Title
Zoning out of Zoom and Zooming In towards Learning Experience Design to Support Online Undergraduate Teaching and Learning

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Publication Date
2024

UNIVERSITY OF CALIFORNIA,
IRVINE

Zoning out of Zoom and Zooming In towards Learning Experience Design to Support Online Undergraduate Teaching and Learning

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in EDUCATION

by

Joseph T. Wong

Dissertation Committee:
Professor Lindsey Richland Co-Chair
Associate Professor Bradley Hughes Co-Chair
Professor Rossella Santagata

2024

DEDICATION

To

my partner, family, friends, and students,

I extend my heartfelt appreciation for their unwavering

dedication, persistence, and constant support

It is important to draw wisdom from different places.

If you take it from only one place, it becomes rigid and stale.

Sometimes life is like a dark tunnel, you can’t always see the light at the end of the tunnel,

but if you keep going, you will come to a better place.

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ACKNOWLEDGEMENTS

I would like to express my deepest thanks, gratitude, and appreciation to my advisor, Dr. Lindsey Richland, for her expertise, guidance, and mentorship throughout my graduate career. Dr. Richland gave me a chance five years ago when she welcomed me into the doctoral program, which profoundly changed my life. This opportunity not only allowed me to pursue my passion for research in educational technologies but also focused my scholarship to consider the cognitive mechanisms that underpin learning and instruction. Her unwavering support and encouragement have been invaluable, and I am profoundly grateful for her dedication to my academic and professional growth. Dr. Richland's wisdom, encouragement, and belief in my abilities have inspired me to push the boundaries of my research and strive for excellence in all endeavors. I am truly fortunate to have had such an exceptional advisor, and I will always cherish the guidance and lessons learned under her tutelage

I would like to extend my heartfelt gratitude to my longtime mentor, teacher, and advisor, Dr. Bradley Hughes, for his unwavering commitment, persistence, and invaluable support throughout my journey as an academic researcher. My collaboration with Dr. Hughes spans over the last decade, starting from my freshman year as an undergraduate student. His dedication to nurturing my growth and development has been instrumental in shaping my academic trajectory. Dr. Hughes' mentorship has provided me with invaluable insights, challenged me to think critically, and encouraged me to pursue excellence in my scholarly pursuits. I am deeply appreciative of his ongoing guidance and mentorship, which have played a pivotal role in my personal, academic and professional endeavors. Dr. Hughes' guidance has been a beacon of light, illuminating my path as I navigate the complexities of academia, and for that, I am profoundly grateful.

I would like to express my sincere appreciation to Dr. Rossella Santagata for her significant contributions to my academic journey. As a member of my committee and the director of the Center for Teaching Development and Professional Practice, Dr. Santagata has played a crucial role in shaping my scholarly endeavors over the past five years. Working closely with her in my capacity as the center manager has been an enriching experience, providing me with unique opportunities to disseminate research, foster connections with scholars globally, and oversee research communications across our extensive network of over 100 members. Dr. Santagata's unwavering support, expertise, and guidance have been invaluable assets, empowering me to grow as a researcher and educator. I am deeply grateful for her dedication and mentorship, which have profoundly influenced my academic and professional development. Dr. Santagata's commitment to excellence and passion for teaching have inspired me to strive for greatness in my own endeavors, and for that, I am truly thankful.

Thank you Dr. Janice Hansen for her mentorship as a teaching advisor. I first served as a teaching assistant to Dr. Hansen which really ignited my passion for teaching at the undergraduate level. I was very fortunate to then have the opportunity to teach my own course this summer as the instructor of record. Her unwavering support, patience, and expertise have been instrumental in my growth as an educator. Dr. Hansen's dedication to teaching excellence and her commitment to nurturing the next generation of educators have inspired me to continuously strive for excellence in my teaching practices. I am deeply appreciative of her mentorship, which has profoundly impacted my professional development. Dr. Hansen's guidance and encouragement have been invaluable, and I am truly thankful for her support.

I would like to extend my heartfelt love and appreciation to those who have been closest to me throughout my academic journey, shaping me into the person I am today. My partner, Vivian Mai, has been my unwavering source of light through every high and low of my doctoral candidacy. To my parents, Kyin Wong and Jasmin Kai, who have not only raised me but also served as my steadfast pillars of support, I am forever grateful. And to my brother, Jonathan Wong, your constant encouragement and belief in my abilities have propelled me forward in every endeavor. As a first-generation Burmese-American student, this achievement stands as a testament to the collective hard work, perseverance, and sacrifices of my family, without which obtaining this doctoral degree would not have been possible.

I want to thank Elsevier Press for permission to include Chapter One of my dissertation, which was originally published in Computers and Education Open. I also want to thank Springer Nature for permission to include Chapter Two of my dissertation, which was originally published in Journal of Computing in Higher Education. Lastly, I would like to thank the National Science Foundation for their support through the Graduate Research Fellowship under grant number 2020304238, as well as through grants #DRL-1321343 and #32027447. Additionally, this work was also supported by the Institute of Education Sciences (IES) under grant numbers: R305A170488 and R305A190467.

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Wong, J. T., Richland, L. E., & Hughes, B. S. (2024). Immediate Versus Delayed Low-Stakes Questioning: Encouraging the Testing Effect Through Embedded Video Questions to Support Students' Knowledge Outcomes, Self-Regulation, and Critical Thinking. *Technology, Knowledge and Learning*, 1-37.

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ABSTRACT OF THE DISSERTATION

Zoning out of Zoom and Zooming In towards Learning Experience Design to Support Online Undergraduate Teaching and Learning

by

Joseph T. Wong

Doctor of Philosophy in Education

University of California, Irvine, 2024

Professor Lindsey Richland, Co-Chair

Professor Bradley Hughes, Co-Chair

Professor Rossella Santagata

My dissertation examines undergraduates' online learning experiences during the COVID-19 pandemic through three distinct studies. The primary goal of my dissertation is to shed light on crucial aspects of social cognitive learning theories and learning experience design (LXD) applied in distance learning. These studies, using an LXD approach integrated with cognitive science theory, revealed that online video-based instruction can lead to reduced mind wandering, increased engagement, and improved retention of key conceptual knowledge. This is achieved through questions embedded into videos and thoughtful LX design choices that consider individual differences in self-regulation, self-efficacy, and anxiety.

In Study 1, I evaluate the impact of experiences with video-based online educational technology on student learning using theories of cognitive engagement and mind-wandering. Using Structural Equation Modeling (SEM) and survey data collected from 14 classes in

California (*n* = 633), I validate that self-efficacy, task-value, and trait anxiety directly influence learners' engagement. Additionally, I find that self-efficacy and trait anxiety as significant sources of students' mind-wandering, with mind-wandering partially mediating the relationship between self-efficacy and engagement. These findings shed light on potential mechanisms underlying students' online engagement and offer practical recommendations for instructors to enhance their pedagogical strategies when using Zoom and other online learning platforms.

In Study 2, I expand on the insights from Study 1 to redesign an undergraduate biology course with the LXD paradigm, utilizing 4k videography, customized dashboards, and user experience design. Through in situ Design-Based Research (DBR) and mixed-methods analysis (*n* = 181), the results highlight the impacts of self-efficacy, task-value, and self-regulation significantly predicting higher levels of student engagement, elaboration, and critical thinking, further corroborated by qualitative analysis showing the positive effects of LXD interventions on student motivation and learning experiences. This research significantly contributes to STEM online teaching and learning in higher education, advocating for the thoughtful deployment of LXD strategies.

In Study 3, I address the opportunities and challenges highlighted in Study 2 and expand upon these findings by conducting a quasi-experimental investigation. As such, I delve into the efficacy of interactive embedded video questions in enhancing students' learning outcomes in a second iteration of the same asynchronous biology course. Guided by LXD principles, these questions aim to leverage the testing effect on students' retrieval and conceptual understanding by prompting learners to answer low-stakes questions while watching course videos. The results from the two treatment conditions (*n* = 92 for "delayed" and *n* = 91 for "immediate") indicate significant differences in low-stakes question accuracy, summative quiz scores, engagement, mind-wandering, self-regulation, and cognitive load, with the effects being more pronounced for students in the immediate condition.

Overall, my dissertation underscores the importance of adapting pedagogical strategies to meet the evolving needs of learners in higher education with a human-centered empathetic approach. Through rigorous empirical research, it provides invaluable insights and practical recommendations for educators striving to optimize the online learning experiences of their students.

Overview of Studies

My dissertation attempts to address a few specific questions regarding the roles of undergraduate students' social, cognitive, and behavioral engagement on their learning experiences while learning remotely during the pandemic. In particular, my dissertation studies consider the social cognitive learning theories (Bandura 1986, 1989) that are theorized to explain learners' engagement while distance learning and how we might use these underpinning mechanisms to design, develop, and deploy online courses informed by my findings. In Chapter 1, I first investigated undergraduates learning through Zoom synchronously while examining the social, cognitive, and behavioral factors that may influence learners' engagement. Mind-wandering is believed to represent an attentional lapse in students' learning process (Desideri et al., 2019; McVay & Kane, 2012; Smallwood, 2013). Sources of mind-wandering include students' anxieties, task-value, and self-efficacy which have also been shown to influence students' engagement (Hartanto & Yang, 2020; Son et al., 2020; Wong et al., 2024). However, measuring these characteristics simultaneously as students learn through Zoom, given the transition of learning modalities of the pandemic (Hodges et al., 2020; Son et al., 2020), offers a unique glimpse into the interactions of how students' social context or environment and learning behaviors affect their learning experiences. Thus, in Chapter 1, I investigated a proposed structural equation model (SEM) informed by learning theories, examining students' self-efficacy, task-value, and trait anxiety influencing learners' mind-wandering and its mediating effects on students' engagement while learning synchronously on Zoom (Wong et al., 2023). Additionally, I consider what the theoretical and practical learning experience design implications researchers in the field of online learning have suggested in order to combat mind-wandering and boost engagement. Findings from this study suggest a model for understanding students’ social, cognitive, and behavioral impacts from learning synchronously through Zoom and advance our understanding of how students’ engagement can be mediated by their frequency to mind-wander, raising further questions about how might we design an online course that mitigates mind-wandering and increases engagement.

In Chapter 2, I considered the findings from Study 1 and designed an asynchronous self-paced online course to support undergraduates in an upper-division biological sciences course. Results from study 1 show that students’ self-efficacy and task-value have positive significant impacts on learners’ engagement (Wong et al., 2023). Conversely, it's evident that when students experience low levels of self-efficacy and task-value, their engagement levels drop. Synchronously learning through Zoom is only one alternative modality to facilitate teaching and learning during the pandemic (Hodges, 2020), however, other modes of learning grounded in decades of research on online learning may support students’ learning experiences even further (El Ahrache et al., 2013; Marrongelle et al., 2013; Cetina et al, 2018). As such, in Chapter 2, I co-designed an online course with the learning experience design pedagogical framework and conducted an *in-situ* design-based research study that tested the efficacy of my course designs, examining learners’ self-efficacy, task-value, self-regulation, engagement, elaboration, and critical thinking skills as a result of the LXD efforts. Chapter 2 dives deeper into students' metacognitive learning and their learning strategy behaviors to evaluate the impacts of the course design, technological affordances, and the constraints that were identified (Wong & Hughes, 2023). As a result, I found that implementing asynchronous self-paced online courses with LXD approaches positively impacts students’ learning behaviors, potentially by influencing students’ social cognitive motivational traits. I discovered that self-efficacy, task-value, and self-regulation significantly predicted undergraduates' online engagement, elaboration skills, and critical thinking. By utilizing a mixed-method approach, I reinforced the quantitative analyses with qualitative insights drawn from the comprehensive descriptions of learners' course feedback, thereby elucidating the resulting impacts on their learning experiences. Three overarching themes emerged from the analysis: Findability, referring to the ease of locating relevant content; Video Navigability, denoting the ability to efficiently navigate through video materials; and self-pacing, highlighting the flexibility for learners to progress at their own speed. In particular, these descriptions explicitly pointed to the LXD features explaining how our design efforts contributed to students' motivations and changing learning behaviors in the course. This research study makes an important contribution to the field of STEM online teaching and learning in higher education, presenting evidence for how LXD can be deployed iteratively, rapidly, and thoughtfully.

In Chapter 3, I executed a design iteration of the online course initially developed in Chapter 2, incorporating adjustments based on student commentaries and feedback. More specifically, students mentioned how they wanted more active learning student-centered opportunities to interact and engage with the course materials while watching the video scaffolds. Drawing on the cognitive theories for multimedia learning (Meyer, 2001, 2019), I proposed the use of embedded video questions as a modality to facilitate opportunities for digital learning interactions with the video in order to foster the cognitive process of the testing effect. That is, the phenomenon in which attempting or even failing to reproduce the correct answer or testing before a learning event improves students' learning outcomes (Carpenter, 2009; Littrell-Baez et al., 2015; Richland et al., 2009). Embedded video questions are the technological medium that provides an avenue to transform passive video viewing into an interactive and participatory experience (Christiansen et al., 2017; van der Meij & Böckmann, 2021). In a quasi-experimental design-based research study, I assessed the impact of integrating low-stakes video questions on reducing students' instances of mind-wandering and cognitive load. Additionally, I investigated how this approach could enhance learning quiz grades, engagement, and self-regulation. The study extended over a period of 10 weeks, during which half of the students encountered questions immediately embedded within the video player, while the remaining half received the same questions after viewing all the instructional videos within the unit, prompting delayed questioning. Consequently, this study experimentally manipulated the timing of the questions across the two class conditions: immediate vs delayed. These questions functioned as opportunities for low-stakes content practice and retention, designed to encourage learners to experience testing effect and augment the formation of their conceptual understanding (Littrell-Baez et al., 2015; Richland et al. 2009). On average, the outcomes indicated that learners in the immediate questioning condition exhibited notably superior quiz scores, increased page views, and enhanced participation in the course. Additionally, those who experienced immediate questioning demonstrated heightened levels of online engagement, self-regulation, and critical thinking. Moreover, our analysis delved into the intricate interplay between the two conditions, learners' low-stakes accuracy, self-regulation, cognitive load, mind-wandering, and quiz grades. Notably, the interaction between participants in the immediate questioning condition and the accuracy of low-stakes questions proved noteworthy, suggesting that learners in the immediate condition experienced amplified effects on their quiz grades. Furthermore, the interaction between those in the immediate questioning condition and self-regulation emerged as a significant factor, suggesting that the influence of immediate questioning on quiz grades varies based on learners' self-regulation abilities. Collectively, these findings highlight the substantial positive effects of immediate questioning of online video lectures on both academic performance and the benefits of supporting learners' cognitive skills through the testing effect within an online learning context.

INTRODUCTION

Pandemic Shifting Teaching and Learning

Paying attention in a class, staying engaged, and actively participating in college lectures have been widely stated as critical components necessary for learners' academic achievement and success. Given the large dependence between learners' attention and academic achievement (Kane et al., 2017; Wammes et al., 2019; Wammes & Smilek, 2017), it has been increasingly important to identify ways in which learners' attentional engagement might be sustained, free from distractions that may hinder the learning experience. However, with the world currently facing a global pandemic that has abruptly caused shifts in workflows across many sectors, teaching and learning specifically in 2020 was required to fundamentally modify course delivery infrastructure in just a matter of weeks. The COVID-19 pandemic necessitated a systematic change in course modalities due to mandatory nationwide orders of social distancing to mitigate spread, resulting in the suspension of in-person instruction (Agarwal & Kaushik, 2020; Ferrel & Ryan, 2020). Data from the United States in the fall of 2020 indicate that approximately 11.8 million (75%) undergraduate students were enrolled in at least one distance learning course, while 7.0 million (44%) of undergraduates exclusively took distance education courses (National Center for Education Statistics [NCES], 2022). In order to facilitate teaching and learning during this the crisis circumstances of COVID-19, many educational institutions, including higher education, pivoted and rapidly adopted internet-mediated educational technology platforms (Asad et al., 2020; Chick et al., 2020; Sandars et al., 2020), such as Zoom Teleconferencing and expanded Learning Management System (LMS) features, to support students while transitioning from in-person to emergency remote distance learning.

While online learning and the use of technological tools for education are not new, the implementation of these "edtech tools" at scale during this critical period represented a major paradigm shift for both educators and learners alike. For many instructors, it may have been the first time utilizing software or tools to teach online, and for students, the tools themselves generated new problems and issues that may not have been accounted for by the instructors. Compounded with the adoption and integration of tools so quickly, the efficacy and the effectiveness of the tools themselves perhaps may not have had the intended effect. With the transition to remote instruction having occurred so rapidly, researchers have highlighted students' commentaries on issues regarding accessibility, content validity, and the educational value of the tools implemented (Hodges et al., 2020; Rudman, 2020). On the other hand, some instructors questioned the rigor and lack of "edtech tools" available at their disposal, given that less than "5% of college budgets are dedicated to information technology pre-pandemic" spending for teaching and learning (harvard business review.) Further, it has been reported by the U.S. Department of Education that pre-pandemic, only one-third of all college students had experienced some form of an online class before the pandemic, while the remaining two-thirds of students exclusively experienced traditional in-person lectures, representing a 186% increase in undergraduates exclusively enrolled in distance learning courses between 2020 and 2019 (NCES, 2022). This difference highlights the vastness and expediency with which institutions had to transition and change within an instant at a pace that has never been done before. As such, this helps illustrate the scale of the current juncture we face with distance education and the necessity to evaluate online learning modalities to better understand whether tools like Zoom worked, how learners were impacted, and how we might better support their learning experiences in the future.

Zoom Video Conferencing as the Alternative

With this displacement of traditional in-person lectures to distance education, many institutions widely adopted video conferencing platforms as an immediate alternative to facilitate teaching and learning. Zoom (2020), quickly became the most widely adopted by educational institutions and many workplaces (Joia & Lorenzo, 2021; Serhan, 2020). Zoom is a web-based collaborative video conferencing platform that provides video, audio, and screen-sharing capabilities in order to facilitate teaching and learning remotely through the internet. The emergency remote instructional shift to online platforms is a solution devised in response to a world crisis in order to maintain the status quo in the quickest way possible. As Hodges et al. (2020) described, “emergency remote teaching is a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances" (p. 7). For many educators and students, emergency remote distance learning resembled a rapid transplant of the same in-person university lectures mediated through Zoom. This synchronous learning modality through Zoom video-conferencing mostly consisted of long instructor-focused monologues over an extended period of time with little to no student interaction; however, it was the only method to rapidly facilitate teaching and learning at scale. Thus, the level of learners’ engagement may differ quite drastically, and sustaining learners’ engagement poses a significant challenge with learners’ citing fatigue, distractions, and less willingness to self-nominate or speak up in a large Zoom class (Kohnke & Moorhouse, 2022; Moorhouse, 2020). As such, Study 1 primarily focuses on undergraduate classes where teaching and learning took place synchronously on Zoom with instructors teaching in this manner, just through a different modality. Taking this distinction into account, this transition that led to a nationwide migration to emergency remote distance learning at this scale represents a markedly new and unexplored critical juncture in the undergraduate teaching and learning context, establishing a gap in the literature for examining student engagement and mind-wandering while distance learning, warranting analysis.

Constraints of Synchronous Learning on Zoom

One key issue that I identified that may have exacerbated learners' engagement by learning through Zoom is the degree to which students' mind-wandered during an online synchronous class session. Mind-wandering has been defined as the phenomenon in which learners' thoughts or attention drift away from the task at hand to some unrelated thought (Al-Balushi et al., 2022; Feng et al., 2013). Certainly, mind-wandering occurred in the classroom context where students do not always fully pay attention to the lectures prior to the emergency remote learning (Pachaei et al., 2016; Wammes et al., 2016), but the transition to Zoom along with the day-to-day negative news of pandemic may have furthered worsened students' task-unrelated thoughts. For example, students were highly anxious, with 71% of undergraduates sampled agreeing that they experienced "increased stress and anxiety" due to the COVID-19 pandemic (Son et al., 2020). A report by the U.S. Department of Education published that COVID-19 raised new unforeseen barriers and widened disparities such as access, connectivity, and technological limitations that make it harder to stay engaged in virtual classrooms (Department of Education [DOE], 2022). Additionally, Smith et al. (2020) found that students were less attentive on Zoom when compared to students physically in the same classrooms with their instructor, experienced reduced attentiveness for synchronous only classes, and even lower engagement for synchronous classes greater than 30 minutes, posing the question: Are they paying attention, or are they shoe shopping? On the other hand, students described fears related to the impacts of the COVID-19 pandemic itself while also citing issues related to increased distractions, willingness to speak up in front of large online Zoom classes, difficulty concentrating, lack of prior experience, increased worries, and decreased motivation, with emergency remote distance learning —all of which are maybe critical factors affecting the students' mind-wandering (Agarwal & Kaushik, 2020; Fawaz & Samaha, 2021; Kaharuddin, 2020; Kohnke & Moorhouse, 2022; Son et al., 2020). Furthermore, Was and colleagues (2019) surveyed students' beliefs about mind-wandering during an online lecture and found that online lectures can be detrimental to academic performance and that task-related thoughts would lead to higher levels of performance. This corroborates Risko et al. (2012) findings that college students watching a long video lecture with no interactions mind-wandered more frequently and was related to poorer performance. As such, we might infer that in addition to academic performance, the frequency of students' mind-wandering given the transition to Zoom and the negative experiences of the pandemic may also have a critical role in impacting students' social, cognitive, and behavioral learning experiences.

