. Parker is young and fearless and with the help of her intergalactic friends, she is destined to save the Universe.
   b. A stressed-out pre-teen, whose main skills are avoiding school and binge-watching TV suddenly realizes that she, along with her cosmic alter egos, must stop an evil supervillain intent on stealing all that is good from the universe.
   c. A super villainy interdimensional entity decides to wreak havoc on the universe by sucking up all of the positive energy, leaving the rest of the universe to slowly rot.
   d. A young, reluctant girl is faced with the decision of her life. Stay home and chillaxe or get off her butt and save the world. When the chillaxing thing goes wrong, she's forced to save the world instead.

16. To what *Save the Cat (Snyder, 2005)* movie genre does Parallel Parker belong?
    a. Monster in the House.
    b. Dude with a problem.
    c. Superhero.
    d. Golden Fleece.
17. Stories are important because
    a. The entertain and educate us
    b. The make us feel more human
    c. The help us understand others
    d. All of the above
18. Joseph Campbell suggests that the "Hero's Journey" represents myths and rituals that are typically associated with the following in most cultures.
    a. Battles between good and evil
    b. A story to explain nature and cosmic events
    c. The initiation process
    d. None of the above.
19. The animatic or first prototype does typically not contain the following.
    a. Actor voices, sound and music
    b. The characters and worlds or backgrounds
    c. Animation Rendering
    d. Storyboards
20. If the story appears to work well and you've figured out the costs, you can move into the production phase of the movie. If not, you must do the following.
    a. Recast the actors because a good actor can make all the difference.
    b. Rewrite the script as the three most important elements are story, story, and story.
    c. Redo some or all of the creative preproduction elements as required.
    d. Revisit the design aesthetic of the characters and world designs until you get them right.

Appendix H - Positive Affect Negative Affect Schedule

PANAS Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. **Indicate to what extent you feel this way right now, that is, at the present moment *OR* indicate the extent you have felt this way over the past week (circle the instructions you followed when taking this measure)**

1	2	3	4	5
Very Slightly or Not at All	A Little	Moderately	Quite a Bit	Extremely

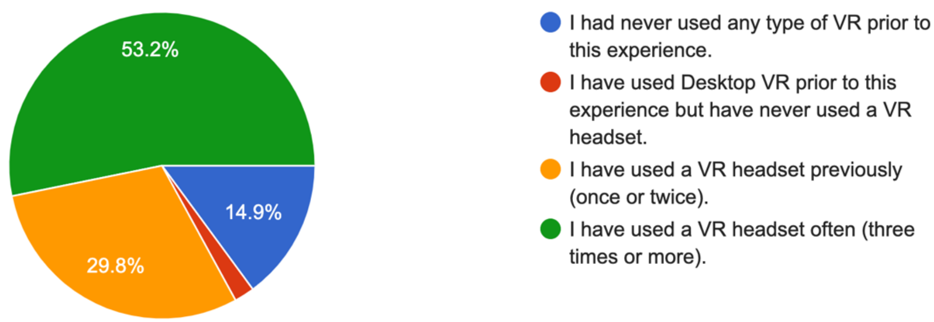
__________ 1. Interested	__________ 11. Irritable
__________ 2. Distressed	__________ 12. Alert
__________ 3. Excited	__________ 13. Ashamed
__________ 4. Upset	__________ 14. Inspired
__________ 5. Strong	__________ 15. Nervous
__________ 6. Guilty	__________ 16. Determined
__________ 7. Scared	__________ 17. Attentive
__________ 8. Hostile	__________ 18. Jittery
__________ 9. Enthusiastic	__________ 19. Active
__________ 10. Proud	__________ 20. Afraid

Figure 55 PANAS Questionnaire

Appendix I – Visualization of UX Results

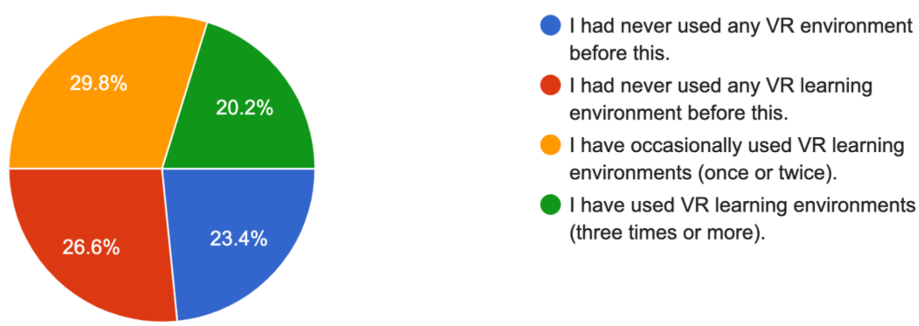
How would you characterize your level of VR experience?

94 responses



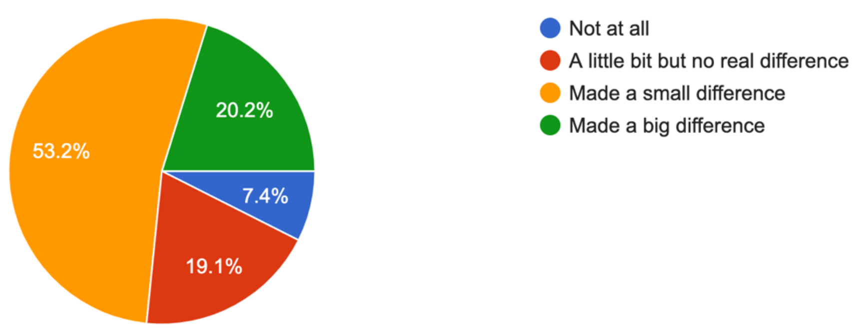
How would you characterize your level of experience with VR Learning Environments?