Social Cognitive Learning Theory

Bandura's (1986) social cognitive theory for learning provides a framework to situate the learning experiences of undergraduates during the COVID-19 pandemic and the social, cognitive, and behavioral impacts learning synchronously through Zoom may have caused. Bandura's social cognitive learning theory posits that the environment and cognitive factors interact to influence human learning and behavior (Bandura, 1977). This theory argues that human learning is dependent on the reciprocal interactions of the environment, cognition, and behavior. In this way, learning is assumed to occur in a social context such that learners are active agents who can both influence and be influenced by their environment (Bandura, 1989). More specifically, social cognitive learning theory has a major emphasis on the cognitive factors involved in a learning environment which Bandura identified as mediational processes. These mediational processes include attention, retention, reproduction, and motivation of the individuals themselves and the environment in which learners are in that influences them. Each of these mediational processes represents a mental cognitive state which learners undergo due to some input from the environment which influences their learning, resulting in output or action of behavior, which in turn, affects their environmental and personal factors that ultimately inform or alter subsequent behavior (Bandura, 1989; Schunk, 2012). The central tenet grounding Bandura's social cognitive learning theory is reciprocal determinism which refers to the reciprocal interactions of individuals with a set of learned experiences, the environment, social context or behavior, and the response to stimuli to achieve their goals (Schunk, 2012). As learners seek to develop control and agency throughout the learning process, Bandura (1989) argued that factors such as self-efficacy, outcome expectations, goals, and self-evaluation will support or hinder students' learning experiences. Taking the reciprocal determinism model and the transition from traditional in-person to online learning environments into account, I further consider students' social, cognitive, and behavioral impacts as a result of distance learning through the pandemic.

Social Learning Impacts

When considering the social pillar of Bandura's social cognitive learning theory, I focus on learners' self-efficacy and task value. Bandura's (2000) framework of self-efficacy states that it is a person's awareness of his or her belief in the ability to succeed in a particular situation. Eccles & Wigfield (2002) define task value as the ability of individuals to evaluate their competence, interests, costs, and broad beliefs in a particular domain. As previously mentioned, there was a 186% increase in learners that were enrolled in distance learning courses with over two-thirds of students having never taken an online course prior (NCES, 2022). Since many students are first-time distance learners, students' self-efficacy, or judgments about their confidence and ability to succeed in an online course, are likely to be low, influencing the extent to which learners engage and interact with distance learning (Bates & Khasawneh, 2007). Conversely, students with high levels of self-efficacy are likely to be more engaged in the online course, actively monitoring their performance and setting goals to continually accomplish the course requirements (Colquitt et al., 2000). Furthermore, given the virtually overnight rapid transition to distance learning, the quality of emergency remote distance learning courses may differ drastically from online learning grounded in instructional design principles, which puts into question the validity and rigor of remote of emergency remote learning courses, affecting students' task-value or perceived "worthwhileness and validity" of participating in the course at all (Hodges et al., 2020; Joo et al., 2015). Many online courses subscribed to the popular synchronous "Zoom internet-mediated teleconferencing method" for distance learning, which considering the rapid transition virtually overnight served high utility. However, while learners were offered a hasty solution to an alternative modality for learning during the pandemic, this came at the expense of learners' motivation and engagement. Adnan and Anwar (2020) found that 71.4% of undergraduate students reported that learning in conventional face-to-face classrooms was more motivating than current distance learning remedies, specifically raising concerns related to the inability to actively participate with their instructor and fellow classmates.

Cognitive and Metacognitive Impacts

In considering the cognitive aspects of social cognitive learning theory, I focus specifically on the effects of the shift to distance learning modalities and how it has affected learners cognitively and metacognitively. One of the major concerns with emergency remote distance learning is how to best engage and sustain students online throughout the learning experience, given broad learning challenges such as the heightened anxieties caused by the COVID-19 pandemic and the often drastically different home educational settings (Agarwal & Kaushik, 2020; Son et al., 2020). Anxiety can be defined as the feeling of fear, dread, and uneasiness in a given environment (Gidron, 2013; Spielberger, 1983). The anxiety that the remote learning environment produces is an important factor to consider, as extant literature has shown that anxiety is a key variable that occupies cognitive resources, which can negatively impact learning outcomes and task performance (Eysenck et al., 2007; Jain & Dowson, 2009; Kim et al., 2014). A recent study conducted by Son et al. (2020) conducted interview surveys with undergraduate students in a large public university in the United States and reported that 71% of students experienced increased fear and anxiety due to the COVID-19 pandemic, 89% report difficulty concentrating, and 86% have persistent concerns for their academic performance due to the transition to online classes. This was exemplified in a study conducted by Hartanto and Yang (2020) where anxieties related to online instruction with undergraduate students were positively associated with mind-wandering, which ultimately decreased task performance. Likewise, Parks-Stamm et al. (2010) identified that the effects of anxiety also influence students' distractions, inattention, and concentration. Consequently, heightened anxieties, worries, and distress may occupy learners' cognitive resources which suggests the failure of students to maintain executive control while learning remotely.

Identifying ways in which students might be able to combat these distractions may be equally important. Given that many students are novice distance learners, developing students' self-regulation skills throughout the online learning environment may be a critical factor in improving success for learners. Self-regulation refers to the human's ability to monitor or manipulate their thoughts and actions to reach a specific objective (Pellas, 2014; Vrugt & Oort, 2008; Zimmerman & Schunk, 2001). More specifically, self-regulation in an online course is defined as the extent to which students elicit self-regulated metacognitive skills and strategies during a learning activity in order to be successful in an online course (Wang et al., 2013; Wolters et al., 2006). Given the modality of Zoom instruction and the nature of online learning methods broadly, students are required to assert more autonomy and control over their learning when compared to traditional in-person instruction. Although this might be a significant shift in responsibility to the learner, instructors and designers can support students' self-regulation skill training by explicitly instructing students to monitor their own thinking process, setting proximal and distal goals, allocating enough time to accomplish assignments, digital interactivity, usability descriptions, and proper scaffolding (Al-Harthy et al., 2010; Kanuka, 2006; Shneiderman & Hochheiser, 2001). In doing so, students actively use many cognitive and metacognitive strategies to manipulate, control, and regulate their own learning behaviors to accomplish the required tasks (Wang et al., 2013). In Studies 2 and 3, we focus on instructional design and the thoughtful deployment of "edtech" tools grounded in evidence-based pedagogy to implement embedded opportunities for self-regulation, retrieval and practice, and time management as ways to elicit these cognitive and metacognitive behaviors. I also focus on the deployment of video-based learning as a cognitive tool to foster active information processing throughout the learning process, activating prior knowledge and fostering retrieval by embedding opportunities of the testing effect.

Behavioral Impacts

In this dissertation, four types of student learning behaviors are examined in relation to social cognitive learning theory, which includes mind-wandering, engagement, use of elaboration, and critical thinking skills. Since mind-wandering indicates a fault in information processing, where external task-related information shifts towards processing internal task-unrelated information (Smallwood & Schooler, 2006), this attentional shift is theorized to be a decoupling process between the task (external information) and the existing mental model (self-generated thoughts) of the individual (Mills et al., 2013; Smallwood et al., 2007). Smallwood (2013) proposes that sustained external attention requires executive control in order to reduce the number of internal and external distractions in nature (McVay & Kane, 2012; Smallwood, 2013). Through this lens, mind-wandering is a derivative of a person's inability to exhibit the necessary executive control to regulate their cognitive resources in order to perform or accomplish a task when encountering distractions (Kane et al., 2007). According to McVay & Kane (2012), it is thus hypothesized that individuals with higher levels of WMC exhibiting more executive control, are more likely to combat distractions, preventing the onset of mind-wandering given the availability of cognitive resources. Specifically, mind-wandering is suggested to be related to cognition through the default-mode network (DMN), a large network of constellation regions of the brain supporting automatic and self-relevant information processing (Fox et al., 2015; Golchert et al., 2017). Recent studies have found that both deliberate and spontaneous mind-wandering arise through the attentional differences in attentional regulatory control such that the DMN and executive control systems function together the allow information from memory to contribute to a controlled train of thought (Golchert et al., 2017; Krieger-Redwood et al., 2016; Piccoli et al., 2015). Through this line of inquiry, it is, therefore, possible that mind-wandering may be closely aligned with a person's intentions.

Given that task-unrelated mind-wandering represents a detached attentional state, we would then expect to see consequences of mind-wandering (i.e. inattention, distractions, zoning out) specifically for students learning under the emergency remote distance learning contexts.

One way to identify students' affinity towards on-task thought is to consider students' task engagement within the online learning environment. In education, student engagement is defined as the amount of student effort or active participation needed to complete a learning task (Hu & Kuh, 2002; Richardson & Newby, 2010). In an online course, engagement can be further described as the attention, curiosity, interactivity, and interest that students exhibit during an instructional unit, which further extends to the level of motivational traits that students may utilize during the learning process (Pellas, 2014). Engagement has been found to have a significant and positive relationship with student outcomes such as students' progress in learning, course satisfaction, and course grades (Bolliger & Halupa, 2018). When online courses are not grounded in learning theory, or they are difficult to navigate, uninteresting, or unengaging, studies have shown that this will likely lead to negative course engagement behaviors such as increased mind-wandering, or the directing of attention away from a primary task (Desideri et al., 2019).

Elaboration strategies are students' approach to storing information in their long-term memory through the summative aligning of conceptual content and activities (Pintrich et al., 1993). These activities are considered to be "meaningful and sensemaking" which include strategies such as summarizing, generative note-taking, analogical reasoning, and mental representations of new conceptual information learned (Weinstein, 1986). Social cognitive researchers have linked students' self-efficacy and task value to positive predictions in students' usage of elaboration in distance learning environments (Artino & McCoach, 2008; Ali et al., 2014). Moreover, elaboration has also been consistently predictive of greater student achievement, especially when students move away from shallow processing strategies such as merely underlining or mechanically memorizing information (Greene et al., 2004; Pintrich et al., 1993).

On the other hand, critical thinking is the ability of students to apply new and prior knowledge of conceptual content and derive decisions based on the evaluation of that content (Pintrich et al., 1993). Student-generated critical thinking behaviors might include searching for multiple sources of representations, critically questioning information, and making assessments based on this information to draw conclusions (Uzuntiryaki-Kondakci & Capa-Aydin, 2013). More specifically, Brookfield (1987) defines critical thinking in the context of research, as the recognition of the learners' assumptions that underpin their thoughts and actions. As students perform critical thinking behaviors in a learning environment, research has found that critical thinking requires learners to metacognitively monitor their own thoughts, reactions, perceptions, assumptions, and confidence in the material (Bruning, 2005; Halpern, 1998; Jain & Dowson, 2009; Wang et al., 2013). This indicates that students' critical thinking skills may be influenced by students' self-efficacy, task value, and self-regulation. Furthermore, fostering students' critical thinking skill building may also support their transferable skills (Fries et al., 2020), a key competency for undergraduate students linking course materials to real-world applications. In order to collectively target these social, cognitive, and behavioral impacts to support students' learning experiences, instructors, course designers, and administrators might consider grounding distance learning courses in evidence-based pedagogies and learning theories.

Online learning is a well-studied and effective mode of learning in its own right for the last decade (see Castro & Tumibay, 2021; Zheng et al., 2020), it represents a different form of learning that took place during emergency remote distance learning during the pandemic. Online learning is developed with intentionality and operationalized through systematic models of pedagogical instructional design frameworks from its inception (Branch & Dousay, 2015; Means et al., 2014). An instructional design model is the planned systematic creation of learning experiences and materials to support the acquisition and application of knowledge through a pedagogical learning design process of learning activities (Gibbons et al., 2014; Lee & Jang, 2014; Merril et al.,1996). A recent meta-analysis conducted by Castro & Tumiby (2021) of over 30 studies showed that the primary element of successful online learning experiences is the extent to which an online course is developed in conjunction with pedagogical learning design principles. For many, Zoom emergency remote distance learning resembled a rapid transplant of the same in-person lectures mediated through Zoom, the mass deployment of remote learning courses operationalized with pedagogical learning design frameworks was likely overlooked. It's not to say that these courses delivered synchronously on Zoom did not contain pedagogical frameworks that carried over from their traditional in-person offering, but a majority of Zoom course offerings did not integrate best practices from online teaching and learning (Hodges, 2020; Wong & Hughes, 2022). Taking this distinction into account, my dissertation proposes the implementation of the learning experience design paradigm in undergraduate courses to shift synchronous Zoom learning towards an asynchronous self-paced online course grounded in learning theories and pedagogical learning design.

Online Learning

Over the last two decades, there has been growing interest in online courses supporting student teaching and learning, particularly for their flexibility, convenience, and the ability to reach more isolated populations (El Ahrache et al., 2013; Marrongelle et al., 2013; Cetina et al, 2018). Online learning facilitates learning partially or entirely over the internet (Means et al., 2009; Richardson & Newby, 2010), through synchronous and asynchronous modalities. Looking at MOOCs (Massive Open Online Courses), course platforms such as Udemy and Coursera offer online degrees and certificates over an asynchronous delivery platform, facilitating online self-paced learning (Cetina et al., 2018). Conversely, synchronous learning requires students to be present during an allotted time, emphasizing the social presence between teachers and students through teleconferencing (Cobb, 2009; Jaggars & Xu, 2016; Means et al., 2009; Xu & Xu, 2020). Compared to synchronous courses, asynchronous self-paced courses have been shown to foster increased learner independence, individualized instruction, personal responsibility, review and practice, and increased test preparation (Alqurashi, 2016; Holmberg, 2003; Morris et al., 1978; Richardson et al., 2016). Furthermore, Tullis and Benjamin (2011) argue that when learners actively engage in their own productive metacognitive judgments at their own pace, students are more likely to succeed in online learning environments by monitoring their study-time allocation, self-agency, and motivational traits. However, these successful skill-building learning outcomes in online courses are attributed to careful considerations of learning experience design. Without quality learning experience design, students are more likely to feel disengaged, lose motivation, and oftentimes fail to complete the online course (Czerkawski & Lyman, 2016; You, 2016). Thus, in order to better support students to develop these skills, actively engage in their coursework, and achieve high completion rates, online courses might be transformed to be grounded in evidence-based teaching pedagogy and learning experience design principles.

Learning Experience Design

Online courses grounded in Learning Experience Design (LXD) are one such approach that aims to leverage the affordances of evidence-based learning design. LXD refers to the creation of learning situations that extend beyond the formal classroom learning environment and which often utilize online and virtual technological formats (Ahn, 2019). Coined as a term in 2015, LXD is the pedagogical learning design process of developing effective learning experiences that enable learners to reach a specified learning outcome in a human-centered goal-oriented method (Floor, 2018). LXD is a departure from the traditional term "instructional design," which is primarily focused on curriculum development and programming instruction to support knowledge acquisition (Correia, 2021). More specifically, instructional design refers to the systematic approach of delivering effective instruction for learners with the goal of reaching high levels of achievement and consuming information (Branch & Merill, 2012; Joo et al., 2015). Conversely, Weigel (2015) further defines LXD as an interdisciplinary synthesis of instructional design, teaching pedagogy, cognitive science, learning sciences, social science, and user experience design (UXD). LXD certainly has its roots in user experience design (UXD) and instructional design (ID) (Chang & Kuwata, 2020). The former focuses on the human-computer interaction between the user, the system platform, and the satisfactory experience of the user while using an interface (Lallemand et al., 2015; Simunich et al., 2015). The latter is the planned systematic authoring of curriculum instruction to support the acquisition and application of knowledge through a pedagogical learning design process (Wong & Hughes, 2022). As a result, LXD builds on both UXD (user-focused) and ID (learner-focused) in an attempt to reconceptualize the online learning experience, bridging design practice with curriculum instruction to address the limitations of both. In practice, Floor (2018) describes five fundamental elements of LXD which include aspects of being: human-centered, goal-oriented, based upon a theory of learning, learning through practice, and heavily interdisciplinary. Finally, there is also a major emphasis on empathy, taking into consideration the learners' needs and experiences during all elements of the course design process in order to more fully consider both the intended and unintended learning design outcomes (Matthews et al., 2017). As such, LXD broadens our definitions of what is to be considered a learning experience, affording instructors, designers, and researchers the opportunity to empathize with learners and develop experiences that expand our design toolbox to support students' motivation as well as learning behaviors in diverse learning settings (Ahn et al., 2019; Weigel, 2015).

Research in online learning attributes increased student learning behaviors due to quality instructional design (Marrongelle et al., 2013; Pappas, 2015), learner experience within the course user interface (Floor, 2018; Hu, 2008), and student social, cognitive, and behavioral factors that can be developed as a result of the learning environment (Artino & McCoach, 2008; Belcheir & Cucek, 2001; Sun & Rueda, 2012). By implementing LXD, I take a human-centered empathetic lens and attune our course designs to better account for students' diverse learning conditions and changing learning behaviors (Ahn et al., 2019; Xie, 2020). For example, I designed the online modules to be flexible and learner-paced, enabling students to start on their own time and work through the course at their own speed (Richardson & Newby, 2010). Additionally, opportunities for engagement, elaboration, and critical thinking were maximized through the inclusion of virtual coaching, scaffolded videos, and metacognitive journal reflections embedded within each weekly module that facilitated students in more sustained participation and interactivity. Fink (2007) writes, "when course design models are used to restructure the learning experience, as a response, students become more actively engaged in the learning process because the intended learning holds greater meaning." Thus, I designed, developed, and deployed an asynchronous self-paced online course grounded with LXD that was informed by students' needs to move away from Zoom and better support students' social, cognitive, and behavioral impacts while distance learning.

PROPOSED STUDY AIMS AND HYPOTHESIZED FINDINGS

Study 1

Study 1 represents an *in situ* survey analysis of undergraduate students examining the mediating role of students' mind-wandering and the social, cognitive, and behavioral factors that impacted learners' online engagement during the transition to emergency remote distance learning. This study attended specifically to the role of students' tendency to mind-wander and, conversely, students' online engagement, in relation to the online delivery of courses through the Zoom platform itself. Additionally, we considered students' heightened anxieties and examined the role of students' self-efficacy and task value, given the personal and contextual factors influencing students' learning experience due to the transition to emergency remote distance learning. By conducting an SEM path analysis, I was able to identify the direct and indirect effects on mind-wandering and engagement. Examining both of these effects in the context of our study, I was able to make suggestions for causal claims on the mediating role of mind-wandering. Through this process, I was able to eliminate pathways and find potential underlying mechanisms by which the effects of variables of interest influenced the outcome.

Drawing from the literature, I was curious about how mind-wandering may have detrimental impacts on students' emergency remote learning experience, and identifying the factors that contribute to the resulting effects of mind-wandering may better inform instructors, course designers, and administrators on how to accommodate learning for students during a crisis learning context and post-pandemic world. Consequently, I conducted a path analysis to examine students' mind-wandering as a potential mediator impacting students' learning experiences. As a result, I hypothesize a model:

[H1]: Students' self-efficacy will have a direct negative effect on students' mind-wandering and a direct positive effect on students' engagement.

[H2]: Students' trait anxiety will have a direct positive effect on students' mind-wandering and will have a direct negative effect on students' engagement.

[H3]: Students' task value will have a direct negative effect on students' mind-wandering and will have a direct positive effect on students' engagement.

[H4]: Students' mind-wandering will have a direct negative effect on students' engagement.

[H5A]: Students' self-efficacy will have an indirect positive effect on students' engagement.

[H5B]: Students' trait anxiety will have an indirect negative effect on students' engagement.

[H5C]: Students' task value will have an indirect positive effect on students' engagement.

Finally, I considered lessons learned and practical pedagogical design principles that may aid in reducing students' frequency of mind-wandering while learning remotely.

Study 2

To move beyond Zoom and consider the lessons learned from Study 1, I designed and developed a course with a university instructor that incorporated some of my findings and tested whether we could improve students' learning experiences. Study 2 represents an *in situ* design-based research (DBR) study to investigate learning experience design (LXD) methods, where I deployed several learning design facets such as asynchronous video, course dashboards, and enhanced user experience within the online course platform. Through this process, I designed an online course for the purpose of increasing students' social cognitive motivations (self-efficacy, task-value, self-regulation) and learning behaviors (engagement, elaboration, critical thinking) by grounding the online learning environment in LXD.

LXD was operationalized by aligning the online course with the Situated Cognition Theory (SCT) theory of learning, producing segmented animated video scaffolds, and implementing user experience design (UXD) heuristics to create affordances that directly support students empathetically. To our knowledge, this integration of learning design and user experience is a relatively new field of education in its infancy and this study sought to better understand how undergraduates' personal social cognitive motivational factors (self-efficacy, task-value, self-regulation) support or hindered their online learning behaviors (engagement, elaboration, critical thinking) as a direct result of the LXD efforts. Thus, this study is guided by the following research hypotheses:

[H1]: Students' self-efficacy, task-value, and self-regulation significantly predict students' engagement learning behaviors while learning in this LXD-based online course.

[H2]: Students' self-efficacy, task-value, and self-regulation significantly predict students' elaboration learning behaviors while learning in this LXD-based online course.

[H3]: Students’ self-efficacy, task-value, and self-regulation significantly predict students’ critical thinking learning behaviors while learning in this LXD-based online course.

[H4]: LXD as a pedagogical learning design framework will support students' online learning experiences due to the thoughtful and intentional design affordances of the technology and digital media made accessible to learners.

Finally, I provided practical pedagogical design recommendations that instructors can implement immediately while also considering the uncovered unintended design constraints.

Study 3

Attuning to several of the design constraints found in mind-wandering and asynchronous video in Studies 1 and 2 respectively, Study 3 examines the potential benefits of deploying embedded video questions as a cognitive learning tool to an asynchronous online course. In Study 3, I aimed to test the extent to which asynchronous embedded video questions support or hinder students' engagement, mind-wandering, self-regulation, and critical thinking while grounding the online course in the LXD framework. In order to examine this, I conducted an experimental study consisting of two randomly self-enrolled, identically sized classes in the School of Biological Sciences over 10 instructional weeks where the treatment conditions differed by the curriculum delivery of the quiz assessment. In the first condition, learners are presented with quiz questions only after watching a series of assigned video scaffolds. In the second condition, learners were presented with questions immediately embedded within the video player, which were time-stamped and triggered to match the presented conceptual content. The conceptual questions in both conditions were completely identical, while the timing and placement of the questions were experimentally manipulated.

To design this interface, I worked collaboratively with a university instructor to deploy innovative digital learning features such as high-end studio production quality, 4K multi-camera videos, green screen inserts, voice-over narrations, and animated infographics. Videos were chunked into smaller three to five-minute scaffolded video phases, which aimed to reduce fatigue, cognitive load, and opportunities for students to mind-wander. These videos were designed to pre-train students in general concepts and terminologies with scientific visuals and simplified explanations, prior to engaging in the more in-depth and detailed study with a textbook. After this initial pretraining, students would engage in their readings of the text, followed by taking a separate weekly quiz that assessed content mastery. Therefore, I took a DBR in situ approach that applies theories of learning to evaluate the efficacy of design and instructional tools with learners “in the wild” to test the effectiveness of embedded video questions supporting or hindering students’ learning experience. For this study, I examined both survey data and behavioral learning analytics data to corroborate my findings. The following research hypotheses guided this study:

[H1]: Learners in the immediate questioning condition will have significantly higher quiz grades, page views, and online course participation rates.

[H2]: Learners in the immediate questioning condition will experience significantly higher engagement, self-regulation, while showing significantly fewer instances of mind-wandering and cognitive load.

[H3]: Learners in the immediate questioning condition will experience higher quiz grades and this effect will be dependent on the level of learners’ self-regulation and mind-wandering.

Lastly, implications on how institutions may adopt these course designs, iteratively design, and effectively foster successful science online teaching and learning with embedded video questions grounded in pedagogical learning experience design are discussed.

CHAPTER 1: STUDY 1

Zooming in or Zoning Out: Examining Undergraduate Online Learning Experiences with Zoom and the Role of Mind-Wandering

Published in Journal of *Computer and Education Open*

Wong, J. T., Mesghina, A., Chen, E., Yeung, N. A., Lerner, B. S., & Richland, L. E. (2023). Zooming in or zoning out: examining undergraduate learning experiences with zoom and the role of mind-wandering. Computers and Education Open, 4, 100118. https://doi.org/10.1016/j.caeo.2022.100118

Introduction

Paying attention in a class, staying engaged, and actively participating in a lecture have been widely stated as critical components necessary for learners' academic success. Given the large dependence between learners' attention and academic achievement (Kane et al., 2017; Wammes et al., 2019; Wammes & Smilek, 2017), it has been increasingly important to identify ways in which learners' attentional engagement might be sustained, free from distractions that may hinder the learning experience. When the world faced a global pandemic that abruptly caused shifts in workflows across many sectors, teaching and learning specifically in 2020 was required to fundamentally modify course delivery infrastructure in just a matter of weeks. The COVID-19 pandemic necessitated a systematic change in course modalities due to nationwide orders of social distancing to mitigate spread, resulting in the suspension of in-person instruction (Agarwal & Kaushik, 2020; Ferrel & Ryan, 2020). Data from the United States in the fall of 2020 indicated that approximately 11.8 million (75%) undergraduate students learned from home and were enrolled in at least one distance learning course, while 7.0 million (44%) of undergraduates exclusively took distance education courses (National Center for Education Statistics [NCES], 2022). In order to facilitate teaching and learning given the circumstances of COVID-19, many educational institutions, including higher education, rapidly adopted internet-mediated educational technology platforms (Asad et al., 2020; Chick et al., 2020; Sandars et al., 2020), such as Zoom Teleconferencing and expanded Learning Management System (LMS) features, to support students while transitioning from in-person to emergency remote distance learning. Zoom is a web-based collaborative video conferencing platform that provides video, audio, and screen sharing capabilities in order to facilitate teaching and learning remotely through the internet.

In some ways, technology in this period was well equipped to help make this transition successful. Much of in-person higher education instruction prior to the pandemic took the form of synchronous lecture-style classroom instruction, sometimes with little verbal participation from large groups of students. Accordingly, a very similar form of instruction was able to be produced via Zoom or similar platforms. As Hodges et al. (2020) described, “emergency remote teaching is a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances" (p. 7). Thus for many educators and students, emergency remote distance learning resembled a rapid transplant of the same in-person university lectures as would typically be delivered, now mediated through Zoom. This learning modality mostly consisted of instructor-centered lectures to present students, or asynchronously available videos, which were made available to students and involved little to no student interaction.

While seemingly a very comparable learning context, data from the pandemic period suggest this transition was not seamless, with high rates of disengagement by students, lower learning standards and levels, and higher failure rates. (Hodges et al., 2020; Goldberg, 2021; Maimaiti et al., 2021; Makhrus et al., 2021). Thus, this difference raised questions about why this type of technology-delivered instruction proceeded differently from in-person instruction, and one candidate theory has been that students may have much more difficulty in sustaining engagement and attention in this format (Kohnke & Moorhouse, 2022; Moorhouse, 2020). Cognitive challenges such as mind-wandering and attentional control can become exacerbated when students are at home in a synchronous or asynchronous fully online space. In an effort to understand this context and implications for broader instructional design, this study examined a hypothesized model which: 1) identifies the indicators impacting students’ mind-wandering, 2) examines factors influencing online engagement, and 3) explores students’ mind-wandering as a mediating variable of student online engagement. Finally, we consider lessons learned and the theoretical and practical pedagogical design principles that may help to reduce students' frequency to mind-wander while learning remotely.

Mind-wandering has been defined as the phenomenon in which learners' thoughts or attention drift away from the task at hand to some unrelated thought (Al-Balushi et al., 2022; Feng et al., 2013). Certainly, mind-wandering occurred in the classroom context where students do not always fully pay attention to the lectures prior to the emergency remote learning (Pachaei et al., 2016; Wammes et al., 2016), but the transition to Zoom along with the day-to-day negative news of pandemic may have furthered worsened students' task-unrelated thoughts. For example, students were highly anxious, with 71% of undergraduates sampled agreeing that they experienced "increased stress and anxiety" due to the COVID-19 pandemic (Son et al., 2020). Additionally, Smith et al. (2020) found that students were less attentive on Zoom when compared to students physically in the same classrooms with their instructor, experienced reduced attentiveness for synchronous only classes, and even lower engagement for synchronous classes greater than 30 minutes, posing the question: Are they paying attention, or are they shoe shopping? On the other hand, students described fears related to the impacts of the COVID-19 pandemic itself while also citing issues related to increased distractions, willingness to speak up in front of large online Zoom class, difficulty concentrating, lack of prior experience, increased worries, and decreased motivation, with emergency remote distance learning —all of which are maybe critical factors affecting the students' mind-wandering (Agarwal & Kaushik, 2020; Fawaz & Samaha, 2021; Kaharuddin, 2020; Kohnke & Moorhouse, 2022; Son et al., 2020).

Was and colleagues (2019) surveyed students' beliefs about mind-wandering during an online lecture and found that online lectures can be detrimental to academic performance and that task-related thoughts would lead to higher levels of performance. This corroborates Risko et al. (2012) findings that college students watching a video lecture with no interactions mind-wandered more frequently and was related to poorer performance. As such, we might infer that in addition to academic performance, the frequency of students' mind-wandering given the transition to Zoom and the negative experiences of the pandemic may also have a critical role in impacting students' engagement. This study provided an opportunity to clarify how the associations between students' self-efficacy, task value, anxieties, and online engagement are influenced by students' mind-wandering. Corroborating results from multiple studies, we specifically focus on unintentional mind-wandering, which is hypothesized to be the result of shifting incentivized values, failure of executive control, and lack of meta-awareness, with the ultimate consequence of poor task engagement (Kozlowski & Bell, 2006; Orvis et al., 2009; Risko et al., 2012). Additionally, student engagement is hypothesized to be higher when learners have control and some autonomy over the learning task, rather than unintentionally mind-wandering to unrelated tasks (Hidi & Renninger, 2006). Since student self-efficacy fosters goal setting and increases in students' judgments about their abilities to learn and successfully complete tasks (Colquitt et al., 2000; Gist & Mitchell, 1992), we would expect to see that students with higher self-efficacy would be less likely to lose interest and persevere on challenging tasks. Additionally, we would expect a similar trend in students with high levels of task-value, that is, students' evaluations of how important and useful a task might likely lead to more active involvement within the course (Artino & McCoach, 2008; Eccles & Wigfield, 2002; Pintrich, 1991). Together, students' motivations such as self-efficacy and task-value are likely to increase student involvement and combat distraction, thereby reducing the frequency of mind-wandering (Randall et al., 2014; Randall, 2015). On the other hand, students' increased trait anxiety with regards to the drastic changes in learning modalities and the pandemic may signal a failure of attentional cognitive resources, increasing students' mind-wandering and negatively influencing students' online engagement. Drawing from the literature, we can begin to understand how mind-wandering may have detrimental impacts on students' emergency remote learning experience, and identifying the factors that contribute to the resulting effects of mind-wandering may better inform instructors, course designers, and administrators on how to accommodate learning for students. Consequently, we conducted a path analysis to examine students' mind-wandering as a potential mediator impacting students' learning experiences.

Student engagement is hypothesized to be increased when learners exhibit interests, control, and some autonomy over the learning task, (Hidi & Renninger, 2006). Online courses with low student involvement, instructor-focused, and lack of student-centered activities are often plagued with student's feeling uninterested, disengaged, and increased absenteeism due to increased mind-wandering, or the directing of attention away from a primary task (Desideri et al., 2019; Eastwood et al., 2012; Hodges et al., 2020; Son et al., 2020). For example, Wong and Lim (2021) found that learners who engaged in long-hand note taking encouraged less mind-wandering during online lectures, leading to greater course performance than those who took photos or did not engage in note-taking at all. Wong and Lim (2021) further reveal that this finding was the result of mind-wandering mediating the impact of note-taking strategies on video lectures. As the human mind starts to wander, our ability to monitor our own performance and behaviors subsequently is reduced, making us more prone to mistakes and preventing the internalization of new information while learning (Kam, 2017; Kam et al., 2012). Informed by the hypotheses of why mind-wandering occurs, this attentional lapse or zoning out is hypothesized to be a detrimental source for students' disengagement, as mind-wandering while learning exacerbates cognitive task performance, concentration, and course participation (Szpunar et al., 2013). Additionally, since many students are first-time distance learners, students' self-efficacy, or judgments about their confidence and ability to succeed in an online course, are likely to be low, influencing the extent to which learners engage and interact with distance learning (Bates & Khasawneh, 2007). Conversely, students with high levels of self-efficacy are likely to be more engaged in the online course, actively monitoring their performance and setting goals to continually accomplish the course requirements (Colquitt et al., 2000). Furthermore, given the virtually overnight rapid transition to distance learning, the quality of emergency remote distance learning courses may differ drastically from online learning grounded in instructional design principles, which puts into question the validity and rigor of remote of emergency remote learning courses, affecting students' task-value or perceived "worthwhileness and validity" of participating in the course at all (Hodges et al., 2020; Joo et al., 2015). Moreover, these negative competing thoughts disrupt task engagement, as anxiety, or feelings of worry specifically, take up limited cognitive resources (Ashcraft & Kirk, 2001; Mesghina & Richland, 2020). As such, this study examined the relationship between students' self-efficacy, trait anxiety, task-value, and mind-wandering on students' online engagement, and tested students' mind-wandering as a mediating factor during this time period of the rapid conversation to emergency remote distance education.

Current Study

Hence, this paper builds on the prior literature on distance learning to examine the social, cognitive, and behavioral factors that influence students' learning experiences under these conditions. We attend specifically to the role of students' tendency to mind-wander and, conversely, students' online engagement, in relation to the online delivery of courses through the

Zoom platform itself. Additionally, we considered students' heightened anxieties and examined the role of students' self-efficacy and task-value, given the personal and contextual factors influencing students' learning experience due to the transition to emergency remote distance learning. Taking these factors into account, this study represents an *in situ* survey analysis of undergraduate students examining the mediating role of students' mind-wandering and the factors that impact learners' online engagement during the transition to emergency remote distance learning. By conducting a path analysis, we were able to identify the direct and indirect effects on mind-wandering and engagement. Examining both of these effects in the context of our study, we are able to make suggestions for causal and mechanistic claims on the mediating role of mind-wandering. Through this process, we were able to eliminate pathways and find the underlying mechanisms by which the effects influenced the outcome. Collecting student survey data allows insights into learners' actions, attitudes, and beliefs in their everyday life as they naturally occur (Voida et al., 2014). Selecting this *in situ* observational approach enabled researchers the opportunity to elicit student information characterized by high ecological validity (Verhagen et al., 2016, 2019), as students responded to the questionnaires while fully immersed in emergency remote distance learning courses during the academic terms in the middle of a global pandemic. As a result, the purpose of the present study aimed to examine the impact of these hypothetically related variables such as learner's self-efficacy, trait anxiety, task-value beliefs, mind-wandering, and online course engagement as suggested by the literature. Thus, this study is guided by the following hypotheses (see Figure 1.1 and Table 1.5):

> [H1]: Students' self-efficacy will have a direct negative effect on students' mind-wandering and a direct positive effect on students' engagement.

[H2]: Students' trait anxiety will have a direct positive effect on students' mind-wandering and will have a direct negative effect on students' engagement.

[H3]: Students' task-value will have a direct negative effect on students' mind-wandering and will have a direct positive effect on students' engagement.

[H4]: Students' mind-wandering will have a direct negative effect on students' engagement.

[H5A]: Students' self-efficacy will have an indirect positive effect on students' engagement.

[H5B]: Students' trait anxiety will have an indirect negative effect on students' engagement.

[H5C]: Students' task value will have an indirect positive effect on students' engagement.

Materials and Methods

Ethical Considerations

This study was funded by the National Science Foundation (NSF) and received Institutional Review Board (IRB) approval. IRB approval was obtained by the university institution in order to conduct human subjects research as mandated by the universities and the grant funder. An IRB-exempt protocol status was granted since the data collected was anonymously submitted online and posed no more than minimal risk as students were already enrolled in those classes. Data of the participants were recorded confidentially and anonymously and none of the questionnaires, topics, or content asked could harm students. This protocol was approved by the university ethics committee.

Research Design

This study was a cross-sectional survey analysis of undergraduate students who experienced distance learning through Zoom during the COVID-19 pandemic. Cross-sectional studies are an observational research procedure characterized by measuring variables of interest within a population during a specific period of time (Setia, 2016). For this study, data were collected for one year between April 2021 and March 2022, from the onset of the COVID-19 pandemic to the one year point. As such, the survey was administered three times during the university's quarter system, Spring, Fall, and Winter, and only new students were recruited to participate while the survey was open. Data from these three cohorts were then pooled together for analysis of students learning through the Zoom modality for an entire year.

Participants

Participants in this study included undergraduate students from two large undergraduate research institutions in California within 14 different online courses across five university schools which include: the School of Education, the School of Biological Sciences, School of Social Ecology, School of Law, and School of Social Sciences. Undergraduate students were recruited to participate in this study by invitation through their course instructor. All of the instructors contacted to participate in this study utilized synchronous Zoom lectures as their teaching and learning modality. This meant that all students were required to attend their lectures at their regularly scheduled time and join the professor and other students in a live synchronous session which was facilitated by Zoom. A large recruitment call was sent out to professors and these instructors were chosen to participate specifically to fit our criteria in order to better account for the Zoom synchronous learning environment.

Students who participated were compensated a $20 Amazon gift card upon completion of the study. Of the 2,121 students who were recruited from 14 classes over three academic terms, 706 students responded to surveys. Out of the 706 students who responded, 73 students were eliminated because they failed to meet the attention checks built into the online survey questionnaire used to identify if the participant was paying attention to the survey questions and instructions. The exclusion criteria were made up of three types of attention check questions, which included attention filters, trap questions, and reverse wording. These questions were not relevant to the survey constructs of interests and were randomized within the survey to establish a criterion for checking if students were paying attention (Oppenheimer et al, 2009). Students failing two or more of the attention check questions were removed (Meyvis & van Osselaer, 2017).

Subsequently, the resulting final sample size was ($n = 633$). As a result, the present study had a survey response rate of 29.8%. The undergraduate student participants in this study were of varying student-level statuses, with 27.5% first years, 15.8% second years, 31.3% third years, 23.1% fourth years, and 2.37% fifth years (See Table 1.1). Student demographics in this study were 1.42% African American, 44.2% Asian/ Pacific Islander, 34.1% Hispanic/ LatinX, 10.9% White, 7.10% Multiple/ Mixed, and 2.21% other ethnic/ racial groups, comprised of ($n = 496$) females, ($n = 128$) males and ($n = 9$) other. (See Table 1.1). In addition, school-level demographic data revealed that 54.5% of student participants were classified as first-generation and 2.2% of students were classified as international (See Table 1.1). To ensure that demographic bias was not introduced after eliminating students' failing the attention checks, participant demographics were compared with the universities. Public demographic data provided directly by the universities indicate that the race and ethnicity make up for the 2020-21 academic was made up of 2.34% African American, 44.1% Asian/ Pacific Islander, 30.4% Hispanic/ LatinX, 15.8% White, 5.7% Multiple/ Mixed, and 1.5% other ethnic/ racial groups. A chi-square difference test was performed to examine the difference between study participants and the race/ ethnicity of the universities. The difference between the study participants and the university's student race and ethnic profiles was not significant ($\chi^{2D} = 16.6$, $p = 0.454$).

Data Collection and Instrumentation

Data in this study were collected electronically through online surveys via Qualtrics XM. Participants were provided a direct link to the survey which was emailed by their course instructors. Five questionnaires were utilized in this study which included the student demographics survey, Online Value and Self-Efficacy Scale (OLVSES), State-Trait Anxiety Inventory (STAI), Online Engagement Scale, and the Mind-Wandering Questionnaire (MWQ). These are described below.

Demographics Survey

The demographics survey was self-report and included questions regarding participant age, gender, race/ ethnicity, and education level. Additionally, statuses regarding graduation, international, first-generation, and undergraduate minority markers were requested.

Online Value and Self-Efficacy Scale

To assess students' self-efficacy and task-value beliefs in an online learning environment, the Online Value and Self-Efficacy Scale (OLVSES) was employed. This instrument was developed by Artino and McCoach (2008) to measure students' self-report self-efficacy and task-value beliefs while learning specifically in online courses. Composed of two sub-constructs self-efficacy and task-value, there were a total of 11 items scored on a 7-point Likert scale ranging from 1 (completely disagree) to 7 (completely agree). Sample items include “It is personally important for me to perform well in this course” and “even in the face of technical difficulties, I am certain I can learn the material presented in an online course” (see Table 1.6). Artino and McCoach (2008) report the internal consistency coefficients (Cronbach alphas) for self-efficacy as 0.93 and task-value as 0.90. In this study, Cronbach's alphas of self-efficacy and task-value were 0.879 and 0.875, respectively (See Table 1.2).

State-Trait Anxiety Inventory

The State-Trait Anxiety Inventory (STAI) was developed by Spielberger and colleagues (1983) and was used in this study to evaluate students’ anxieties. The STAI instrument contains 20 items within two sub-scales: state-anxiety and trait-anxiety. For the purposes of this study, we only assessed students’ trait anxiety. All items are rated on a 4-point Likert scale ranging from 1 (almost never) to 7 (almost always). Sample items include “I get in a state of tension or turmoil as I think over my recent concerns and interest” and “Some intrusive thought runs through my mind and bothers me” (see Table 1.9). Speilberger (1980) reports the internal consistency coefficients to be 0.92. In this study, the Cronbach’s alpha of STAI factor was 0.880 (See Table 1.2).

Online Engagement Scale

In order to assess students’ perceived online engagement, we utilized the 12-item perceived engagement scale (Rossing et al., 2012). Response options were designated on a 5-point scale, 1 (completely disagree) to 5 (completely agree). The construct consisted of a combination of questions about students’ perceptions of learning and their perceived engagement in an online course. Sample items include, “When I am in the online class, I just ‘pretend’ as if I am learning” and “If I do not know about a concept when I am learning in the online class, I do something to figure it out” (see Table 1.7). Rossing et al. (2012) report that the internal consistency coefficient for this instrument is 0.90. In this study, the Cronbach's alpha of the perceived engagement scale was 0.885 (See Table 1.2).

Mind-Wandering Questionnaire

To determine students’ levels of mind-wandering, the Mind-Wandering Questionnaire (MWQ), developed by Mrazek and colleagues (2013), was deployed to assess students’ inattention while taking online courses. This instrument includes five items with response options designated on a 6-point Likert scale, 1 (almost never) to 6 (almost always). Sample items include “I mind-wander during lectures or presentations” and “I find myself listening with one ear and thinking about something else at the same time” (see Table 1.8). Mrazek et al. (2013) reported the internal consistency coefficient as 0.85 and was revalidated by Trigueros and colleagues (2019) with an internal consistency coefficient of 0.94. In this study, the Cronbach’s alpha of MWQ was 0.887 (See Table 1.2).

Preliminary Data Analysis

Data were analyzed using SPSS to conduct scale reliabilities, descriptive statistics, missing data analysis, correlations, and AMOS for structural equation modeling. Scale reliability checks were conducted to verify the Cronbach’s alpha coefficients for all of the validated instruments used in this study. Cronbach’s alpha coefficients greater than $\alpha = 0.70$ were considered acceptable levels of reliability (Nunnally, 1978). Measured variables were analyzed by first recoding the Likert questions into their respective positive or negative values, followed by computing descriptive statistics of the items associated with each instrument. Full information maximum likelihood (FIML) was utilized as the missing data estimation approach to account for data missing at random, maximizing the case-wise likelihood of the observed data (Carter, 2006; Wothke, 1998). Then, preliminary analysis tested assumptions of sample size, multivariate normality, linearity, and multicollinearity of the variables of interest. Lastly, bivariate correlation analysis evaluated the linear relationships between the different study variables.

Assumptions of Sample Size, Normal Distribution, and Multicollinearity

To fulfill the requirements to perform a path analysis, assumptions regarding sample size, multivariate normal distribution, and multicollinearity were examined. A sufficient sample size for analysis is twenty times greater than the number of indicator variables utilized in the model (Kline, 2015). As such, a sample size of 100 was determined to meet the provisions of a necessary sample for a path analysis that contained five variables. To confirm multivariate normality, the mean, standard deviations, and the skewness and kurtosis of the measured variables were calculated. Normal distributions are met with acceptable values between -3 and 3 for skewness, and -10 and 10 for kurtosis when utilizing structural equation modeling (Brown, 2015; Kline, 2005). Table 2 documents that the current study data fulfills the assumptions of multivariate normality. Furthermore, assumptions of multicollinearity were tested by calculating the variance increase factor (VIF) and tolerance values. Hair and colleagues (2015) indicate that if the VIF values are greater than 5 and tolerance values are less than 0.1, then multicollinearity exists. Table 2 shows that the VIF and tolerance values are within the specified range for the variables of interest.