94 responses

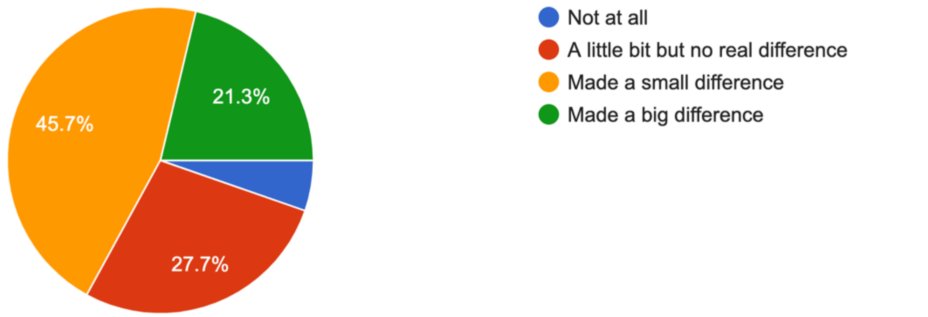


Did the VR experience increase your overall interest and engagement with the course material?

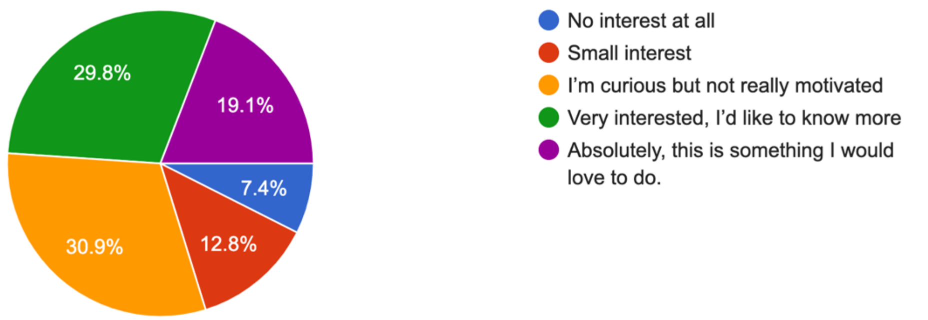
94 responses



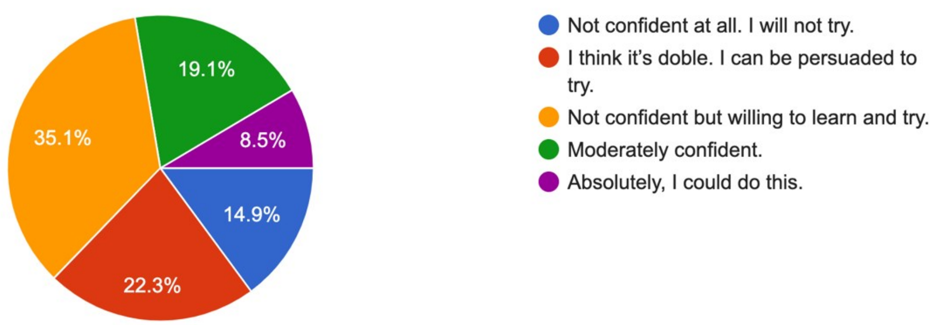
Did the VR Experience motivate you to learn more about the subject material?
94 responses



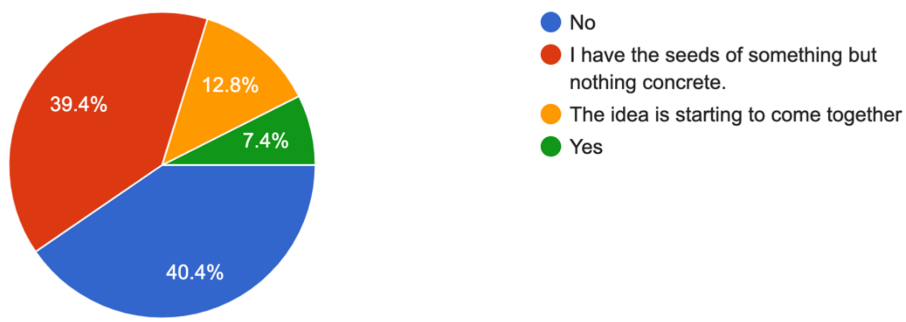
How motivated do you feel to participate in the creation or production of an animated movie?
94 responses