Data Analysis Plan

Lastly, SPSS AMOS 28.0 was used as the statistical software to conduct a path analysis using the maximum likelihood estimation (MLE) in order to analyze the hypothesized research model (See Figure 1.1). The direct and indirect relationships between the variables of trait anxiety, self-efficacy, task-value, mind-wandering, and online engagement were defined. More specifically, we conducted a covariance-based path analysis, a subset of structural equation modeling (SEM), with a maximum likelihood estimation (MLE) approach to examine our research questions and hypotheses with measured variables (Lleras, 2005; Ullman & Bentler, 2012). Fit indices such as the goodness of fit test conformity (Chi-square statistic), the goodness of fit index (GFI), comparative fit index (CFI), normed fit index (NFI), and the root mean square error of approximation (RMSEA) were calculated (Kline, 2012; Schumacker & Lomax, 2004). Initially, a fully saturated model was conducted to test our hypothesized model. Finally, we respecified our hypothesized model by making stepwise modifications to achieve a more parsimonious model with higher levels of model fitness (Hox & Bechger, 1998; Ullman & Bentler, 2012). Based on these test results, unique direct and indirect effects were analyzed to examine the factors influencing students' mind-wandering and online engagement.

Results

Table 1.2 summarizes the descriptive statistics for all the scale constructs used in this study. Bivariate Pearson correlations document the linearity between the endogenous and exogenous variables in Table 1.2. All study variables indicated significant linear trends except for the relationship between students' task-value and their trait-anxiety ($r = -0.004$, $n = 633$, $p < 0.914$) and mind-wandering ($r = 0.014$, $n = 633$, $p < 0.098$).

Testing the Hypothesized Model

In the initial examination of the path analysis, we tested a fully saturated hypothesized model, analyzing the conformity indices and direct effects of trait-anxiety, self-efficacy, task-value, mind-wandering influencing students' online engagement The χ^2 conformity index of the model was significant $\chi^2 (3, N = 633) = 7.759$, $p < 0.001$. A non-significant p-value is typically required to prove a high level of conformance; however, this is highly sensitive to large sample sizes (Hoyle, 1995). As such, the Root Mean Square of Approximation (RMSEA) was calculated to accommodate for the slightly significant Chi-square statistic due to the large sample size. In this initial model, the RMSEA was 0.063 (See Table 1.4). Values of < 0.08 indicate a good fit, with values closer to 0 representing a perfect fit (Kline, 2015). To determine the square root of the difference between the residuals of the sample covariance matrix and the hypothesized model (Kline, 2005), the Standardized Root Mean Square Residual (SRMR) was calculated to be 0.061. The recommended cut-off value of less than 0.08 (See Table 1.4). Lastly, the goodness of fit index (GFI), comparative fit index (CFI), Tucker Lewis index (TLI), and normed fit index (NFI) was calculated to be 0.988, 0.981, 0.811, and 0.781 respectively (See Table 1.4). Index values of 0.95 or greater represent acceptable conformity (Schumacker & Lomax, 2004). Estimating the structural β coefficients of the model provided the statistically significant and nonsignificant pathways. The effects of students' self-efficacy ($\beta = 0.578$, $p < 0.001$), task-value ($\beta = 0.124$, $p < 0.001$), trait-anxiety ($\beta = -0.052$, $p < 0.075$) and mind-wandering ($\beta = -0.052$, $p < 0.001$) on online engagement were statistically significant. In addition, the effect of students' trait-anxiety ($\beta = -0.464$, $p < 0.001$) and self-efficacy ($\beta = -0.269$, $p < 0.001$) on mind-wandering was statistically significant. However, the direct effect of students' task-value ($\beta = 0.064$, $p > 0.05$) on mind-wandering was not statistically significant. As a result, one nonsignificant pathway was removed, and the final model was respecified.

Testing the Respecified Model

Model Fitness. In order to evaluate the model fitness of the competing model, the goodness of fit measures of the respecified path model was calculated (See Table 1.4). The χ^2 conformity index of the model was non-significant, $\chi^2\,(3, n = 633) = 3.492$, $p = 0.062$ and the

GFI, CFI, TLI, and NFI were 0.998, 0.997, 0.974, 0.996, respectively. The RMSEA was 0.063 the SRMR was calculated to be 0.015. A Chi-square difference test was computed to compare the statistical significance between the two competing models (Schermelleh-Engel et al., 2003). Results from the Chi-square difference test confirmed that there was no statistically significant difference between the hypothesized and final respecified models in terms of the goodness-of-fit ($\chi^{2D} = 4.267$, $p = 0.118$). As such, the respecified model was chosen as the final model for parsimony for this study. The comparison between the fit statistics of both models can be found in Table 1.4 and the final respecified model with standardized path coefficients is shown in Figure 1.2.

Direct Effects on Mind-wandering. After determining the model conformity indices of the respecified model, the standardized beta coefficients of the direct effects were further examined. First, we found that students' self-efficacy ($\beta = -0.240$, $p < 0.001$) had a significant negative direct effect on students' mind-wandering (See Table 1.5). This indicated that as students' self-efficacy increased by 1 standard deviation, students' mind-wandering decreased by 0.240 standard deviations. Meanwhile, students' trait-anxiety ($\beta = 0.445$, $p < 0.001$) had a significant positive direct effect on students' mind-wandering (See Table 1.5). As students' trait-anxiety increased by 1 standard deviation, students' mind-wandering increased by 0.445 standard deviations. Thus, students' self-efficacy and trait-anxiety together accounted for 36.5% of the explained variance in students' mind-wandering ($R^2 = 0.365$).

Direct Effects on Engagement. Secondly, as a result of examining the direct effects of students' self-efficacy, task-value, trait-anxiety, and mind-wandering on students' online engagement, we found that students' self-efficacy ($\beta = 0.559$, $p < 0.001$) and task-value ($\beta = 0.321$, $p < 0.001$) were both positive and statistically significant (See Table 1.5). Thus, when students' self-efficacy increased by 1 standard deviation, students' online engagement increased by 0.536 standard deviations. A similar trend was recorded by students' task-value. As students' task-value increased by 1 standard deviation, students' online engagement increased by 0.325 standard deviations. Meanwhile, students' trait-anxiety (β = -0.073, $p < 0.05$) mind-wandering (β = -0.149, $p < 0.001$) had a negative significant direct effect on students' online engagement (See Table 1.5). As students' trait anxiety increased by 1 standard deviation, students' online engagement decreased by 0.073 standard deviations. Likewise, as students' mind-wandering increased by 1 standard deviation, students' online engagement decreased by 0.119 standard deviations. Students' self-efficacy, task-value, trait anxiety and mind-wandering, all of which indicated significant direct effects, accounted for 53.0% of the explained variance in students' online engagement (R^2 = 0.530).

Indirect Effects. As the aforementioned direct effects were significant, the mediating effects of students' mind-wandering were explored. To evaluate the mediation effect, we examined the significance of the indirect effects of students' mind-wandering on (1) students' self-efficacy and students' online engagement and (2) students' trait anxiety and students' online engagement. The indirect effect of students' task-value was not tested in this final model because of the removal of the non-significant pathway after selecting the final model. The standardized indirect (mediated) effect of students' self-efficacy on their online engagement was significant (β = 0.036, $p < 0.001$) (See Table 1.5). When students' self-efficacy goes up by 1 standard deviation, their online engagement goes up by 0.028 standard deviations. In addition, the standardized indirect (mediated) effect of trait-anxiety on online engagement was significant (β = -0.066, $p < 0.001$) (See Table 1.5). That is, due to the indirect (mediated) effect of trait anxiety on student online engagement, as trait anxiety goes up by 1 standard deviation, students' online engagement goes down by 0.066 standard deviations. Since the direct effect of self-efficacy on online engagement was statistically significant, mind-wandering partially mediates the relationship between self-efficacy and online engagement. Similarly, as the direct effect of students' trait anxiety was significant, mind-wandering partially mediates the relationship between trait anxiety and online engagement. Thus, students' mind-wandering partially mediates the relationship between (1) self-efficacy and online engagement and (2) partially mediates the relationship between trait anxiety and online engagement.

Total Effects. As a result of testing the relationships among the study variables, self-efficacy and trait anxiety had a statistically significant total effect on students' mind-wandering (see Table 1.5). The total effect of trait anxiety (β = 0.445) was larger than that of the total effect of self-efficacy (β = -0.240) (See Table 1.5). Additionally, students' self-efficacy, task-value, trait anxiety, and mind-wandering had a statistically significant total effect on students' online engagement. The total effect self-efficacy (β = 0.595) was greater than task-value (β = 0.321), trait anxiety ((β = -0.053) and mind-wandering (β = -0.149) (See Table 1.5). Finally, the results indicated that students' mind-wandering as a meaningful mediator for the relationship between self-efficacy and online engagement as well as trait anxiety and online engagement.

Discussion

To investigate undergraduate students' learning experiences during the transition to emergency remote online distance learning context, this in situ study examined factors contributing to students' frequency to mind-wander and identified online engagement as a negative consequence of off-task thought. Informed by the three theoretical hypotheses that suggest why mind-wandering occurs, we found students' self-efficacy, and trait anxiety as predictors of mind-wandering, and students' course engagement as a negative outcome of mind-wandering. However, based on analysis of the initial hypothesized research model, students' task-value was not significantly correlated with students' mind-wandering, and thus the results indicated the model fitness was not acceptable. We then conducted a model re-specification which was required to reach a more adequately fitting model after identifying the non-significant pathway between task-value and mind-wandering. As a result, our study findings revealed that (1) self-efficacy and trait-anxiety had a significant direct effect on students' mind-wandering; (2) self-efficacy, trait anxiety, task-value, and mind-wandering had significant direct effects on students' online engagement; and finally (3) the frequency of students' mind-wandering mediates the relationship between self-efficacy and engagement and trait-anxiety and engagement. Our hypotheses and statistical validations are summarized in Table 1.5.

Hypothesis [1] on the negative direct effect of self-efficacy on students' mind-wandering and the direct positive effect on students' engagement was supported and this relationship was significant. Students' awareness about their judgments to be successful and their ability to actively monitor those judgments while distance learning, plays an influential role in students' frequency to mind-wander. As such, students in emergency remote distance learning contexts who had higher levels of self-efficacy, mind-wandered less. More specifically, students who were able to consciously monitor their own judgments and beliefs of success in the present moment while learning remotely were less likely to engage in off-task thought. The results on the effect of self-efficacy and mind-wandering are in agreement with the meta-awareness hypothesis, positing that decreased mind-wandering occurs when there is increased awareness and self-monitoring while performing a task (Smallwood, 2013). Additionally, as students' self-efficacy about online learning increased, their engagement within the course significantly increased. The results of this study are therefore consistent with that of social cognitive behavioral theorists linking students' self-efficacy as a significant positive predictor promoting students' online engagement, while also documenting a negative significant association with students' mind-wandering as a result of learners exhibiting increased meta-awareness (Artino Jr & McCoach, 2008; Bandura, 2000; Smallwood, 2013; Taipjutorus, 2014).

Hypothesis [2] was supported, as the direct effect of students' trait anxiety on their degree of mind-wandering and the direct negative effect on students' engagement was statistically significant. Under these current learning conditions, individuals are likely experiencing greater levels of anxiety as the learning conditions, modalities, and external commitments have changed when compared to in-person learning (Hapsari, 2020; Son et al., 2020). In this way, these worries occupy limited cognitive resources in the working memory which can be pervasive, indicating a lack of executive control. According to the executive failure hypothesis, the failure of executive control to regulate cognitive resources, such as combating distractions of worries and fear while learning remotely, is indicative of the onset of mind-wandering as well as poor task engagement (Jackson & Balota, 2012; McVay & Kane, 2012; Randall et al., 2014; Smeekens & Kane, 2016). The persistence of negative thoughts has been shown to disrupt performance, as feelings of worry take up limited cognitive resources in the working memory that are often in high demand while learning (Ashcraft & Kirk, 2001; Mesghina & Richland, 2020). Mesghina et al. (2021) found undergraduates higher in COVID-19 distress and anxiety saw lower learning gains due to increased mind-wandering during the online lectures, creating gaps that compound and impair students' learning over time, resulting in disengagement. Moreover, Hapsari (2021) identified other contributing factors citing students' anxieties related to distance learning, such as unstable internet connection, technology device malfunctions, and lack of opportunities for students to actively participate. These results reflect that of the literature, indicating that high levels of anxiety are associated with lower levels of course engagement (Cassidy & Johnson, 2002; Yang et al., 2021).

Interestingly, Hypothesis [3] was partially rejected, where the negative direct effect of students' task-value on mind-wandering was not significant. However, the positive direct effect of students’ task-value on students’ engagement was significant. While the literature shows that students with high levels of task-value should exhibit more active involvement within the course (Artino & McCoach, 2008; Eccles & Wigfield, 2002; Pintrich, 1990), the results of this study found that students’ task-value beliefs did not significantly impact students’ frequency to mind-wander. Drawing on the current concerns hypothesis, theorists suggest that mind-wandering is the result of the decrease in reward for participating in a task while increasing the reward of another (Klinger, 2009). One possible explanation for this inconclusive result is to consider the four components that makeup task-value: attainment value, intrinsic value, extrinsic utility value, and cost. The former three components are made up of factors that positively influence students’ motivational factors (Artino & McCoach, 2008; Joo et al., 2012; Ryan & Deci, 2000). However, cost or consequences of participation, is a less explored factor of task-value construct which invokes a negative valence of task participation, while attainment, intrinsic, and extrinsic value represent a positive valence of task (Artino & Mcocach; Eccles & Wigfield, 1995).

On the other hand, as students' perceived interests, importance, usefulness, and “worthwhileness” when participating in the online learning course increases, so does their active engagement. Past research has found that when students participate in learning activities that actively develop such value components, students are more likely to develop and solidify their involvement in the course (Chen et al., 2010; Joo et al., 2015). Increased learner involvement may serve as a powerful motivator, as high task-value beliefs are likely to lead to more learner participation, interaction, and engagement throughout the learning process (Pintrich, 1991). Johnson et al. (2013) further asserts that the conceptual underpinning between task engagement and perceived instrumentality while learning, is the personal incentivized value of success. This is extremely important when considering the nature of emergency remote distance learning where learner motivation and online engagement in course activities have been evidenced by undergraduate students to be at an all-time low (Chick et al., 2020; Hodges et al., 2020; Son et al., 2020). Consequently, although task-value was unable to predict students' mind-wandering, the brevity of the four dimensions that make up student task-value beliefs as a motivational construct may help to further explain students' engagement or disengagement in the emergency remote distance learning contexts.

Meanwhile, students' mind-wandering had a significant negative direct effect on students' online engagement, confirming Hypothesis [4]. As students' frequency of mind-wandering increased, students were less likely to be engaged in the course through active participation, on-task performance, or effortful involvement. One potential reason explaining this result is the distinct difference between emergency remote distance learning and online learning grounded in pedagogical learning design (Hodges et al., 2020). Since emergency remote distance remote learning with Zoom was meant to be a rapid solution to facilitate the continuance of learning, pedagogical instructional design principles were likely overlooked in favor of deploying a means to facilitate teaching and learning. This is fundamentally different from evidenced-based online learning environments that facilitate teaching and learning grounded in theory and practice-driven pedagogical learning design principles (Castro et al., 2021; Jeon et al., 2019). Research on the efficacy of online learning models has shown that courses developed in conjunction with learning design principles take advantage of the affordances of educational technologies through enhanced digital interactivity, active instructor-student presence through coaching and scaffolding, and exploration through multimodal student-centered instruction, to name a few (Chen, 2016; Nadiyah & Faaizah, 2015; Obizoba, 2015). As task-unrelated mind-wandering is more likely to occur during monotonous environments (Eastwood et al., 2012) or long cognitively undemanding tasks (Smallwood & Schooler, 2015), instructor-centered Zoom learning without opportunities for student-centered active learning opportunities such as cooperative learning and peer discussions may have exacerbated the quality of remote learning contexts (Muheidat, 2020), further explaining the negative effects between mind-wandering and course engagement. Szpunar and colleagues (2013) argue, when comparing those being lectured to that of the lecturer, if the lecture is extremely engaging for the lecturer, but less so for those being lectured, this difference in perspective further perpetuates students' mind-wandering. As such, to reduce the extent to which students' mind-wander in online courses, designing online instruction to shift from passive monotonous instructor-centered teaching to active opportunities for student-centered learning is likely to reduce the occurrence of mind-wandering and foster engagement (Chase et al., 2009; Szpunar et al., 2013).

Hypothesis [5A] was accepted as this study found that students' mind-wandering mediates self-efficacy and online engagement. Based on prior research, there is broad support for students' self-efficacy as a strong and significant predictor of engagement in online courses (Linnenbrink & Pintrich, 2003; Pellas, 2014; Ucar & Sungur, 2017). However, there is much less research exploring how the effects of mind-wandering might mediate this relationship. Consequently, this significant mediating pathway indicates that students' self-efficacy positively influences students' online engagement, when factoring in lower levels of students' mind-wandering. We might attribute this finding by considering the social cognitive effects of self-efficacy on student learning. As Bandura (2000) states, “the act of regulating one’s own motivations, thought processes, and affective states directly influence cognitive and behavioral actions within a learning environment.” Furthermore, as self-efficacy facilitates positive self-appraisals, students with higher self-efficacy are more resilient and willing to persevere in more challenging situations. This critical meta-awareness of their ability to succeed and persevere in difficult tasks may deter instances of off-task thoughts, thereby preventing the onset of mind-wandering and increasing course engagement.

The significant indirect effect of students' trait anxiety and online engagement supported Hypothesis [5B]. As a result, this significant indirect pathway indicates that students’ trait anxiety negatively affects students’ online engagement, when factoring in the degree to which students’ mind-wander. One possible reason for these trends is that anxiety, specifically the worries component, takes up cognitively demanding limited resources in the working memory (Mesghina & Richland, 2020), likely influencing the degree to which students’ mind-wander or “zone out” may be impacted by students’ level of anxiety (Kam, 2017; Smallwood & Schooler, 2006). Additionally, the act of mind-wandering impacted by anxiety, be that task-related or task-unrelated, further occupies the working memory capacity and cognitively shifts students’ thoughts away from the primary task at hand. Such disruption in awareness, in turn, prevents the working memory capacity from internalizing new information, subsequently leading to poor engagement within an online course (Danckert, 2018; Desideri et al., 2019; Randall, 2015). Such findings corroborate the theoretical assumptions of the executive failure hypothesis on why mind-wandering occurs (McVay & Kane, 2010). Thus, the correlations identified in this study provide rich insights into explaining the relationships between students’ attention, or lack thereof, as a result of competing for attentional demands of cognitive resources, influencing learners' online engagement.

Limitations

Certainly, more research is warranted to further evaluate the limitations to and affordances for undergraduate emergency remote distance learning. This in situ survey analysis was the first iteration of a multi-year analysis identifying the social cognitive motivational factors influencing students' mind-wandering and online engagement. While considerable efforts were made to recruit as many students as possible across two universities, our survey response rate of (633/2121) = 29.8% was considered "reasonable." Survey response rates at 15% are considered low, while rates as low as 30% are reasonable, with response rates over 50% indicated as remarkably high (Sitzia & Wood, 1998). We suspect that this might have been the case due to competing priorities, which this study alone requires an additional hour of participant time. Considering survey response rates as a potential source of bias is an important methodological factor as it contributes to the uncertainty to make generalizable findings (Fowler Jr., 2013). However, to minimize potential demographic bias, a chi-square difference test was conducted to compare the demographics of the study participants to the research institutions and no statistically significant differences were found.

It is also important to take into account that the measured variables used in this study were completely self-reported. While validated survey constructs informed by the literature were deployed to capture representative aspects of each variable measured, self-report responses are based upon a student's perception that may be fluid at one specific point in time (Stone et al., 1999). Self-report assessments might offer biased estimates of behavior, attitudes, and perceptions as a result of misunderstanding questions or prompts, overestimations of selfevaluations, and even social desirability to name a few (Rosenman et al., 2011). As such, we acknowledge the inherent constraints that are associated with the extent to which self-report measures are interpreted and have been taken into account. Furthermore, future follow-up analysis might also consider log analysis to obtain a more precise measure to capture students' online course engagement data such as time on task, rate of course participation, rate of assignment submissions, and course grades. Taking a multi-modal approach to combine self-report with clickstream logged student achievement data may provide more global and rigorous reporting of students' course behaviors (Hopewood et al., 2018). However, the benefit of this survey analysis approach reaching across multiple institutions, schools, and departments is advantageous in the wide range of data collected to improve the generalizability of our findings beyond a particular classroom. As such, while we acknowledge survey research may introduce bias, this methodological approach affords the opportunity to examine a wider population of learner experiences.

Further, it has been noted by the researchers that the survey questionnaires were deployed and collected in three different waves, which indicates that the research participants may differ between groups due to the time variance of survey assessment. This was not accounted for in the analysis of the present study, which may constitute bias in the study results. However, one of the primary goals of this study was to test a hypothesized model for factors influencing students' online engagement and the role of mind-wandering during the entire year long period higher education institutions were in remote instruction to provide generalizable findings. Nevertheless, the time factor is an important consideration as students' social, cognitive, and behavioral factors may have fluctuated as emergency remote learning continued. Future analysis will include nested model comparisons in SPSS AMOS. Conducting a multiple group analysis in structural equation modeling will afford the comparison of the same measurements between multiple population samples collected at different points in time (Deng & Yuan, 2015). This method will then allow the researchers to test the assumptions of whether the groups examined are equal by examining if the different sets of path coefficients are invariant (Loehlin, 2004). Alternatively, we might also consider using fixed-effects modeling to test the relationship between the predictor and outcome variables varying over time. Controlling for the time-invariant characteristics affords researchers to test the net effect of the predicted outcome variables, as the assumption that time may be a biasing factor may be accounted for (Torres-Reyna, 2007).