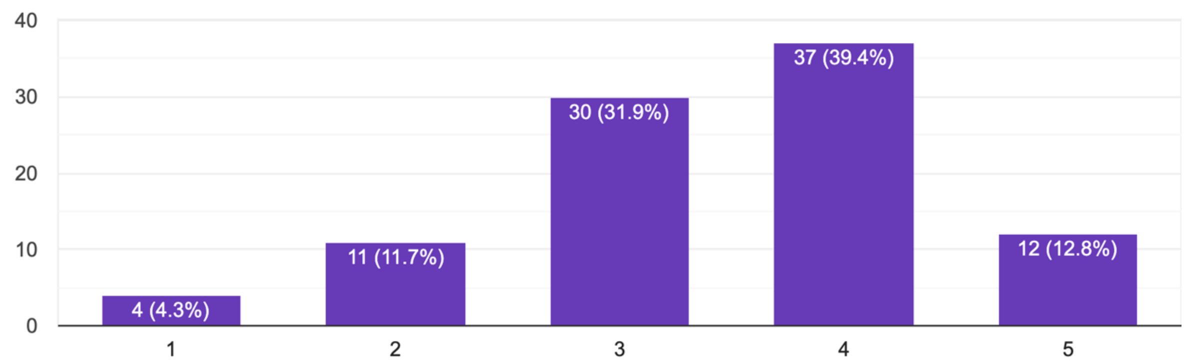
How confident do you feel in your ability to create your own animated story?
94 responses



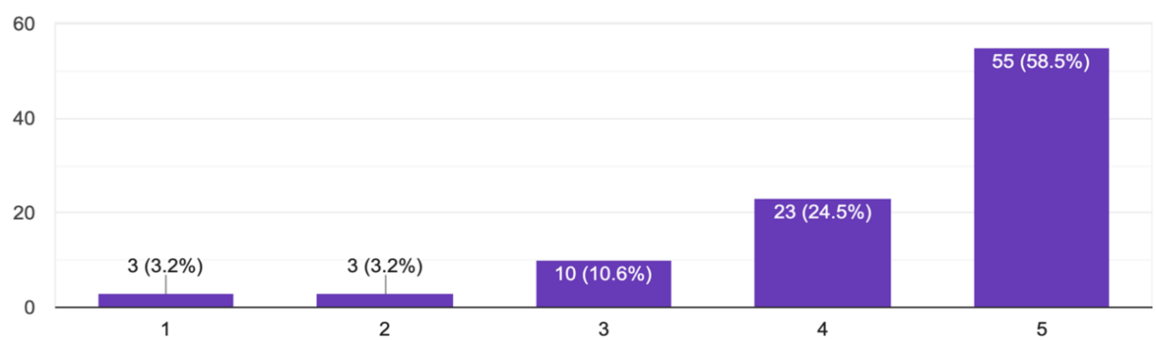
As a result of the presentation, have you thought about a possible animated story idea?
94 responses



The VR experience helped me learn.
94 responses

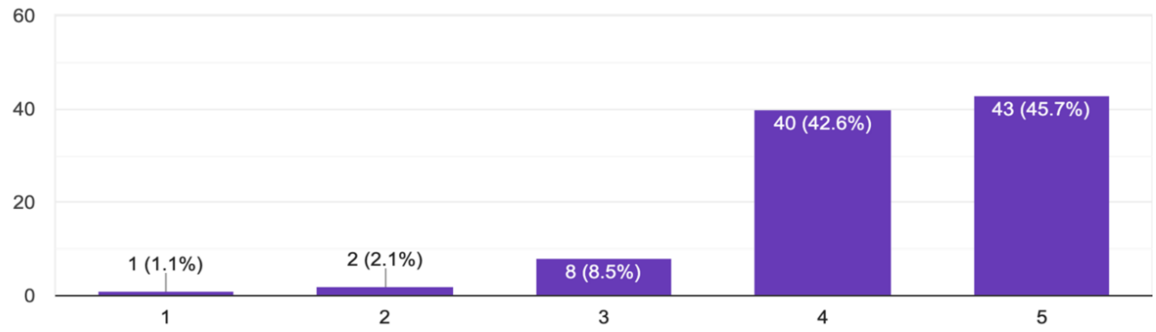


The VR environment was easy to use.
94 responses



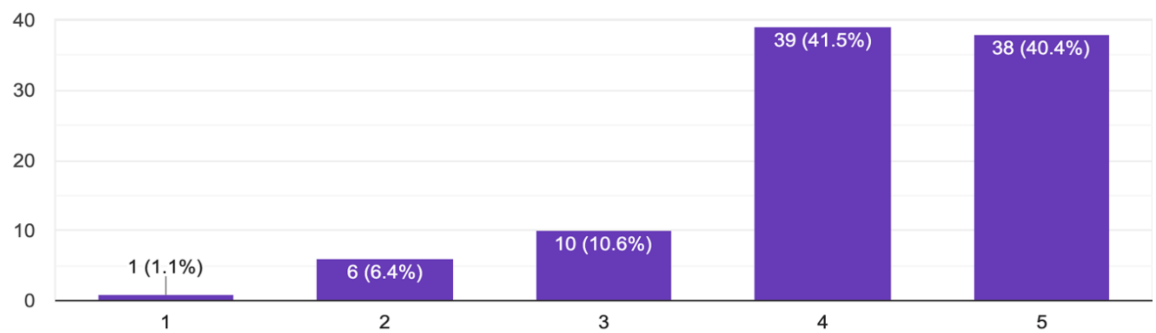
The VR experience was well organized.