In lieu of the non-significant pathway found on task value and mind-wandering Hypothesis [3 & 5C], we might also consider specific components of task-value in the future, as the positive and negative valances within the construct may be affecting student responses. Since the non-significant finding of task value and mind-wandering was contradictory to our hypothesis, exploring the dimensional components of task value such as cost or intrinsic value alone might provide a more nuanced understanding to students' task-value beliefs. In addition, the current mind-wandering questionnaire does not distinguish between task-related and task-unrelated mind-wandering. Identifying the subtle differences might serve to better capture what students are, thinking or not thinking, about while learning in such vastly different contexts. Moreover, while we were able to identify relationships between the variables of interest, the current study lacks an equivalent control comparison to experimentally test the effects of distance learning modalities with more traditional methods. Since the current data is correlational in nature, future experimental study manipulations between asynchronous online courses compared to Zoom synchronous course designs to support students' motivations, anxieties, and online engagement, while reducing students' mind-wandering might help to further develop, validate, and scale the efficacies of remote and hybrid online learning environments in higher education institutions.

Lastly, this manuscript was centered on collecting data from a Southern California public university system with over 30,000 enrolled at any given time. The university system, across its 11 campuses, purchased an enterprise-level license of Zoom just days before students were required to evacuate the campus. In order to find a deeper understanding of students' in situ mind-wandering while distance learning at the university during this period of time, we specifically focused on courses that were implemented through Zoom synchronously. It is not to say that other platforms such as Microsoft Teams, Google Meet, or Discord are not comparable mediums to facilitate teaching and learning. Future research may dive deeper into the affordances and constraints of such platforms as educational tools to support teaching and learning and examine the differences in features to further enhance emergency distance remote learning. And while it is not the scope of this manuscript to test the affordances of constraints between teleconferencing mediums for distance learning, it is certainly a limitation of our study and Zoom is just one example.

Theoretical Implications

The present study demonstrated that students' mind-wandering partially mediates the relationship between students' self-efficacy and engagement as well as students' trait anxiety and engagement with minimal to no online pedagogical design frameworks. In addition, students' self-efficacy, trait anxiety, task-value, and mind-wandering are significant predictors of students' online engagement. Importantly, the results in this study are consistent with two of the three major hypothesized explanations for why students mind-wander, further affirming our conjectures of the executive failure and meta-awareness hypotheses. This study afforded us the opportunity to verify the competing theories of mind-wandering in an educational setting during a critical period of teaching and learning that certainly affects students' learning experiences, but also provides rigorous explanations mechanistically of how learners may have coped to continue learning through Zoom. However, more research is needed to test students' task-value beliefs grounded within the current concerns hypothesis as a potential source of why students mind-wander. Nevertheless, our model supports the theoretical conclusions that suggest students' who have high levels of self-efficacy are less susceptible to mind-wandering, and more likely to be engaged in their courses. Moreover, the model also confirms the theoretical assumption suggesting that students' preoccupation with anxieties and worries results in the failure of regulation in cognitive resources, thereby resulting in the increase of students' mind-wandering and a decrease in online engagement. As a result, students' self-efficacy and trait-anxiety affect their level of engagement in an online Zoom class, mediated by their frequency to mind-wander.

Practical Implications

In light of these findings demonstrated in this study, we recommend practical implications that instructors and administrators might draw from successful evidence-based online pedagogical learning design frameworks that are aimed at reducing the frequency of student mind-wandering and increasing student course engagement in remote learning environments. While more research is needed to show that online pedagogical design models reduce the frequency of mind-wandering, a promising and emerging framework for online learning includes learning experience design (LXD). Coined as a term in 2015, LXD is the process of creating learning environments to foster learning in a human-centered, goal-oriented method (Ahn, 2019; Correia, 2018; Floor, 2018; Wong et al., 2022). In practice, Floor (2018) defines the five fundamentals of LXD as human-centered, goal-oriented, based upon a theory of learning, including learning through practice, and being heavily interdisciplinary. In each of these five facets, there is a major emphasis on empathy, focusing on the intended and unintended design outcomes for the learners (Matthews et al., 2017). Upon selecting an online pedagogical framework to implement, instructors might consider instances in which sources of self-efficacy, task-value beliefs, anxiety, mind-wandering, and engagement are accounted for within the design of the course.

Drawing on the three hypotheses of mind-wandering, instructors might consider instances in which sources of self-efficacy are promoted for students, such as consistently providing considerable amounts of feedback and providing sufficient source examples for students to develop confidence in their online learning capabilities (Adams et al., 2020; Berges et al., 2021; Norlin, 2014; Wong et al., 2022). This feedback may occur synchronously online with the use of real-time live polling that may aid in student's engagement and reduce instances of mind-wandering while learning (Price, 2021). On the other hand, this feedback might take the form asynchronously with weekly feedback provided by the instructional team on weekly assignments, assessments or projects (Wong et al., 2022). Furthermore, by implementing a needs assessment or pre-course survey, the instructor might assess early on what students value and how students are feeling about the course. This not only encompasses a method to assess students' concerns and worries about the learning experience, but also allows novice instructors facilitating online teaching and learning a pathway to serving the students who stand to benefit the most. Additionally, assessing students' needs might allow instructors to determine the modality in which synchronous, asynchronous, or hybrid may be more beneficial to students' learning. As Wong and Hughes (2022) showed in their study, conducting a needs assessment early on also doubled as a pre and post assessment such that the researchers were able to measure the change in learners' attitudes, feelings, reactions, and behaviors over 10 instructional weeks. Moreover, we recommend that instructors might consider the elimination or reduction of traditional rote memorization exams in favor of more high-order thinking transfer application assessments (Richland & Simms, 2015), such as cross-functional group projects or a conceptual final essay. Reconsidering the types of assessments and the extent to which we evaluate student performance, a balance between formative and summative, has been shown to reduce learning anxiety (Cha & Kim, 2008; Daniels et al., 2008). Further, expressive writing in particular has been shown to be an anxiety-reducing activity that can effectively free up working memory resources (Mesghina & Richland, 2020), offloading more worry-related anxieties (Raghubar et al., 2010; Ramirez & Beilock, 2011) facilitating increased task performance. Additionally, Wong et al. (2022) found that learners writing physical notes instead of using smartphone photography to capture information during video recorded lectures mind-wandered less, which in turn led to higher retention and learning performance. Other course design features informed by the executive failure and meta-awareness hypotheses are embedded opportunities for metacognitive learning strategies such as time management, planning, monitoring, reflections, and mindfulness training (Faber et al., 2018; Randall, 2015; Sullivan & Davis, 2020, Szpuna et al., 2013).

Conclusion

Consequently, while the results of this study are correlational, there are still important theoretical underpinnings and practical implications that support students' social, cognitive, and behavioral factors that can be applied to Zoom teaching and learning immediately. As referenced earlier, emergency remote learning with little to no online pedagogy are fundamentally different from courses grounded in online pedagogical evidence-based theory and practice. However, this presents a unique opportunity to further research and identify how instructors can better support their students' learning experience through these remote learning contexts at a time when the COVID-19 pandemic has shifted learning modalities. Based on our study findings, we have learned that students' engagement are, in part, explained by their motivations, anxiety, and mediated by mind-wandering while learning through Zoom synchronously. These results are important as it affords instructors to consider elements of instructional design features to better attend to factors that positively impact students' mind-wandering and online engagement. Thus, our study makes an important contribution as it suggests factors contributing to students' frequency to mind-wander and how mind-wandering mediates students' online engagement. Moreover, these results add to our understanding of students' learning experiences during emergency remote distance learning, serving as the foundation for future experimental research iterations to implement online learning design principles based upon theory that minimizes mind-wandering, increases student engagement, while supporting learners' anxieties and self-efficacy at the same time. As the ever-changing landscape of teaching and learning in higher education institutions evolve, this research may inform the theory, design, and practice of expanded learning modalities of in-person, asynchronous online, synchronous online, blended, flipped, and hybrid models offered to undergraduate learners.

Appendix

Table 1.1

Sociodemographic Characteristic of Participants

Student Characteristics	Students Enrolled	
	n	%
Gender		
Female	496	78.3
Male	128	20.2
Other	9	1.42
Ethnicity		
African American	9	1.42
Asian	280	44.2
Hispanic	216	34.1
Multiple	45	7.11
Other	14	2.21
White	69	10.9
Student Year		
First	174	27.5
Second	100	15.8
Third	198	31.3
Fourth	146	23.1
Fifth	15	2.37
International Student		
Yes	14	2.21
No	619	97.8
First Generation		
Yes	345	54.5

No	288	45.5

Note. total n = 633 Reflects the number and percentage of participants answering "yes" to this question.

Table 1.2

Descriptive Statistics and Correlations for Study Variables (n = 633)

Variable	1	2	3	4	5
1. Self-efficacy	—				
2. Task-value	.174***	—			
3. Trait Anxiety	-.510***	-.004	—		
4. Mind-wandering	-.467***	.014	.568***	—	
5. Engagement	.649***	.417***	-.299***	-.365***	—
Cronbach Alpha (α)	.902	.883	.888	.887	.910
Mean	23.8	35.9	50.6	20.0	42.3
Standard Deviation	6.36	4.94	11.5	5.17	7.93
Skewness	-.520	-1.08	-.117	-.402	-.449
Kurtosis	-.023	2.35	.194	.095	.730
Tolerance	*.662*	*.955*	*.599*	*.632*	—
Variance Increase Factor	*1.51*	*1.05*	*1.67*	*1.58*	—
Sample	*633*	*633*	*633*	*633*	*633*

****. Correlation is significant at the 0.01 level (2-tailed).*

Table 1.3

Fit Statistics for the hypothesized and respecified structural model (n = 633)

	CMIN (c^2)	Df	GFI	CFI	TLI	NFI	RMSEA	SRMR
Initial structural model	3.49	3	.918	.976	.811	996	.063	.023
Respecified structural model	7.76	3	.998	.997	.974	.996	.063	.001
Criteria	—	—	>.95	>.90	>.95	>.95	<0.08	<0.08

Table 1.4

Effect decomposition for the respecified model (n = 633)

			Unstandardized			Standardized		
			Total	Direct	Indirect	Total	Direct	Indirect
Mind-wandering	←	Self-efficacy	-.209	-.209*	.000	-.240	-.240*	.000
	←	Trait-anxiety	.726	.726*	.000	.445	.445*	.000
	←	Task-Value	.000	.000	.000	.000	.000	.000
Engagement	←	Self-efficacy	.171	.163*	.009*	.595	.536	.036*
	←	Trait-anxiety	-.030	.000*	-.030*	-.053	-.073*	-.066*
	←	Task-Value	.125	.125*	.000	.321	.321*	.000
	←	Mind-wandering	-.041	-.041*	.000	-.149	-.149*	.000

**p < 0.05. Correlation is significant at the 0.05 level (2-tailed).*

Table 1.5

The Hypotheses of the study findings.

Hypotheses	***Rejection Status***	***Statistical Proof***
[H1]: Students' self-efficacy will have a direct negative effect on students' mind-wandering and will have a direct positive effect on students' engagement.	Fail to reject	$\beta = -.40, p < .001$; $\beta = .536, p < .001$
[H2]: Students' trait anxiety will have a direct positive effect on students' mind-wandering and will have a direct negative effect on students' engagement.	Fail to reject	$\beta = -.445, p < .001$; $\beta = -.073, p < .001$
[H3]: Students' task-value will have a direct negative effect on students' mind-wandering and will have a direct positive effect on students' engagement.	Reject; Fail to reject	$\beta = .064, p > .05$; $\beta = .321, p < .001$
[H4]: Students' mind-wandering will have a direct negative effect on students' engagement.	Fail to reject	$\beta = -.149, p < .001$
[H5A]: Students' self-efficacy will have an indirect positive effect on students' engagement.	Fail to reject	$\beta = .036, p < .001$
[H5B]: Students' trait-anxiety will have an indirect negative effect on students' engagement.	Fail to reject	$\beta = .066, p < .001$
[H5C]: Students' task value will have an indirect positive effect on students' engagement.	Reject	$\beta = -.009, p > .05$

Table 1.6
Items from Online Value and Self-efficacy Scale

Self-efficacy

Even in the face of technical difficulties, I am certain I can learn the material presented in an online course. (1)

I am confident I can learn without the presence of an instructor to assist me. (2)

I am confident I can do an outstanding job on the activities in an online course. (3)

I am certain I can understand the most difficult material presented in an online course. (4)

Even with distractions, I am confident I can learn material presented online. (5)

Task-value

It is personally important for me to perform well in this course. (1)

This course provides a great deal of practical information. (2)

I am very interested in the content of this course. (3)

Completing this course moves me closer to attaining my career goals. (4)

It is important for me to learn the material in this course. (5)

Table 1.7
Items from Online Engagement

<u>Behavioral Engagement</u>

I adhere to the policies of the online class. (1)

I have difficulties navigating the online class. (2)

When I am in the online class, I just 'pretend' as if I am learning. (3)

I am able to consistently pay attention when I am participating in the online class. (4)

I complete my online assignments on time. (5)

<u>Emotional Engagement</u>

I like taking this online class. (1)

I feel excited by my work in the online class. (2)

The online classroom environment is a fun place to be. (3)

I am interested in the work I do in the online class. (4)

I feel happy when taking the online class. (5)

I feel bored when taking the online class. (6)

<u>Cognitive Engagement</u>

I check my assignments for mistakes. (1)

I study even when I do not have an exam. (2)

I try to look for some course-related information on other resources such as the internet, journal papers, magazines, etc. (3)

When I read the course materials, I ask myself questions to make sure I understand what it is about. (4)

I read extra materials to learn more about things we do in the online class. (5)

If I do not know about a concept when I am learning in the online class, I do something to figure it out. (6)

If I do not understand what I learn online, I go back to watch the recorded session and learn again. (7)

I talk with people outside of school about what I am learning in the online class. (8)

Table 1.8
Items from Mind-wandering Questionnaires

I have difficulty maintaining focus on simple or repetitive work. (1)
While reading, I find I haven’t been thinking about the text and must, therefore, read it again. (2)
I do things without paying full attention. (3)
I find myself listening with one ear and thinking about something else at the same time. (4)
I mind-wander during lectures or presentations. (5)

Table 1.9
Items from State Trait Anxiety Inventory

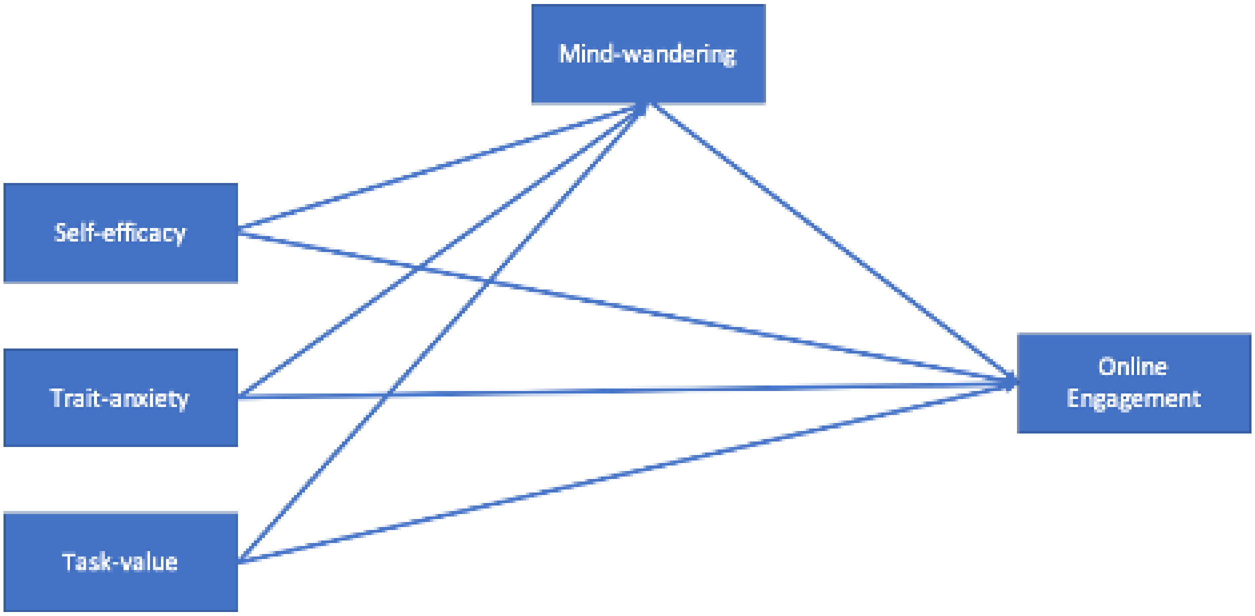
I feel pleasant (1)
I feel nervous and restless (2)
I feel satisfied with myself (3)
I wish I could be as happy as others seem to be (4)
I feel like a failure (5)
I feel rested (6)
I am "calm, cool, and collected" (7)
I feel that difficulties are piling up so that I cannot overcome them (8)
I worry too much over something that really doesn't matter (9)
I am happy (10)
I have distracting thoughts (11)
I lack self-confidence (12)
I feel secure (13)
I make decisions easily (14)
I feel inadequate (15)
I am content (16)
Some intrusive thought runs through my mind and bothers me (17)
I take disappointments so keenly that I can't put them out of my mind (18)
I am a steady person (19)
I get in a state of tension or turmoil as I think over my recent concerns and interests (20)

Table 1.10

List of Measurement Instruments

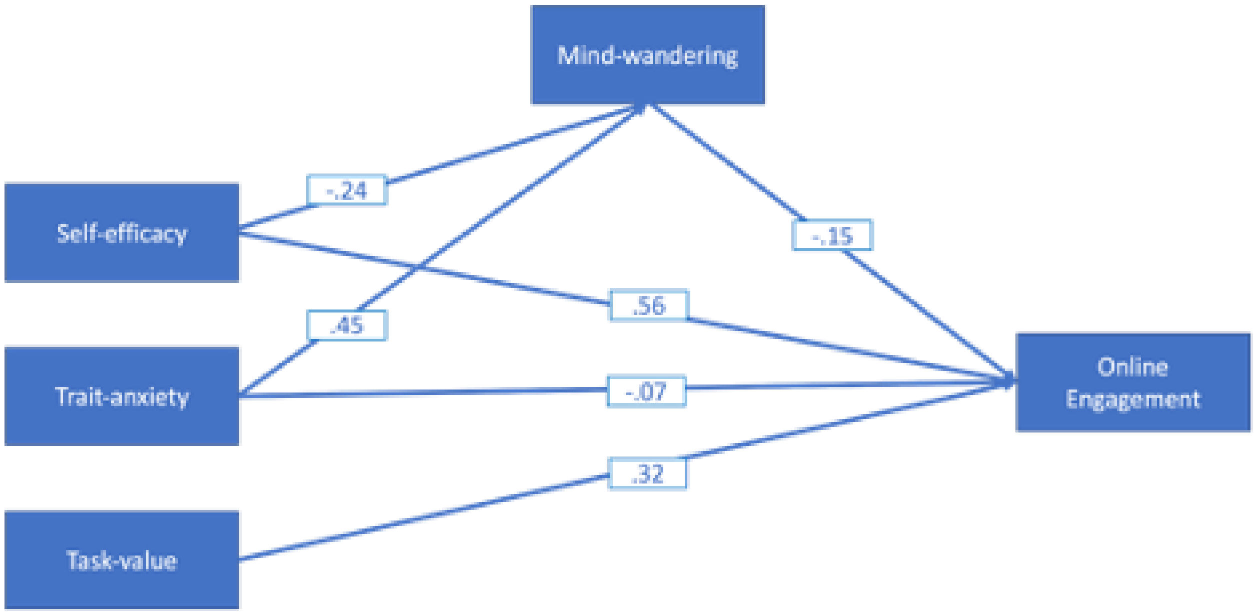
Construct	Cronbach's Alpha	# of Items	Item Examples	Source
Self-Efficacy	0.93	6	"Even in the face of technical difficulties, I am certain I can learn the material presented in an online course"	Artino Jr, A. R., & McCoach, D. B. (2008).
Task-value	0.90	5	"It is personally important for me to perform well in this course"	Artino Jr, A. R., & McCoach, D. B. (2008).
State-Trait Anxiety Inventory	0.92	20	"I get in a state of tension or turmoil as I think over my recent concerns and interest" and "Some intrusive thought runs through my mind and bothers me"	Spielberger, C. D. (1983).
Online Engagement Scale	0.90	12	"When I am in the online class, I just 'pretend' as if I am learning" and "If I do not know about a concept when I am learning in the online class, I do something to figure it out"	Rossing, J. P., Miller, W., Cecil, A. K., & Stamper, S. E. (2012).
Mind-Wandering Questionnaire	0.94	5	"I mind-wander during lectures or presentations" and "I find myself listening with one ear and thinking about something else at the same time"	Mrazek, M. D., Phillips, D. T., Franklin, M. S., Broadway, J. M., & Schooler, J. W. (2013).

Figure 1.1



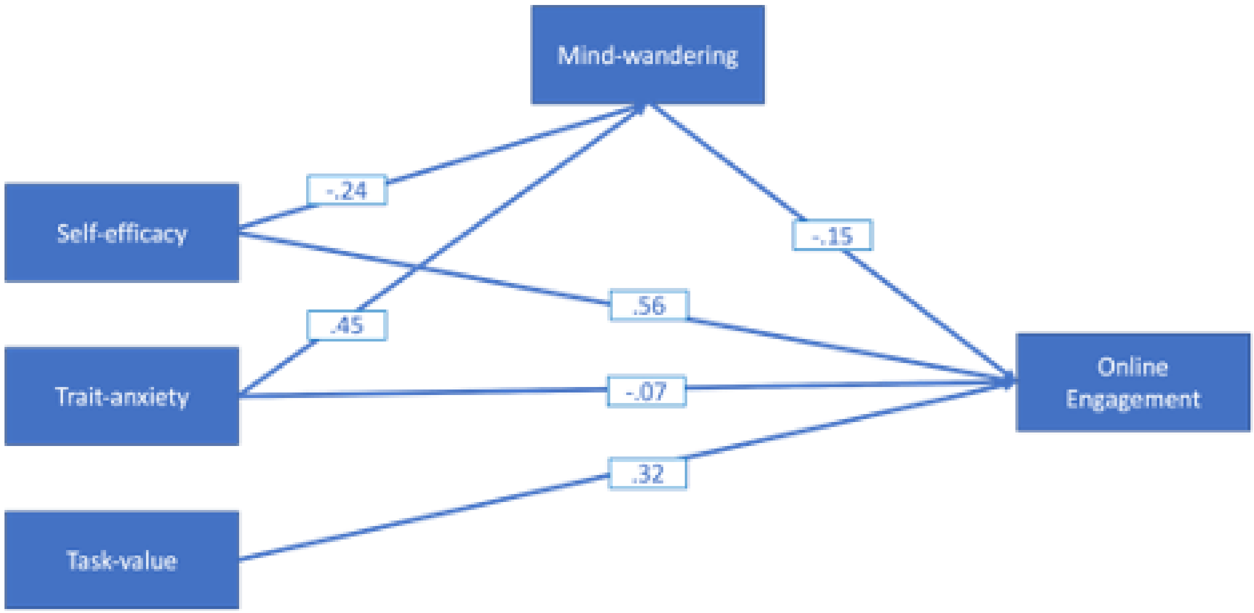
The hypothesized model suggested by the literature explaining factors predicting mind-wandering and the effects of undergraduate students' online engagement.

Figure 1.2



The standardized path coefficients of the hypothesized model suggested by the literature explaining factors predicting mind-wandering and the effects of undergraduate students' online engagement.

Figure 1.3



The standardized path coefficients of the respecificied model suggested by the literature explaining factors predicting mind-wandering and the effects of undergraduate students' online engagement.

CHAPTER 2: STUDY 2

Leveraging Learning Experience Design: Digital Media Approaches to Influence Motivational Traits that Support Student Learning Behaviors in Undergraduate Online Courses

Published in *Journal of Computing in Higher Education*

Wong, J. T., & Hughes, B. S. (2023). Leveraging learning experience design: digital media approaches to influence motivational traits that support student learning behaviors in undergraduate online courses. *Journal of Computing in Higher Education*, 35(3), 595-632. https://doi.org/10.1007/s12528-022-09342-1

Study 2

In my dissertation Study 1, I found that the relationship between learners' engagement, self-efficacy, and trait-anxiety was mediated by learners' frequency to mind-wander while learning synchronously through Zoom. I also found significant direct effects between learners' engagement and their self-efficacy, task-value, trait-anxiety, and mind-wandering. Importantly, Study 1 helped to establish a model for how learners' social, cognitive, and behavioral factors were influenced due to the change in learning modality students experienced and provide a roadmap for specific areas we might target to support teaching and learning through online mediums. As a result, Study 1 provides a contextual overview of what students felt and how they reacted during the height of teaching and learning through the pandemic. This leaves questions remaining on how we might design courses that consider students' needs, are grounded in cognitive learning theories and pedagogies, and make data-driven decisions that inform the instructional design of courses that are empathetic to learners' changing behaviors. In light of the findings found in Study 1 and the suggested course design recommendations, in Study 2, I designed an online asynchronous undergraduate course informed by the learning experience findings from Study 1. In this *in situ* design-based research study, I test the efficacy of implementing the learner experience design (LXD) pedagogical paradigm, deploying approaches of asynchronous 4K video, interactive course dashboards, and enhanced user experience design. I use a mixed-methods analytic approach that assesses the associations of students' social cognitive motivational traits (self-efficacy, task-value, self-regulation) and their learning behaviors (engagement, elaboration, critical thinking) that resulted from the LXD applications. This study is now published in the Journal of Computing in Higher Education and improves our understanding of the affordances and constraints of implementing LXD. In the following sections, I briefly review the original study, materials and procedures, results, and discussion.

Introduction

Higher education may have significant potential to identify practical ways to improve undergraduate online learning experiences through the novel combination of Learner Experience Design (LXD), educational technologies, and testing through design-based research (DBR). This study was afforded by the rare, rapid, and massive conversion to distance learning platforms implemented during the COVID-19 pandemic (WHO, 2020). Through the sudden immersion into an array of online learning implementations, students and learning experience designers are afforded a unique opportunity to rapidly examine which technology-based pedagogical approaches are most effective, based on interventions and observations made within the natural large-scale higher educational settings. The accelerated conversion to online learning provided a unique teaching and learning context, opening a useful window into investigating the applications of online LXD for the study of computers in higher education.

Although it may be commonplace to utilize the popular synchronous “Zoom internet-mediated teleconferencing method” for online learning (Chick et al., 2020; Verma et al., 2020), to the contrary, an LXD investigator might hypothesize higher efficacies from designing an asynchronous self-paced online course that integrates the combination of pedagogical designs and user interface design. However, considering the significant technological, pedagogical, and training demands involved (Rapanta et al., 2020), it may be no surprise that online learning has traditionally been slow to take hold in universities. Taking a design-based research (DBR) approach, this study investigated an online instructional course that enabled researchers to evaluate student interactions *in situ*, in both real-world settings and extreme situations (Collins et al., 2004; Siek et al., 2014). The COVID-19 pandemic necessitated a systematic change in university course delivery (Agarwal & Kaushik, 2020; Ferrel & Ryan, 2020). Consequently, when presented with the rapid transition to remote learning, we quickly conducted a DBR study deploying an instructor-designer developed asynchronous self-paced online course grounded in LXD to collect empirical data in the wild. This notion of "in the wild," is in reference to the naturalistic usage of introducing a novel design in the field and performing extended evaluations within the intended population and context of use (Siek et al., 2014).

The quality of online courses may vary markedly, due to insufficient training from instructors (Hodges et al., 2020) and/or the unwillingness of institutions to adopt digital learning tools (Rapanta et al., 2020), among other reasons. While online learning can be an effective way to foster teaching and learning (Mayer & Moreno, 2010; Muljana & Luo, 2020; Taipjutorus, 2014; Xu & Xu, 2020; You, 2016), many institutions are placing more attention on the expeditious transfer of the same in-person educational content into synchronous teleconferencing lectures in the online learning environment, rather than developing online courses grounded in evidence-based instructional designs and teaching pedagogies. When learning online, students are required to adapt to different learning contexts and modalities, potentially affecting their motivations and learning behaviors within the online environment. In a recent study, Adnan and Anwar (2020) found that 71.4% of undergraduate students reported that learning in conventional face-to-face classrooms was more motivating than distance learning. Additionally, Rapanta and colleagues (2020) argue that instructors not only face the technical struggles of delivering online instruction, but also lack the instructional and pedagogical training necessary to "design and administer meaningful online learning experiences." Furthermore, learners spending more time worrying about accessing, locating, and finding course content within the user interface are likely to experience greater frustration and confusion within an online learning environment (Hu, 2008; Shneiderman & Hochheiser, 2001). This combination of low student motivation, poor instructional grounding in learning design, and overlooking the learner's user experience have led to undergraduate learners citing issues of diminished engagement, poor time management, and low levels of confidence with their own abilities to learn online, primarily due to their unfamiliarity and lack of prior experience with online courses (Agarwal & Kaushik, 2020; Sun & Rueda, 2012; Tullis & Benjamin, 2011; Zayapragassarazan, 2020). Thus, to support students' learning behaviors, attention may be shifted advantageously to include evidence-based principles of learning experience design, with a focus on monitoring factors including students' self-efficacy, task-value, self-regulation, engagement, elaboration, and critical thinking. This presents a challenge and opportunity for the development of online courses that experiment with approaches that go beyond merely duplicating in-person lectures into online spaces through Zoom teleconferencing, and explore DBR approaches to online teaching that leverage the expanding digital learning media tools available to online course designers.

Current study

Little has previously been reported about how online learning with a learning experience design (LXD) approach may affect students' social cognitive motivational factors and students' learning behaviors. As such, we designed an online course for the purpose of increasing students' social cognitive motivations and learning behaviors by grounding the online learning environment in LXD. The LXD was operationalized by aligning the online course with the SCT pedagogical framework, producing segmented animated video scaffolds, and implementing user experience design heuristics to create affordances that directly support students empathetically. To our knowledge, this integration of learning design and user experience is a relatively new field of education in its infancy and this study sought to better understand how undergraduate students' personal social cognitive motivational factors (self-efficacy, task-value, self-regulation) support or hindered their online learning behaviors (engagement, elaboration, critical thinking) as a direct result of the LXD efforts (See Figure 2.1).

Thus, this study is guided by the following research questions:

1. To what extent do students' online self-efficacy, task-value, and self-regulation influence students' perceived online engagement while learning in an online environment?
2. To what extent do student's self-efficacy, task-value, and self-regulation influence students' elaboration learning behaviors while learning in an online environment?
3. To what extent do student's self-efficacy, task-value, and self-regulation influence students' critical thinking learning behaviors while learning in an online environment?
4. To what extent did the LXD approach (learning and user experience design considerations) support students' online learning experience?

Methodology

Participants

Participants in this study included undergraduate students from a large R1 university in California within the School of Biological sciences. There were a total of 207 undergraduate students enrolled in two separate sections of the lower division general education elective Evolutionary Psychology online science course. Out of the 207 students enrolled, (N = 181) students responded to both the pre and post-assessments, representing a survey response rate of 87.4%. These undergraduate students were of varying student-level statuses, with 42.6% first year, 21.3% second year, 12.0% third year, 20.2% fourth year, and 3.8% fifth year students enrolled (See Table 2.1). The demographics of students in this study were 2.76% African

American, 48.6% Asian/ Pacific Islander, 29.8% Hispanic, 12.3% white, and 6.14% other ethnic/ racial groups, comprised of (n = 121) females, and (n = 60) males (See Table 2.1). Additional student demographic data is provided in Table 2.1.

Design-based Research Context

This study employed an in situ design-based research (DBR) approach that applied theories of learning to evaluate the efficacy of design, instructional tools, or prototypes with students “in the wild” or ecologically valid settings (DBR Collective, 2003; Siek et al., 2014). The main objective of this methodology is to assess instructional tools in the ecologically valid real-world environment and to examine whether the tools positively influence students’ learning (Scott et al., 2020). From conducting an initial pre-assessment survey, we were able to identify that learners were particularly worried about their confidence in their abilities to learn online, motivations related to distance learning formats, and whether or not learners would be able to critically engage with the course materials, as an overwhelming majority of students were first-time distance learners. After identifying the learning problems (Wang & Hannafin, 2005), we proceeded to develop solutions with digital learning tools through the application of LXD. Next, we evaluated the effectiveness of our learner experience course designs using evidence directly from students (Anderson & Shattuck, 2012). A longitudinal Pre-Post assessment design was used, in which outcome measurements are collected before and after the intervention (Craig et al., 2012). We selected the measurement method in which all student participants in this study underwent the intervention of the newly developed LXD-based online learning environment. Analytically, we focused on the differences in outcomes for student measures from the same individuals between Time T1 (pre-intervention) and Time T2 (post-intervention) across 10 instructional weeks (White & Sabarwal, 2008) during the Spring 2020 academic term. By selecting this longitudinal research design method, we were able to control for temporal and secular changes in the outcomes observed (Leatherdale, 2019). Finally, we engaged in retrospective analysis for how our design outcomes were able to address our initial problems and further elucidated possible mechanisms to explain the theoretical underpinnings of LXD approaches.

Online Learning Experience Design

The asynchronous self-paced online course focused on teaching Evolutionary Psychology through digital media and educational technologies. The online courses were hosted in Canvas, the university's learning management system (LMS), and consisted of two randomly enrolled, identically sized, and closely scheduled classes in the School of Biological Sciences taught by the same professor over 10 instructional weeks. Cognizant of the research behind effective online learning environments, these online modules were designed to be flexible, interactive, and learner-centered (Floor, 2018; Hawley & Valli, 2000). The curriculum delivery incorporated an innovative self-paced learning experience and digital media features such as high-end studio production quality, 4K multi-camera videos, green screen inserts, voice-over narrations, and animated infographics.

Emphasizing immersion and real-world applications, the online courses were developed within a situated cognition theory (SCT) for e-learning experience design (Brown et al., 1989). Operationalizing situated cognition theory, this online course design was grounded in practical elements of modeling, coaching, scaffolding, articulation, reflection, and exploration (Collins et al., 1991). More specifically, the 80-minute long lessons were chunked into smaller three to five-minute scaffolded video phases instead of one long continuous stream to reduce fatigue, cognitive load, and opportunities for students to mind-wander (Mayer, 2019). These video scaffolds were designed to pre-train students in general concepts and terminologies with scientific visuals and simplified explanations, prior to engaging in the more in-depth and detailed study with a textbook reader. Subsequent to each video scaffold, the lecture questions that followed served as low-stakes content practice and retention exercises for learners to verify their accuracy while developing conceptual understanding. After this initial pretraining, students would engage in their readings of the text, followed by taking a quiz corresponding to the video lecture which assessed content mastery. Concurrently with, or following the quizzes (according to student choice), students were required to respond to journal reflection prompts, applying the concepts learned from the video scaffolds. Three types of journal reflection prompts were utilized in this course: perspective prompts, metacognitive prompts, and empirical prompts. Perspective prompts focus on assessing learners' understanding and application of the concepts of evolutionary psychology and give learners opportunities to synthesize new ideas based on the dynamics they learn about in this course. Metacognitive prompts challenge learners to analyze their developing ideas about evolutionary psychology, and what impact these ideas might have on their worldview and, in some cases, broader culture. Lastly, empirical prompts ask learners to try something and report back on their results. For example, in some cases, learners might be asked to discuss something with family or friends. Learners might even be asked to try practicing elements of ancestral human behavior or culture, gleaned from anthropology, to see if there are any experiential effects worth noting in their journals. A key element of successful LXD is the primary focus of designing for human-centered learning and human behaviors throughout the learning process (Floor, 2018). These LXD principles were applied by designing each asynchronous activity to be goal-oriented and learner-centered. Specifically, students experience completing many small scoring assignments that contribute to and culminate in applying concepts to questions about their own personal perspectives and contextual experiences about their own lives. Furthermore, these design choices enable students to actively engage in their own productive metacognitive judgments and motivations to reflect on "how and why" they arrived at their solutions, which has been found to foster learners' critical thinking and use of elaboration skills within an online learning environment (Tullis & Benjamin, 2011; Wang et al., 2013).

Moreover, drawing on best practices of user experience UXD careful considerations were made within the course interface to promote student ease of use, findability, and navigability (Simunich et al., 2015). This was accomplished by implementing a novel interface design with a "dashboard-style" course introduction page to organize assignments, lecture videos, quizzes, and additional course materials. This served as a "course guide" to help students navigate their learning experience in a progressive manner. As a result, the online course was designed for students to enter the course space and ultimately land on the weekly "course guides" with all of the pertinent resources, assignments, and quizzes located centrally in one space. These asynchronous activities were provided to establish a systematic routine for learners to adopt throughout the 10 weeks of online instruction. This also served to promote flexibility and greater student autonomy within the course, as videos were available for students to play, pause, rewind, and fast forward with closed captioning for greater content accessibility. Efforts to support human-computer interactions through thoughtful UXD were also invested to reduce confusion and frustration (Shneiderman & Hochheiser, 2001), redirecting student efforts toward learning the content, rather than toward worrying about learning how to access the content in the LMS (Hu, 2008). Designing a system that is more usable and human-centered was sought to enhance learners' control and interaction with the information presented. Thus, the course's design intentions were meant to ignite students' motivations and train students to adapt their learning behaviors such as their engagement, critical thinking, and elaboration within the asynchronous self-paced online course.

Instrumentation

Data in this study were collected electronically. All of the measures employed were distributed to participating students and collected online via Qualtrics XM during the Spring 2020 academic term. Participants were provided a direct link to the surveys which were embedded within the Canvas LMS course space. Student online learning self-efficacy data were collected using the self-report Online Value and Self-Efficacy Scale (OLVSES) (Artino & McCoach, 2008). This instrument was developed by Artino and McCoach (2008) to measure students' self-efficacy and task-value for learning specifically within a self-paced, online course. The OLVSES instrument contains a total of 11 questions within two sub-constructs. Each question was scored on a 7-point Likert scale ranging from 1 (*completely disagree*) to 7 (*completely agree*). Artino and McCoach (2008) report the internal consistency coefficients (Cronbach alphas) for self-efficacy and task-value are 0.92 and 0.89, respectively.

The Motivated Strategies for Learning Questionnaire (MLSQ) instrument was developed by a team of researchers from the National Center for Research to Improve Postsecondary Teaching and Learning and the School of Education at the University of Michigan (Pintrich et al., 1993). The MLSQ is a self-report psychometric measure designed to assess undergraduate students’ motivations and their usage of varying learning strategies. Response options were designated on a 7-point scale, 1 (*completely disagree*) to 7 (*completely agree)*. The subscales of self-regulation, elaboration, and critical thinking were utilized in this study to evaluate students in a self-paced online course. Pintrich and colleagues (1993) report that the internal consistency coefficients (Cronbach alphas) are 0.79, 0.76, and 0.80, respectively.

Students' perceived online engagement was measured using a 12-item survey (Rossing et al., 2012). Response options were designated on a 5-point scale, 1 (*completely disagree*) to 5 (*completely agree)*. The survey consisted of a combination of questions about students' perceptions of learning and their perceived engagement in an online course. The internal consistency coefficient (Cronbach alpha) for this instrument is 0.90.

Data Analysis

Descriptives and scale reliability checks were conducted to verify the alpha coefficients for all of the validated instruments used in this study (Table 2.2). All of the variables measured in this study were analyzed by first recoding the Likert questions into their respective positive or negative values, followed by computing the means of the items associated with each subscale. Paired sample t-tests were conducted to assess the change in students' social cognitive motivational traits and learning behaviors at two-time points (pre and post) over the 10-week instructional period. Bivariate correlations evaluated the relationships between students' motivational traits and learning behaviors (See Table 2.2). Lastly, multiple regression analyses were conducted to estimate the association of students' social cognitive motivational traits (self-efficacy, task-value, self-regulation) as independent predictors for students' learning behaviors (engagement, elaboration, critical thinking).

Qualitative analysis of student evaluation responses involved data analysis through Qualtrics Research Core XM text analysis software. A deductive coding approach, or concept-driven coding method (Saldaña, 2021), was selected for analyzing students' post-assessment free-response questionnaire data in order to confirm the validity and reliability of our analytical findings. Through this process, analytic memos were written, while pre-defined subcodes and anchor codes were developed and systematically applied based on our quantitative variables (See Table 2.7). Inclusive and exclusive statements were clearly written to differentiate code applications. After reaching saliency, corroboration of quantitative and qualitative results further discerned potential mechanistic interactions. Researchers in this study made use of spot-checking in order to reach reliability and reduce bias throughout the coding process.

Results

Paired-sample T-tests

Paired-samples (2-tailed) t-tests were conducted to assess the changes in students' social cognitive motivation variables (self-efficacy, task-value, self-regulation) and learning behaviors (engagement, elaboration, and critical thinking) throughout the 10-week instructional period. As Table 2.3 indicates, there was a statistically significant increase in students' self-efficacy from pretest ($M = 5.39$, $SD = 0.87$) to posttest ($M = 5.90$, $SD = 0.70$), $t(161) = 7.48$, $p < 0.001$. The mean increase of students' self-efficacy throughout the 10-week quarter was 0.51 with a 95% confidence interval ranging from 0.38 to 0.65. The effect size for this analysis was medium ($d = 0.59$). The results from the pre-test ($M = 5.47$, $SD = 0.77$) and post-test ($M = 5.67$, $SD = 0.84$) of students' task-value indicate a statistically significant increase throughout the quarter, resulting in a mean increase of 0.19 with a 95% confidence interval of 0.08 to 0.31, $t(161) = 3.30$, $p < 0.001$. The effect size for this analysis was medium ($d = 0.59$). There was a statistically significant increase in students' self-regulation from pretest ($M = 4.31$, $SD = 0.89$) to posttest ($M = 4.48$, $SD = 0.97$), $t(161) = 2.38$, $p < 0.05$. The mean increase of students' self-regulation throughout the 10-week quarter was 0.163 with a 95% confidence interval ranging from 0.03 to 0.29. The effect size for this analysis was small ($d = 0.27$). Additionally, the results from the pretest (*M* = 4.86, *SD* = 0.99) to post-test (*M* = 5.20, *SD* = 0.98) of students' critical thinking indicate a statistically significant increase throughout the quarter, resulting in a mean increase of 0.338 with a 95% confidence interval of 0.18 to 0.49, $t(161) = 4.32$, $p < 0.001$. The effect size for this analysis was medium ($d = 0.34$). However, the relationship between students' elaboration learning strategy from pre-test (*M* = 5.58, *SD* = 0.73) and post-test (*M* = 5.59, *SD* = 0.84) was not statistically significant $t(161) = 0.081$, $p = 0.936$. Overall, the results from the paired samples t-tests indicate that students' self-efficacy, task-value, self-regulation, and critical thinking were significantly increased and distinguishable from pre to post assessment throughout the 10-week instructional period.

Correlations

Exploratory Pearson correlations were documented in Table 2.2. Students' self-efficacy was positively related to students' self-regulation ($r = 0.310$, $n = 181$, $p < 0.01$), usage of elaboration ($r = 0.408$, $n = 181$, $p < 0.01$), and critical thinking ($r = 0.357$, $n = 181$, $p < 0.01$). Meanwhile, students' task-value was significantly associated with self-regulation ($r = 0.368$, $n = 181$, $p < 0.01$), engagement ($r = 0.380$, $n = 181$, $p < 0.01$), elaboration (r = 0.659, $n = 181$, $p < 0.001$), and critical thinking ($r = .521$, $n = 181$, $p < 0.01$). Furthermore, students' self-regulation was significantly correlated with engagement ($r = 0.373$, $n = 161$, $p < 0.01$), elaboration ($r = 0.484$, $n = 181$, $p < 0.01$) and critical thinking ($r = 0.476$, $n = 181$, $p < 0.01$).