94 responses



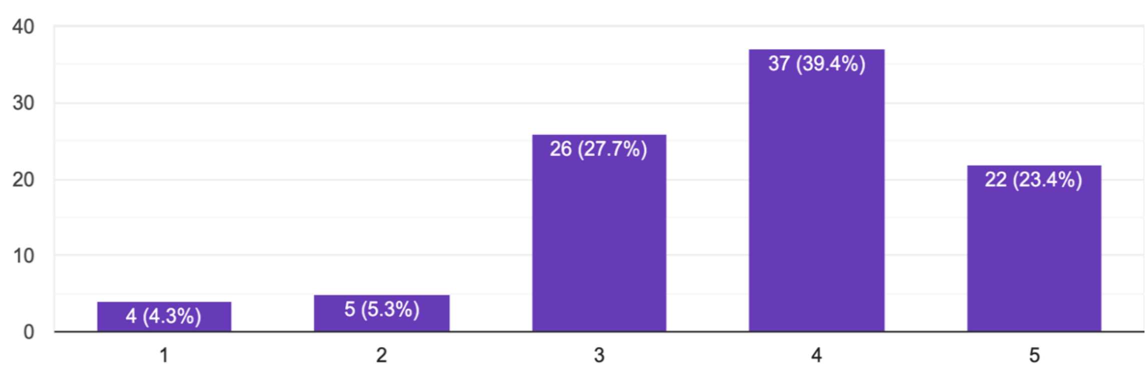
I liked the overall idea/theme of the learning environment.

94 responses

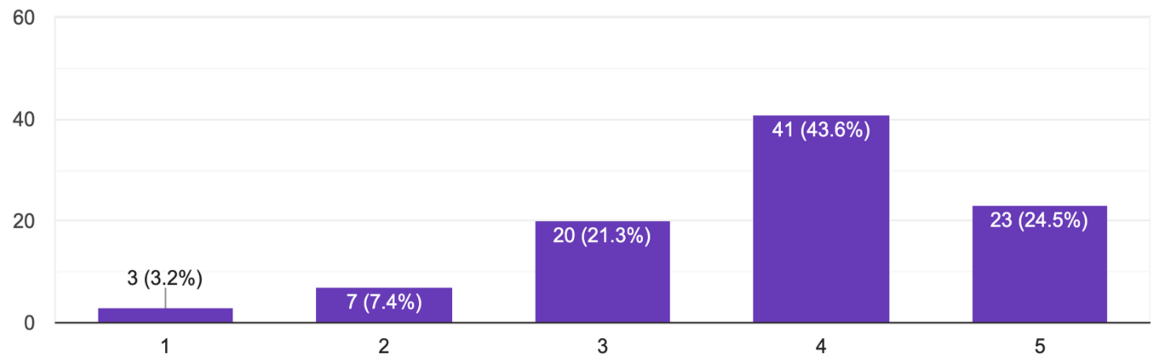


I found the VR experience engaging

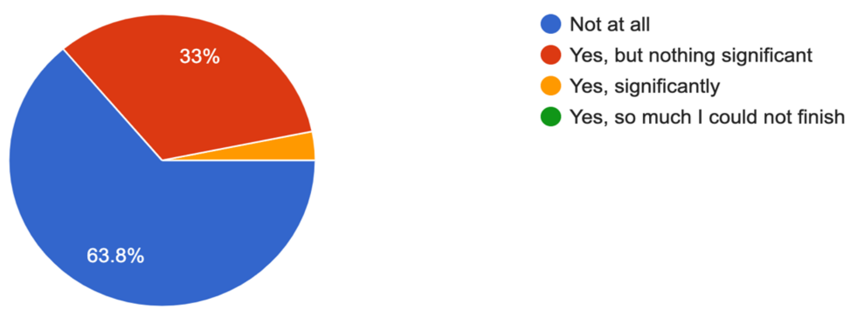
94 responses



The VR experience was fun.
94 responses



Did you feel any negative side effect such as motion sickness or fatigue during the VR experience?
94 responses



Please describe the environment you experienced.

Was there anything unexpected in your experience? Please Explain.

Which elements of the virtual environment was more interesting to you?

In what ways did the environment supported learning?

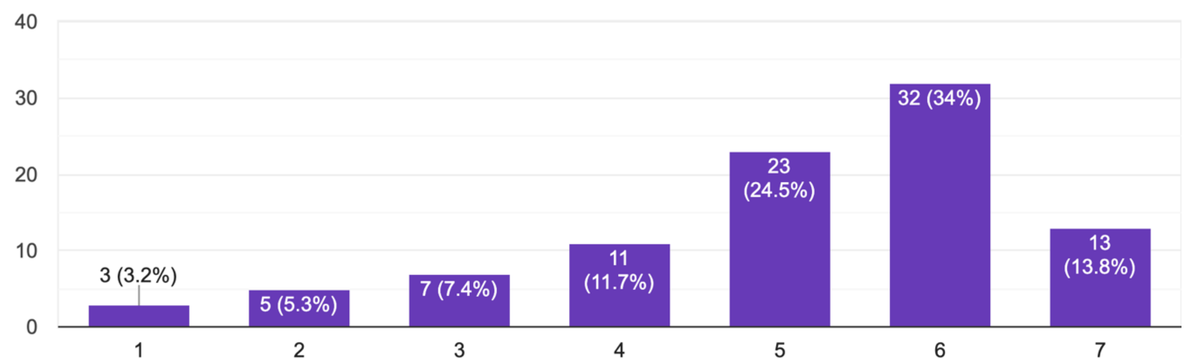
In what ways did the environment hinder learning?

How did you feel when you were in the virtual environment?

How did you feel about the learning material?

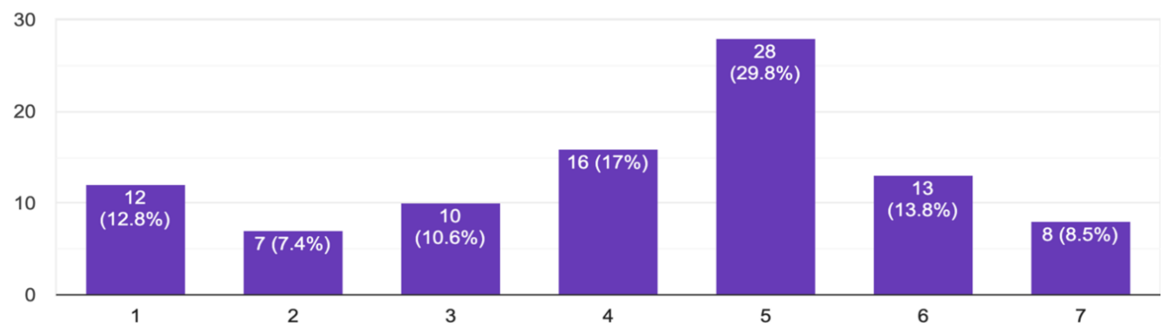
Presence Effects

Please rate your sense of "being there" in the virtual environment, on a scale of 1 to 7, where 7 represents your normal experience of being in a place.
94 responses



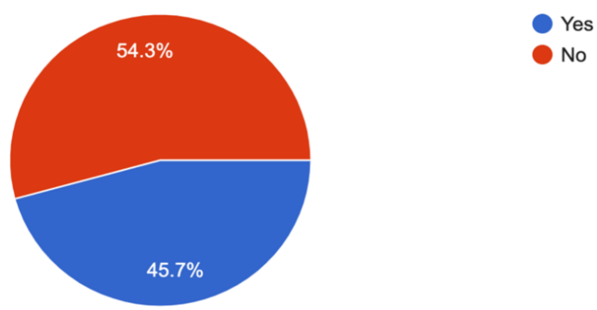
On a scale of 1 to 7 as described in the previous question, to what extent were there times when the virtual environment was reality to you?

94 responses



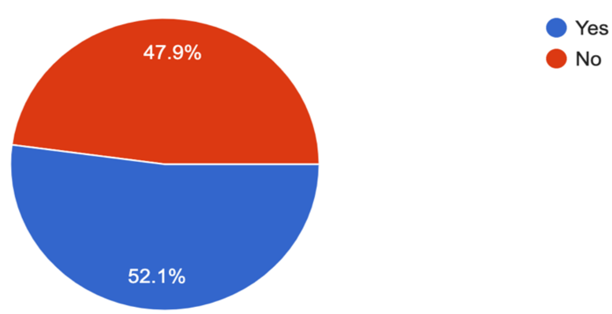
Do you think the virtual environment as a place in a way similar to other places you've been today?

94 responses



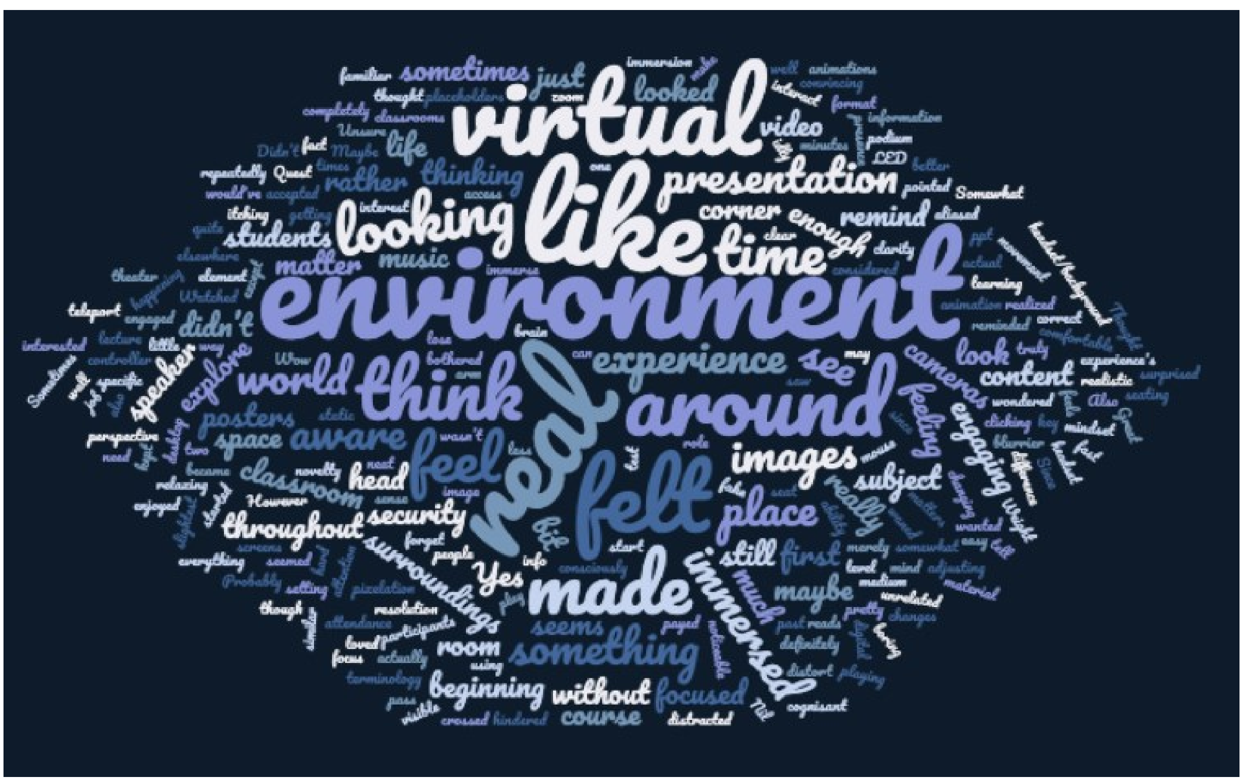
During the time of your experience, did you often think to yourself that you were actually in the virtual environment?