Multiple Regression Analyses

It has been hypothesized by learning experience designers that the underlying mechanisms underpinning LXD and students' learning behaviors are likely to be the result of increasing social cognitive motivational factors. To determine the association between student social cognitive motivation variables and learning strategies, multiple regression analyses were conducted. Three independent variables (self-efficacy, task-value, and self-regulation) of social cognitive motivation factors were used to predict the dependent variables (engagement, elaboration, and critical thinking) of learning strategies. Student socioeconomic characteristic variables such as gender, low income, underrepresented minority, and first-generation were analyzed during preliminary analysis. None of these student variables were significantly related to the outcome variables. As such, these student characteristic variables were not retained in the final regression models. Table 2.4 provides a detailed summary of the regression analyses for each of the predictors on the outcome variables.

In Model 1, we assessed the relationship between students' self-efficacy, task-value, and self-regulation on students' online engagement (See Table 2.4). At step 1, students' self-efficacy ($\beta = 0.469$, $p < 0.001$) was significantly predictive of their online engagement. In step 2, the addition of task-value ($\beta = 0.267$, $p < 0.001$) was statistically significant, accounting for an additional 6.6% of the explained variance (See Table 2.4). In step 3, the association between students' self-regulation and online engagement was statistically significant ($\beta = 0.179$ $p < 0.01$). This final inclusion of self-regulation explained an additional 2.7% of the variance $R^2 = 0.312$, $F(3, 178) = 26.7$, $p < 0.001$ (See Table 2.4). On average, these results indicate that students' self-efficacy, task-value, and self-regulation within the online learning environment were significantly predictive of their online engagement, accounting for 31.2% of the explained variance.

Model 2 estimated the association of students' motivational traits and self-regulation on their elaboration learning strategy while controlling for their elaboration pretest scores (See Table 2.5). Results indicate that self-efficacy ($\beta = 0.460$, $p < 0.01$) was significantly predictive of students' elaboration learning strategy at step 2. In step 3, the addition of task-value was statistically significant, accounting for a 16.7% increase in the explained variance. In the final step, the association of self-efficacy ($\beta = 0.133$, $p < 0.05$), task-value ($\beta = 0.414$, $p < 0.001$), and self-regulation ($\beta = 0.203$, $p < 0.01$) were all significantly predictive of students' elaboration. This accounted for 57% of the explained variance $R^2 = 0.570$, in the model $F(3, 177) = 50.9$, $p < 0.001$ (See Table 2.5).

In Model 3, we estimated the association of students' social cognitive motivational traits on their critical thinking learning behaviors by conducting multiple regression analyses while controlling for students' critical thinking pretest scores (See Table 2.6). At step 2, self-efficacy ($\beta = 0.194$, $p < 0.01$) was significantly predictive of students' critical thinking. In step 3, the inclusion of task-value was statistically significant, accounting for a 10.2% increase of the explained variance. In the final step, the students' self-regulation ($\beta = 0.252$, $p < 0.001$) was significantly predictive of their critical thinking, accounting for an additional 5.0% of the explained variance. These results indicate that students' online self-efficacy, task-value, and self-regulation were significantly predictive of students' critical thinking in the online course $R^2 = 0.471$, $F(3, 178) = 34.3$, $p < 0.001$.

In summary, students' social cognitive motivational traits were positive and significantly different between Time T_1 (pre-intervention) and Time T_2 (post-intervention) across 10 instructional weeks. In addition, students' social cognitive motivational traits were significantly predictive of students' learning behaviors. As a result, as students' self-efficacy, task-value beliefs, and self-regulation factors increased while participating in this LXD based online course, on average, their engagement, usage of elaboration, and critical thinking skills increased. Interestingly, the stepwise addition of students' task-value beliefs as a predictor increased the proportion of the explained variance in each model significantly, above and beyond self-efficacy and self-regulation. For models 1, 2, and 3, the increase in explained variance after the addition of students' task-value beliefs was 6.6%, 16.7%, and 10.2% respectively.

Students' Learning Experience within the Online Course

To obtain a more nuanced understanding of students' learning experience within the online learning environment, we analyzed students' official anonymized course evaluations and free-response data from the post-assessment questionnaire (See Table 2.7). We took a qualitative approach to analyze students' learning experiences during their participation within the online course to further triangulate our qualitative and quantitative findings. Analysis of the qualitative data from students' questionnaire responses provided evidence regarding how the course user interface and UXD supported students' experience within the LX-designed online learning environment. Three key patterns about the students' learning experience emerged – findability, video navigability, and self-pacing. Representative samples of students' descriptions and perspectives are provided on each theme.

Findability. Findability was defined as references to the quick identification of course materials, course structure and organization, and content accessibility (See Table 2.7). As a UXD decision, the course dashboard was employed for the intent of increasing usability so that students might find it easier to locate all of the week's materials such as videos, PDFs, quiz links, and additional supporting resources, having them located centrally all in one course page. It was hypothesized that this dashboard design would serve to provide direct access to the course content to students in a quick and consistent manner, indicating due dates, course objectives, and learning goals to effectively increase findability. *Student A:* "The way the course was set up, from the online lectures to the quizzes, all helped me better organize my time allocated for this course."

Student B: "The accessibility to everything at any time. Easy to navigate, I really enjoyed the lecture videos and how organized they were."

Student C: "For this online course specifically, it was very organized and straightforward. This contributed to my success in this class."

Student D: "Due dates always show up on the Canvas dashboard, which serves as an online agenda for me. Instructions for assignments are always there for me to look back on."

Student E: "I think that the aspects of this course that helped me are all the videos and how this course was formulated for an online class and it was easy and accessible. This made it easier to watch it on my phone and easier to access than zoom recorded lectures."

Video Navigability. We defined video navigability as references to the video user interface and the learner's ability to manipulate the video playback options (See Table 2.7). Such playback options include play, pause, fast forward, rewind, speed up, slow down, toggle full-screen, toggle closed captions, and enable transcripts. As a UXD decision, every video that was produced for this online course was published and embedded within the Canvas LMS with all of these playback options in mind. Our design intentions were to enable flexibility and learner-centered navigation options to provide opportunities for students to re-watch, pause, and play a video if they did not fully grasp the concepts during their first time through.

Student F: "A strength of the online course is that I can complete online assignments any time I want. Another strength is that video lectures can be slowed down or replayed for me to take notes or if I did not understand a part of the lesson."

Student G: "The ability to pause and go back in lecture videos was very helpful in helping me understand difficult concepts that I had to keep going back to in order to fully comprehend."

Student H: "I learn better by videos and then in person, because we have the ability to rewind, slow down, speed up, increase volume. If I happen to miss it in class, it can be difficult to catch up."

Student I: "I have the freedom to watch and rewatch lecture videos when I have time, in order to better understand the content. It is a lot easier to take notes since I can pause the videos whenever and take a moment to understand what I am writing before the lecture moves on."

Student H: "Having recorded lectures allows for students to play back the video and take it at their own speed, whereas in person lectures might not all offer recorded lectures. It has allowed me to learn new, better study habits."

Self-pacing. Self-paced learning was defined as references to autonomy, on your own time, and time frames with regards to pacing while participating in the online course such that students could easily navigate the course space freely to re-watch, pause, and play a video, complete assignments on their own time, and access the course at their own leisure (See Table 2.7). It was hypothesized that by providing clear instructions, usability descriptions, deadlines, and all of the week's material in one space, while learners were particularly able to freely choose how to plan, monitor, and adjust their own study habits and schedules, that students' self-efficacy, task-value, and self-regulation would positively impact their learning behaviors in the online course.

*Student I: "*One of the strengths of online learning is that we get to go at our own pace. If we have a lot of assignments, we need to time ourselves so that we get things done according to what is best for us."

Student J: "Online format gave me the chance to study the material on my own time; I wouldn't have had time to truly learn the material if it was during the official time indicated. It was really interesting, and I wouldn't have enjoyed it as much if it was in a traditional setting"

Student K*: "*I was able to do everything on my own time. I succeed when I don't feel like I am pressured to complete something specifically on that day. The format where assignments/lectures are given early to complete helps me stay on track."

Student L: "The pacing can teach students to overcome obstacles, problem solve, find creative solutions to problems, manage their time better, and improve study habits. In addition, the pace made the journals interesting and fulfilling to answer. The journal entries caused me to think in depth about evolutionary psychology and apply it to my own life"

Student M: "This self-paced online learning has allowed me to learn new, better study habits. I have been better about staying on top of the material and learning and finding solutions to problems on my own. We also got to talk about our own opinions based on what we read and watched in videos for our journals to demonstrate comprehension. It made the class interesting."

These commentaries provide additional measures of verification that the LXD approaches employed in this asynchronous online course aligned with the intended learner experiences. This resulted in students reporting sensitivities to the course being relatively easier to navigate, with course materials that were findable, and a course structure that directly supported their time management (See Table 2.7). The previous traditional in-person synchronous iteration of this same course did not contain these design features. Upon gleaning students' official evaluations of that previous traditional course variant, comments of findability, navigability, or time management were not reported and may be inferred to potentially be uniquely specific to the intentional LXD approaches of this asynchronous course version. Likewise, perhaps the predominant distance-learning method typically employed by most instructors was a Zoom-mediated synchronous delivery that largely sought to more closely resemble traditional in-person methods, which are unlikely to contain the LXD approaches found in this investigation. Here, we note that while fully immersed in this online context, student subjects of the study were enrolled in all of their coursework online, with the preponderance of their courses occurring in Zoom-based synchronous approaches, while they experienced this experimental asynchronous LXD approach, providing realistic comparative sensitivity to the real-world efficacies of the LXD methods.

Further analysis of students' comments on learning behaviors provided descriptive insights into the design advantages of the video interface. With students' recounting of how the video playback choices, we might conjecture that student's playback choices fostered more flexible and self-paced learning strategy behaviors that led to increased engagement with the course videos, elaboration through self-paced note-taking and synthesis of new information, or perhaps contributed to capacities for critically thinking through difficult concepts. We also make note of students highlighting the affordances of video navigability in an online space that would otherwise not be possible in a traditional in-person face-to-face setting. Moreover, we observe instances of how the self-pacing nature of the course may be fostering new opportunities for students to develop confidence in their abilities to learn online, perceive aspects of online learning to be useful, and adapt their learning behaviors for their own learning benefits. As a result, these student excerpts provided illuminating perspectives on how the design decisions and intentions of the course through an LXD lens may have positively influenced the association between students' motivations and their online learning behaviors.

Discussion

Learning Experience Design

This design-based research (DBR) study, made possible through the rapid transition to online learning during the covid pandemic, fostered the examination, synthesis, and application of learning theories to the potential advantages of learning experience design (LXD). Our LXD approach was intended to be empathetic, comprehensible, and above all, usable (Shneiderman & Hochheiser, 2001) to broadly serve students' needs and changing learning behaviors as identified in the pre-assessment. This study operationalized LXD by grounding the asynchronous self-paced online course with Situated Cognition Theory (SCT) as its pedagogical framework and then deploying user design heuristics to support learners' user experience. The LXD approach aimed to address student concerns through an empathy approach that was human-centered, goal-oriented, interdisciplinary, based upon theories of learning and practice to support students' online learning experience. This study concurrently tracked LXD approaches with resultant student learning behaviors to examine an array of emergent factors to inform future digital teaching and learning design decisions. Few studies have explored highly autonomous self-paced online STEM courses grounded in LXD *in situ,* at an R1 university setting. In this study, LXD techniques were rapidly deployed to expedite measurements illustrating how the combination of user experience and learning design has the potential to provide learner-centered affordances to support undergraduate STEM students. When online learning becomes a dominant model of higher education, methods including asynchronous, synchronous, and blended approaches may benefit from investigations highlighting the affordances and constraints of LXD made during the pandemic time of fully online learning immersion to better prepare instructors, researchers, and designers in how to directly supports students' social cognitive motivational traits and learning behaviors.

User Experience Design

The qualitative analysis, which was discharged to complement our quantitative analyses, characterized our understanding of the course's usability for learners with respect to user experience design (UXD). As design decisions, we developed a weekly "course dashboard" displaying all of the pertinent videos, assignments, and quizzes organized centrally in one space to serve as a course roadmap to make content easy to find. In addition, we promoted student flexibility by ensuring a wide variety of learner-centered video playback choices for students to play, pause, rewind, fast forward, and toggle closed captioning for greater student autonomy, content navigability, and ease of use. Upon analyzing student commentaries, we documented evidence suggesting that these usability design facets led to increased learner ease of use, findability, and video navigability of course materials. This, in turn, fostered a self-paced learning environment for students to develop, plan, monitor, and adjust their own study schedules and learning behaviors. More specifically, we recorded instances of students specifically describing ways that usability manipulations directly influenced how they engaged with the course materials, synthesized new information, and thought critically on their reflective metacognitive journal assignments (See Table 2.7). The results of this study are in line with previous research that has identified how strategic manipulations to the course usability promote quality user experience design by facilitating findability and navigability (Simunich et al., 2015). Efforts to support human-computer interactions (HCI) by drawing on UXD heuristics reduce confusion and frustration in locating course materials (Shneiderman & Hochheiser, 2001), redirecting student efforts toward learning the content, rather than worrying about learning how to access the content in the LMS (Hu, 2008). Such findings are consistent and suggestive that the usability considerations applied in this LXD based course promoted students' user experience.

Learning Experience Design Pedagogy Features

The online course was developed within a SCT framework for e-learning experience design to emphasize "learning by doing" (Brown et al., 1989). This pedagogical learning design method was chosen specifically to ground the learning experience in practical elements of modeling, coaching, scaffolding, articulation, reflection, and exploration (Collins et al., 1991). For example, to reduce learner disengagement through lack of instructor presence (Sorensen & Donovan, 2017), we overlaid the instructor's camera feed as a picture in picture within the main content video stream. Additionally, the scaffolded video experiences were designed to train students to systematically navigate their learning experience within the course: the videos served to pre-train students in general concepts and terminologies with scientific visuals and simplified explanations; lecture questions afforded opportunities for rehearsal and practice; the course reader provided conceptual understanding; and the metacognitive reflective journals guided learners toward conceptual applications. We observed that 74.2% of students found that they tried to change the way they studied in order to fit the course requirements and the instructional methods used in the course (See Figure 2.3). 77.2% of students were confident that they could learn without the physical presence of the instructor to assist them (See Figure 2.4). Moreover, 86.1% of students found that the course materials in this self-paced online course were useful for their learning experience (See Figure 2.4). Such findings begin to enhance our understanding of the effectiveness of the SCT instructional pedagogy grounding our LXD approaches.

Linking LXD, Motivation, and Learning Strategy Behavioral Outcomes

The underlying mechanisms underpinning LXD impact on students' learning behaviors are hypothesized to be the catalyzing result of dynamically increasing social cognitive motivational factors. When quantitatively measuring students' change in their social cognitive motivation variables throughout the 10-week instructional period, the mean differences between students' self-efficacy, task-value beliefs, and self-regulation were positive, significantly different, with a medium-sized effect (See Table 2.3). We might attribute these positive increases as a direct result of our LXD applications, specifically the combined impacts of grounding the online course in learning design pedagogy and user experience design. Furthermore, when multiple regressions were conducted to further explain students' social cognitive motivational impacts on their learning behaviors, the results revealed significant predictions on students' engagement, elaboration, and critical thinking skills. The subsequent paragraphs below detail the resulting impacts of how students' social cognitive motivational factors influenced their learning strategy behaviors.

Engagement

Results revealed that students' self-efficacy, task-value, and self-regulation significantly predicted students' online engagement (See Table 2.4). Specifically, students with higher levels of self-efficacy ($\beta = 0.355$, $p < 0.001$), task-value ($\beta = 0.212$, $p < 0.01$), and self-regulation ($\beta = 0.179$, $p < 0.01$), on average, demonstrated higher levels of online engagement, suggesting that it is important to target students' social cognitive motivational factors in order to facilitate students' engagement within an online course (See Table 2.4). Several key LXD facets may explain this positive trend in students' engagement. As evidenced by the representative sample of student commentaries, the usability and user interface of the online course promoted course structure, organization, ease of use, and findability. Such elements in UXD offer affordances to learners to not only develop confidence in their abilities to access the course materials, but also perceive that the course materials are valuable in a way that supports their learning needs. In addition, the SCT video scaffolded pedagogical framework was designed to train students in how to systematically operate the course, providing an instructional protocol for distance learners to plan, monitor, and adapt, thereby facilitating their engagement with the course materials. When comparing all three independent predictors, we found that students' task-value beliefs contributed significantly more toward students' engagement, above and beyond self-efficacy and self-regulation. We suspect that this may be the case because our LXD approaches are contributing toward students elucidating the theorized benefits of asynchronous self-paced online learning.

Elaboration

Students' self-efficacy ($\beta = 0.133$, $p < 0.05$), task-value ($\beta = 0.414$, $p < 0.001$), and self-regulation ($\beta = 0.203$, $p < 0.01$) significantly predicted students' use of elaboration (See Table 2.5). On average, these findings suggest that as students' social cognitive motivational factors increased, so did their elaboration learning behaviors. Interestingly, among self-efficacy, task-value, and self-regulation, students' task-value beliefs were recorded (see Table 2.2) to have the largest correlation coefficient value when observing the associations of students' social cognitive variables with their use of elaboration. This pattern continues to persist when observing the multiple regression analyses. The addition of task-value as a predictor in the stepwise blocks revealed the largest r-square increase, above and beyond self-efficacy and self-regulation (See

Table 2.5). This might be explained by the comments from students highlighting how the video user interface design afforded navigability options for students to play, pause, rewind, fast forward, and read closed captioning that would ordinarily not be possible in an in-person traditional lecture hall. Additionally, students have also commented on how the video playback options allow adaptive note-taking, with the ability to pause the videos at their own leisure to take a moment and understand what they were writing. While our initial hypothesis indicated that self-regulation would contribute more significantly, these findings, however, are consistent with Artino Jr and McCoach (2008), indicating that students' task-value may be more important than self-efficacy and self-regulation when considering highly autonomous and flexible self-paced online courses.

Critical Thinking

Analysis revealed that students' self-efficacy ($\beta = 0.122$, $p < 0.05$), task-value ($\beta = 0.291$, $p < 0.001$), and self-regulation ($\beta = 0.253$, $p < 0.001$) were significantly predictive of students' critical thinking skills, suggesting that on average, as students' social cognitive motivational variables increased, so did their critical thinking skills (see Table 2.6). A similar trend was noted with students' task-value beliefs, with task-value explaining an additional 10.2% of the variance (See Table 2.6). Several key learning design features may explain this trend. By chunking the videos into bite-sized segments and scaffolding them by coherent conceptual topics, the course structure was designed to reduce cognitive load, lower frustration, and promote the accommodation of new conceptual information (Meyer, 2019). In addition, rather than administering midterms or final assessments, as a curriculum design decision, the choice was made for students to apply their critical thinking skills by submitting metacognitive conceptual journals. These conceptual journals challenged learners to analyze their developing ideas about evolutionary psychology, what impact these ideas might have on their worldview, and in some cases, broader culture, assessing understanding and real-world application of the concepts. When gleaning from student excerpts, we documented instances of students perceiving that the pacing of the course taught them to overcome obstacles, problem-solve, and find creative solutions to improve their study habits (See Table 2.7). Moreover, students noted how the pacing of the course made the journal prompts fulfilling to answer. Attuning our understanding of the LXD impacts through the integration of learning design principles with learner-centered user experience heuristics may have helped to discern the resulting increase of students' critical thinking skills as explained by their developing motivations within the course.

Limitations

Future research is warranted to further examine the limitations to and affordances for undergraduate science online teaching and learning that may be gained for future designs. This design-based research (DBR) study was the first iteration of a multi-year LX-design-based *in situ* implementation project. Future research studies would benefit from the experimental manipulations of LXD based courses to further develop, validate, and scale the efficacies of asynchronous online learning environments. In addition, as students continue to grow in their learning experience with different formats of online learning, including synchronous, asynchronous, and hybrid models, such DBR studies would be able to discern potential causal mechanistic relationships between various learning formats and detect which are better suited for undergraduate STEM courses at the R1 instructional level. Another limitation in our study was that all of the measures utilized were self-reported. Self-report data inherently have biases as they serve as an interpretation of the students' perception. However, with increasing access to learning analytics data gained through the improving Canvas LMS, in future studies, we will be exploring students' retrospective course log data such as page views, participation, time-on-task, and completion rate to further corroborate student interactions and behaviors in online learning environments.

Constraints, Affordances, and Implications for Practice

As a part of our evaluation phase within the DBR approach, design constraints for student learners were noted. For example, large quantities of segmented videos can become difficult to keep track of for students who fall behind in the online course; some students may prefer features for tracking the videos based on completion; the lack of direct face to face interactions for students to immediately raise questions with the instructor or socialize with their peers in the course may be a downside for many; although students could communicate via email to discuss difficult concepts, reaching out to the professor this way could present an added barrier. Through this retrospective analysis to critically evaluate our design, we have begun to identify ways in which we can iterate our current designs to focus on these unintended design constraints. This includes adding a system progress indicator bar, system interface feedback (i.e. checkmarks, status indicators, analytics), tracking completed videos and assignments, and adding a FAQ section in between videos of aggregated questions. Further options to add a dynamically updating peer contributed message board embedded alongside videos with digital tools such as Padlet, are currently being explored. As a result, the reflective process guided by the DBR approach has allowed for student contributed perspectives in order to facilitate the next cycle of iterations in our LXD research.