94 responses

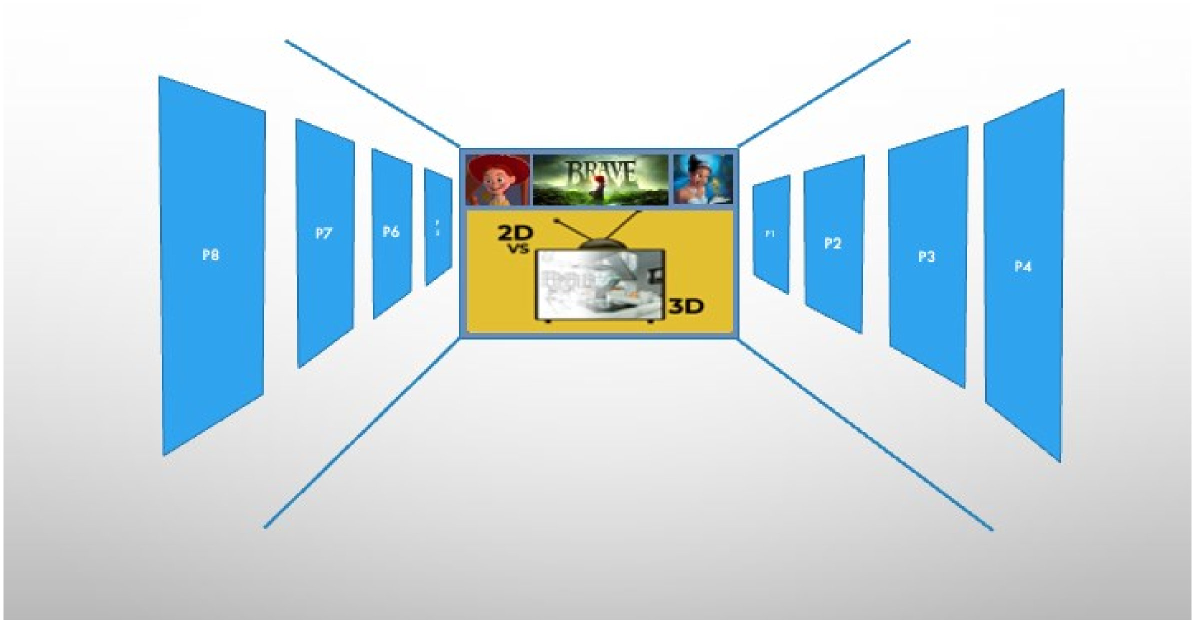


During the time of the experience, which was the strongest overall, your sense of being in the virtual environment or of being elsewhere?

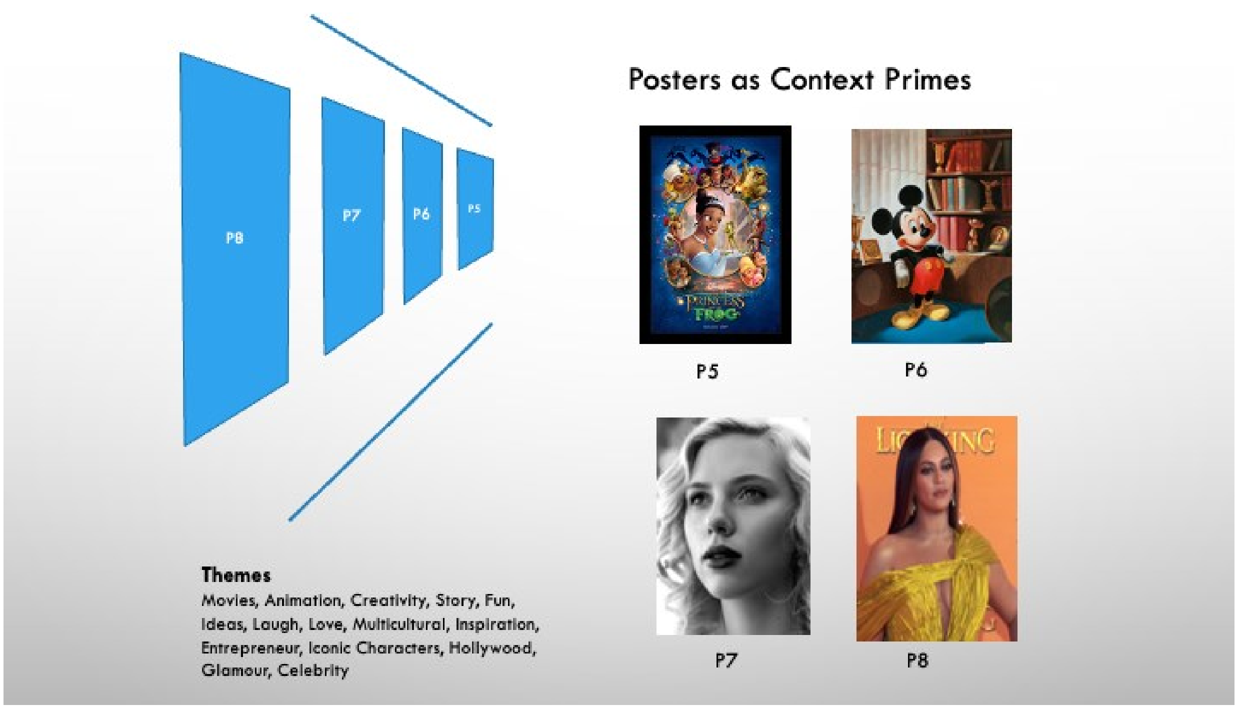
During the time of your experience, did you often think to yourself that you were actually in the virtual environment?



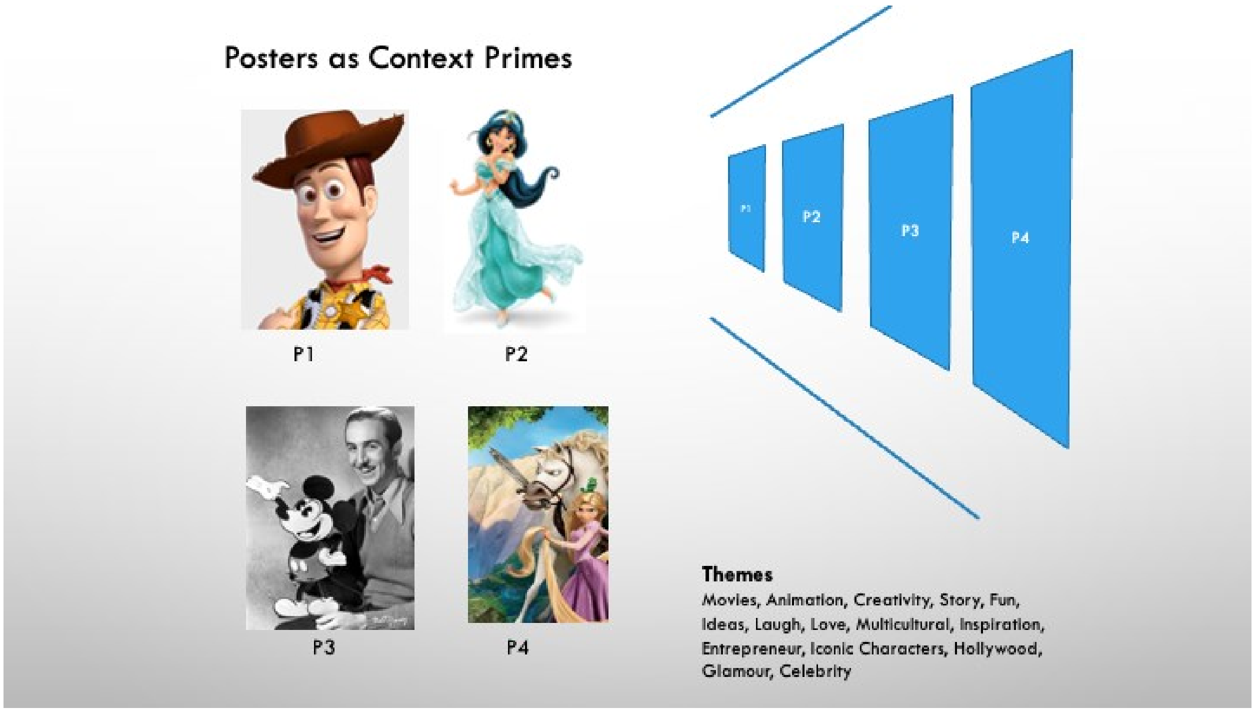
Appendix J – The Context Priming Environment



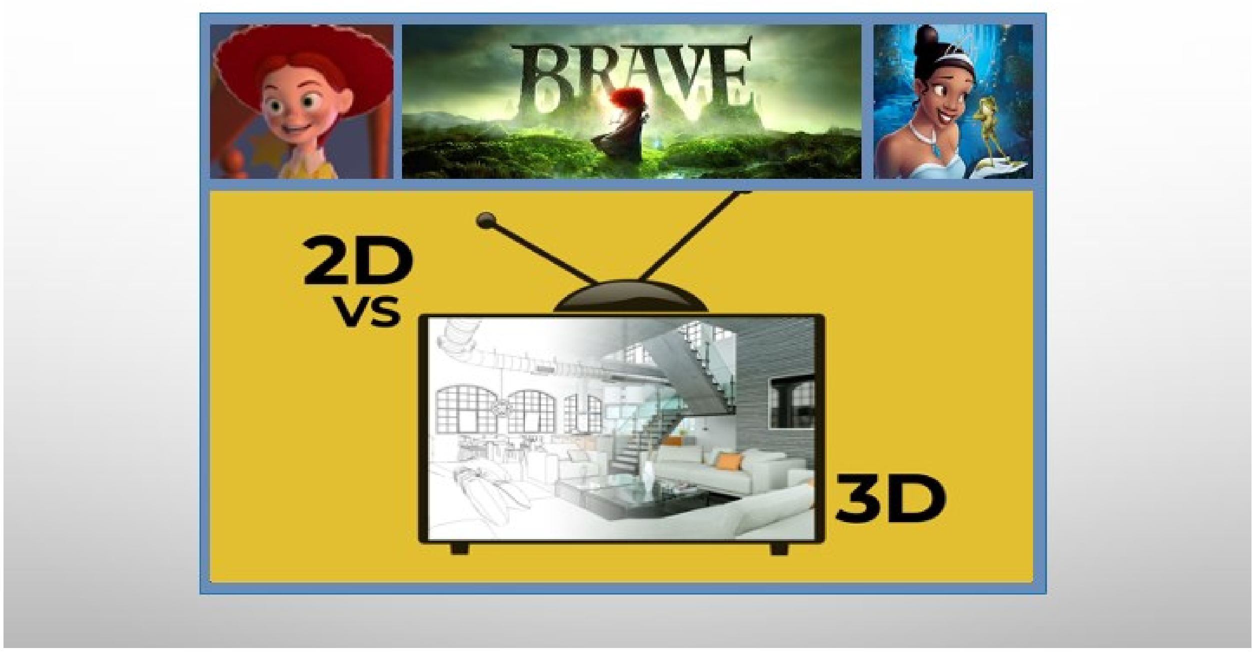
Front View of the Classroom Theatre Poster Positions



Left Side View of the Theatre Poster Positions



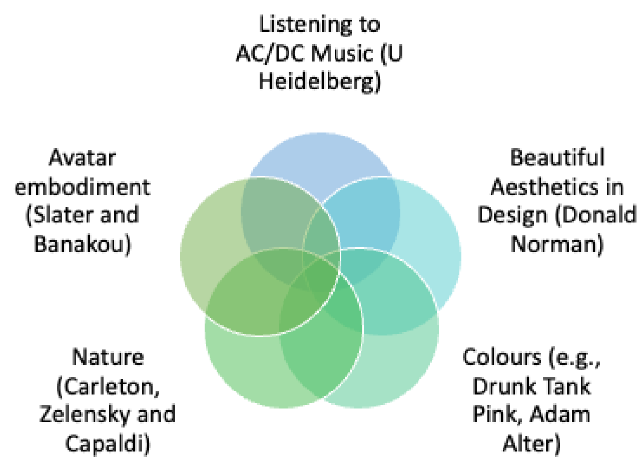
Right Side View of the Theatre Poster Positions



Front Screen Closeup of Main Screen Below and 3 Priming Screens Above

Appendix K – Other Methods of Priming

Other Methods of Context Priming



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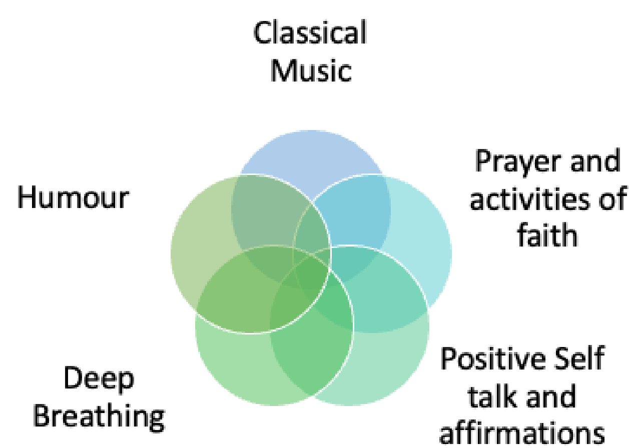
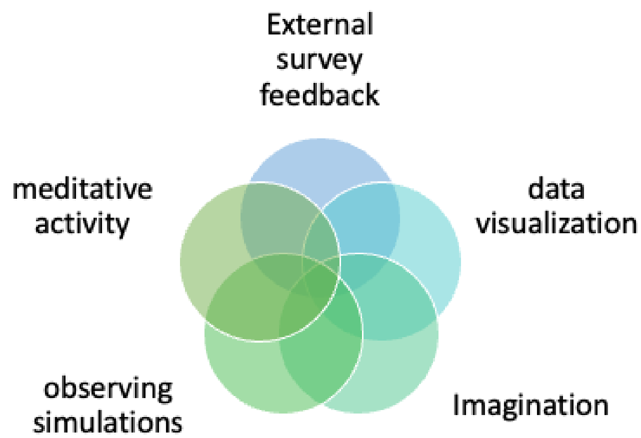
Other Methods of Preparatory Priming



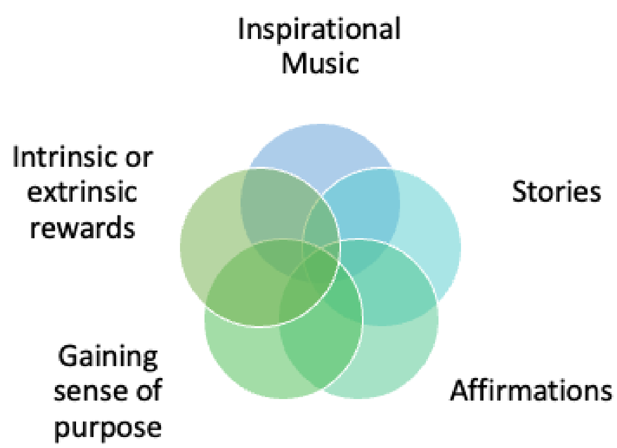
3

Methods of Reflective Priming



4

Methods of Motivational Priming



5

Appendix L – UX Design Suggestions for VR Spaces