For learning experience designers, the challenge is not only to develop learning environments that increase conceptual understanding by drawing on theories of learning sciences, but also to create learning experiences that are interesting, engaging, and support human-centered behaviors (Ahn et al., 2019). By designing with these principles in mind, we are better able to ensure that our LXD approaches specifically target the intended audience who stand to benefit the most, providing learning affordances to distance learners. Specifically, learners were particularly worried about their social cognitive motivational traits and learning behaviors, as identified in the pre-assessment. To directly address students' needs, we designed an online course intervention for the purpose of increasing students' social cognitive motivations (self-efficacy, task-value, self-regulation) and learning behaviors (engagement, elaboration, critical thinking) by grounding the online learning environment in practical elements of learning and user experience design.

From a pedagogical learning design perspective, the LXD choices to create a video scaffolded learning experience that sequentially pre-trained students with immediate recall and retention questions, prior to reading the textbook, and ultimately requiring students to apply their conceptual knowledge in reflective journals, afforded students a systematic learning routine in an online space. As evidenced in our study, this established routine patterns and operational norms, which contributed to students' judgments about their confidence, perceived usefulness, and self-regulation, led to positive changes in their learning behaviors. These affordances dynamically increased students' social cognitive motivational traits which led to positive impacts in learners' online engagement, elaboration, and critical thinking. While more research is certainly warranted, we recommend that instructors and designers of STEM online courses in higher education adopt similar digital media tools (i.e. video production, segmentation, real-world connections) and pedagogical learning designs like the SCT framework (scaffolding, goal-setting, reflecting), providing explicit cues which give learners a means to adopt effective online learning strategies. We also argue that the affordances of the LXD approach were only made possible through the strategic simultaneous combination of learning and user experience design. With careful considerations of user experience design, the LXD choices to incorporate usability manipulations that resulted in the creation of a course dashboard with centralized course content and video navigation autonomy, enabled design affordances that led to direct changes in learning behavior. The inclusion of learning dashboards, as a UXD based approach within an online learning environment, enables student learning processes which include sensemaking, awareness, reflection, and data processing (Ahn et al., 2019; Scheffel et al., 2017). From establishing course structure to increasing findability, the design afforded students a single entry point within the course each week to identify, access, and plan for the required assignments and tasks. Moreover, the ability for learners to play, pause, rewind, and enable closed captioning on the videos afforded precise control and interaction for students to engage, elaborate, and critically interact with the course content. Such interactions enabled learners to pause and reflect on concepts or engage in summative and generative note taking for higher-order thinking. As such, we argue that the parallel affordances provided by bridging the literature on pedagogical learning and user experience design operationalize the benefits of STEM online courses grounded in learning experience design.

Through this DBR study, we have demonstrated how the affordances of LXD specifically influenced positive changes in student learning behaviors. Data from this study suggest that it is students' intuitions about their own confidence, value beliefs, and self-regulated skills that may be the driving factor linking LXD and the significant positive effects in student learning behaviors exemplified in this online course. Recognizing students’ social cognitive motivational traits while learning remotely may further support students’ learning behaviors and the improvement of future iterations of online course delivery (Artino & McCoach, 2008; Eccles & Wigfield, 2002; Pintrich, 1999). We have also identified how our unintended design constraints presented new opportunities for refinement and iterations for the continual improvement of STEM online courses. Consequently, future online courses may benefit from this research and it may inform institutions on how to iteratively design and effectively foster successful online teaching and learning with the use of innovative learning experience design approaches over the more gradual transitions to modernized methods of digital learning of STEM courses in higher education.

Conclusion

In summary, students' social cognitive motivational traits increased significantly throughout the 10-week instructional term. Students' self-efficacy, task-value, and self-regulation were also predictive of students' engagement, usage of elaboration, and critical thinking. As a result, this study suggests that implementing asynchronous self-paced online courses with LXD approaches may positively impact students' learning behaviors, potentially through influencing student's social cognitive motivational traits. Results also suggest that students' task-value beliefs may be most critical in explaining students' learning behaviors when grounding online courses with LXD, above and beyond self-efficacy and self-regulation. Through our mixed-method approach, we further validated our quantitative analyses by qualitatively drawing on the rich descriptions of student's learning experiences and the resulting impacts on their learning experiences. In particular, these descriptions explicitly pointed to the LXD features explaining how our design efforts contributed to students' motivations and changing learning behaviors in the course. Based on these collective findings, we recommend an instructor-designer DBR collaborative workflow to produce and design online courses with LXD approaches through the combination of pedagogical learning design and learner-centered user experience design considerations. This research study makes an important contribution to the field of STEM online teaching and learning in higher education, presenting evidence for how LXD can be deployed iteratively, rapidly, and thoughtfully. By first identifying what students need, we can then attempt to create LXD solutions that provide affordances to support the needs of student learners in a strategic manner. We assert an alternative approach to synchronous Zoom teleconferenced lectures by detailing the efforts toward designing an asynchronous self-paced online course, offering a pathway for students to further develop their motivations and their learning behaviors in online environments. With 67.4% of students in this study reporting that the knowledge they gain by taking this course can be applied in many different situations (See Figure 2.2), these learning behaviors may be transferable, and can certainly be utilized in their other courses as students continue distance learning. Fostering students' learning behaviors such as usage of elaboration and critical thinking are considered key competencies and transferable skills for STEM undergraduate students at R1 institutions linking course materials to real-world practice (Chiaburu & Marinova, 2005; Fries et al., 2020; Halpern, 1998). Moreover, this study may further support the growing literature on learning experience design in higher education courses by drawing on multiple learning design principles, adopting digital learning tools, and user experience design facets intended to enhance students' online learning experiences through empathy (Kafai, 2005), informing designers as well as instructors on how we might effectively improve asynchronous self-paced online teaching and learning of STEM subjects at the R1 institutional level.

Appendix

Table 2.1
Sociodemographic Characteristics of Participants

Student Characteristics	Students Enrolled	
	n	%
Gender		
Female	121	66.1
Male	60	33.9
Ethnicity		
African American	5	2.76
Asian	88	48.6
Hispanic	54	29.8
White	23	12.7
Other	11	6.14
Student Year		
First	78	42.6
Second	39	21.3
Third	22	12.0
Fourth	37	20.2
Fifth	5	3.80
Underrepresented Minority		
Yes	79	43.6
No	102	56.4
First Generation		
Yes	104	57.4
No	77	42.6
Low Income		

Yes	84	46.4
No	97	53.6

Note. n = 181

Table 2.2
Descriptive Statistics and Correlations for Study Variables

Variable	n	M	SD	α	1	2	3	4	5	6
1. Self-efficacy	181	5.92	.719	.903	—					
2. Task-value	181	5.63	.871	.919	.425**	—				
3. Self-regulation	181	4.46	.970	.814	.310**	.368**	—			
4. Engagement	181	3.40	.711	.900	.476**	.380**	.373**	—		
5. Elaboration	181	5.54	.859	.887	.408**	.659**	.484**	.350**	—	
6. Critical Thinking	181	5.16	.975	.859	.357**	.521**	.476**	.302**	.584**	—

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2.3

Results of Paired-samples t-tests examining undergraduates' motivations and learning strategies

Study Variables	Pretest		Posttest		95% CI for Mean Difference		*t*	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*	Lower	Upper			
Self-efficacy	5.39	.874	5.90	.701	.376	.647	7.48	<.001	.588
Task-value	5.47	.773	5.67	.839	.078	.312	3.30	.001	.587
Self-regulation	4.31	.887	4.48	.975	.028	.299	2.39	.018	.267
Elaboration	5.58	.730	5.59	.840	-.108	.118	.081	.936	.006
Critical Thinking	4.86	.994	5.20	.976	.184	.493	4.32	<.001	.340

Note. This table includes the results from the paired samples t-test (2-tailed). M – mean. SD – standard deviation. CI – confidence interval. *d* – effect size

Table 2.4
Multiple regression analysis predicting online engagement from motivational variables

Measure	Engagement			
	R^2	*B*	*SE B*	*ß*
Step 1	.220			
(Constant)		1.47	.274	
Self-efficacy		.367	.052	.469***
Step 2	.286			
(Constant)		.390	.347	
Self-efficacy		.307	.052	.392***
Task-value		.217	.054	.267***
Step 3	.312			
(Constant)		.390	.347	
Self-efficacy		.278	.052	.355***
Task-value		.172	.056	.212**
Self-regulation		.131	.050	.179**

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. *ß*, standardized coefficient. *B*, unstandardized coefficient. *SE B*, standard error.

Table 2.5
Multiple regression analysis predicting students' elaboration from motivational variables

Measure	Elaboration (Post)			
	R^2	*B*	*SE B*	*ß*
Step 1	.314			
(Constant)		2.02	.425	
Elaboration (Pre)		.076	.076	.561***
Step 2	.370			
(Constant)		1.39	.442	
Elaboration (Pre)		.526	.079	.460***
Self-efficacy		.241	.065	.256***
Step 3	.537			
(Constant)		.318	.406	
Elaboration (Pre)		.327	.073	.286***
Self-efficacy		.163	.057	.173**
Task-value		.458	.061	.464***
Step 4	.570			
(Constant)		.193	.395	
Elaboration (Pre)		.297	.071	.260***
Self-efficacy		.126	.056	.133*
Task-value		.408	.061	.414***
Self-regulation		.172	.050	.203**

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. *ß*, standardized coefficient. *B*, unstandardized coefficient. *SE B*, standard error.

Table 2.6
Multiple regression analysis predicting students critical thinking from motivational variables

Measure	Critical Thinking (Post)			
	R^2	*B*	*SE B*	*ß*
Step 1	.251			
(Constant)		2.82	.333	
Critical Thinking (Pre)		.097	.013	.501***
Step 2	.319			
(Constant)		1.55	.451	
Critical Thinking (Pre)		.428	.066	.441***
Self-efficacy		.297	.075	.268**
Step 3	.421			
(Constant)		.232	.488	
Critical Thinking (Pre)		.067	.013	.344***
Self-efficacy		.194	.072	.175**
Task-value		.407	.078	.352***
Step 4	.471			
(Constant)		.029	.470	
Critical Thinking (Pre)		.058	.012	.298***
Self-efficacy		.135	.071	.122*
Task-value		.337	.077	.291***
Self-regulation		.252	.066	.253***

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. *ß*, standardized coefficient. *B*, unstandardized coefficient. *SE B*, standard error.

Table 2.7

Codebook of Student Evaluation Responses		
Unit of Analysis: Student course evaluations and post-assessment questionnaire responses: 1. Please elaborate on what aspects of the online format might have helped your learning experience in this online course. 2. What are the strengths of the online course learning experience? 3. What are the weaknesses of the online course learning experience? 4. How can the technology for this course be improved to support your learning experience?		
Analytic Category: Findability		
Codes	**Definitions**	**Example**
Deadlines Structure Organization Dashboard	Findability was defined as references to the quick identification of course materials, course structure and organization, and content accessibility ***Inclusion:*** *structure, searching, course organization, layouts, content, flow, scaffolding, content accessibility, ease of use* ***Exclusion****: exclude if mentioned in the context of navigation, video playback*	***Student A:*** "The way the course was set up, from the online lectures to the quizzes, all helped me better organize my time allocated for this course." ***Student B:*** "The accessibility to everything at any time. Easy to navigate, I really enjoyed the lecture videos and how organized they were." ***Student C:*** "For this online course specifically, it was very organized and straightforward. This contributed to my success in this class." ***Student D:*** "Due dates always show up on the Canvas dashboard, which serves as an online agenda for me. Instructions for assignments are always there for me to look back on." ***Student E:*** "I think that the aspects of this course that helped me are all the videos and how this course was formulated for an online class and it was easy and accessible. This made it easier to watch it on my phone and easier to access than zoom recorded lectures."

Table 2.7 (cont.)

Analytic Category: Video Navigability		
Codes	**Definitions**	**Example**
Video Playback ● Play ● Pause ● Speed-up ● Slow-down ● Rewind ● Fast-forward ● Maximize ● Minimize ● Captions	We defined video navigability as references to the video user interface and the learner's ability to manipulate the video playback options. Such playback options include play, pause, fast forward, rewind, speed up, slow down, toggle full-screen, toggle closed captions, and enable transcripts. ● Play: the user action to start to a video ● Pause: the user action of stopping a video ● Speed-up: the user action to increase the speed of the video ● Slow-down: the user action to decrease the speed of the video ● Rewind: the user action to go back to a previous timecode of the video ● Speed-up: the user action to go forward to a future timecode of the video ● Maximize: the user action to increase the size of the video player ● Minimize: the user action to decrease the size of the video player ● Captions: the user action to enable subtitles as the video plays ***Inclusion:*** *references to video playback options, course navigation, speed, video interface, flexibility, learner-choice for accessing content*	***Student F:*** "A strength of the online course is that I can complete online assignments any time I want. Another strength is that video lectures can be slowed down or replayed for me to take notes or if I did not understand a part of the lesson." ***Student G:*** "The ability to pause and go back in lecture videos was very helpful in helping me understand difficult concepts that I had to keep going back to in order to fully comprehend." ***Student H:*** "I learn better by videos and then in person, because we have the ability to rewind, slow, down, speed up, increase volume. If I happen to miss it in class it can be difficult to catch up." ***Student I:*** "I have the freedom to watch and rewatch lecture videos when I have time, in order to better understand the content. It is a lot easier to take notes since I can pause the videos whenever and take a moment to understand what I am writing before the lecture moves on." ***Student H:*** "Having recorded lectures allows for students to play back the video and take it at their own speed, whereas in person lectures might not all offer recorded lectures. It has allowed me to learn new, better study habits."

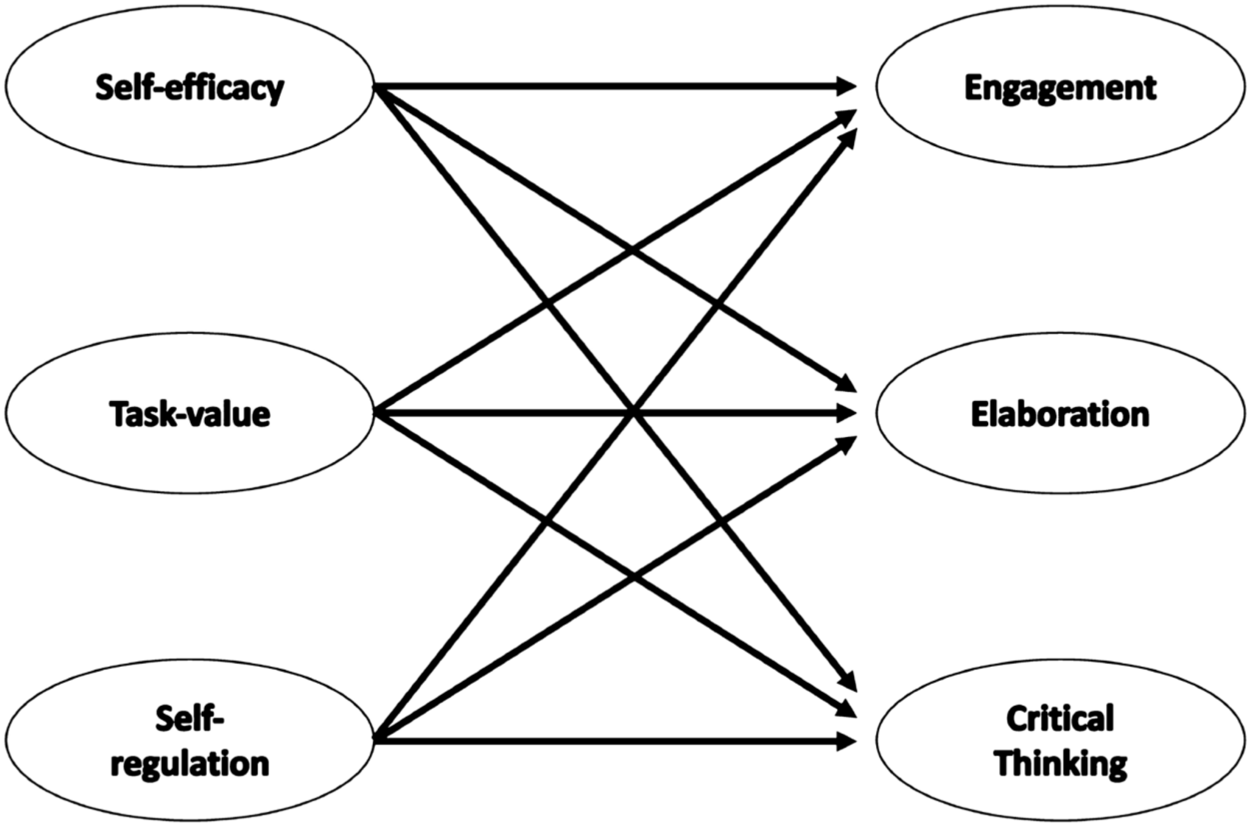
	***Exclusion**: exclude if mentioned in the context of course structure, organization, scaffolding*	

Table 2.7 (cont.)

Analytic Category: Self-pacing		
Codes	**Definitions**	**Example**
Video Playback ● Speed ● Flexibility ● Schedule	Self-paced learning was defined as references to autonomy, on your own time, and time frames with regards to pacing while participating in the online course such that students could easily navigate the course space freely to re-watch, pause, play a video, complete assignments on their own time, and access the course at their own leisure. ● Speed: the specific pacing it takes to complete a lesson, relative speed of completing videos, assignments, and quizzes in relation to others ● Flexibility: to complete on your own time, freedom to learn when it suits the learner, school from home, location can be anywhere ● Schedule: mentioning convenience of one's own schedule, non restrictive, convenience to set own schedule and plans ***Inclusion:*** *include if in reference to freedom to complete course on your own time, location, setting, time management, autonomy* ***Exclusion:*** *don't include if simply describing accessibility through devices, video navigation, or course organization*	***Student I:*** **"**One of the strengths of online learning is that we get to go at our own pace. If we have a lot of assignments we need to time ourselves so that we get things done according to what is best for us." ***Student J:*** "Online format gave me the chance to study the material on my own time; I wouldn't have had time to truly learn the material if it was during the official time indicated. It was really interesting, and I wouldn't have enjoyed it as much if it was in a traditional setting" **Student K*:* "**I was able to do everything on my own time. I succeed when I don't feel like I am pressured to complete something specifically on that day. The format where assignments/lectures are given early to complete helps me stay on track." ***Student L:*** "The pacing can teach students to overcome obstacles, problem solve, find creative solutions to problems, manage their time better, and improve study habits. In addition, the pace made the journals interesting and fulfilling to answer. The journal entries caused me to think in depth about evolutionary psychology and apply it to my own life" ***Student M:*** "This self-paced online learning has allowed me to learn new, better study habits. I have been better about staying on top of the material and learning and finding solutions to problems on my own.

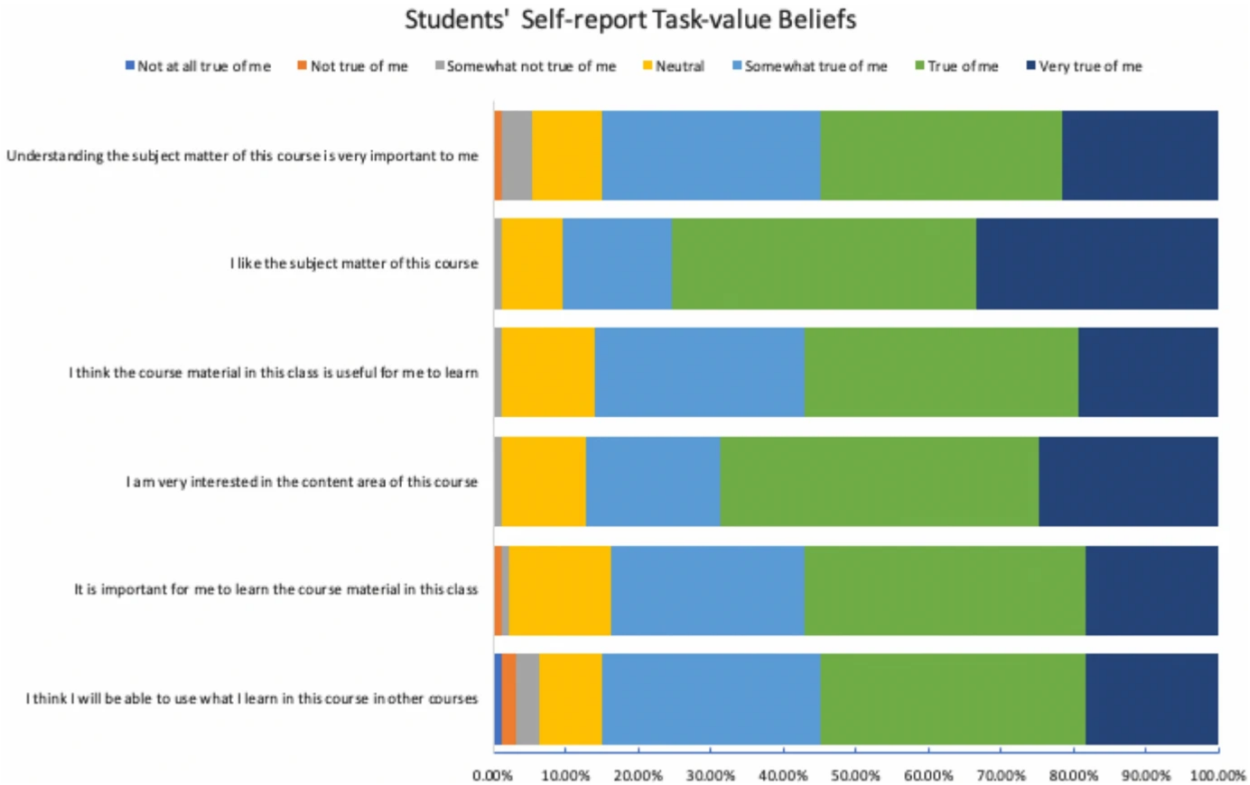
		We also got to talk about our own opinions based on what we read and watched in videos for our journals to demonstrate comprehension. It made the class interesting.”

Figure 2.1



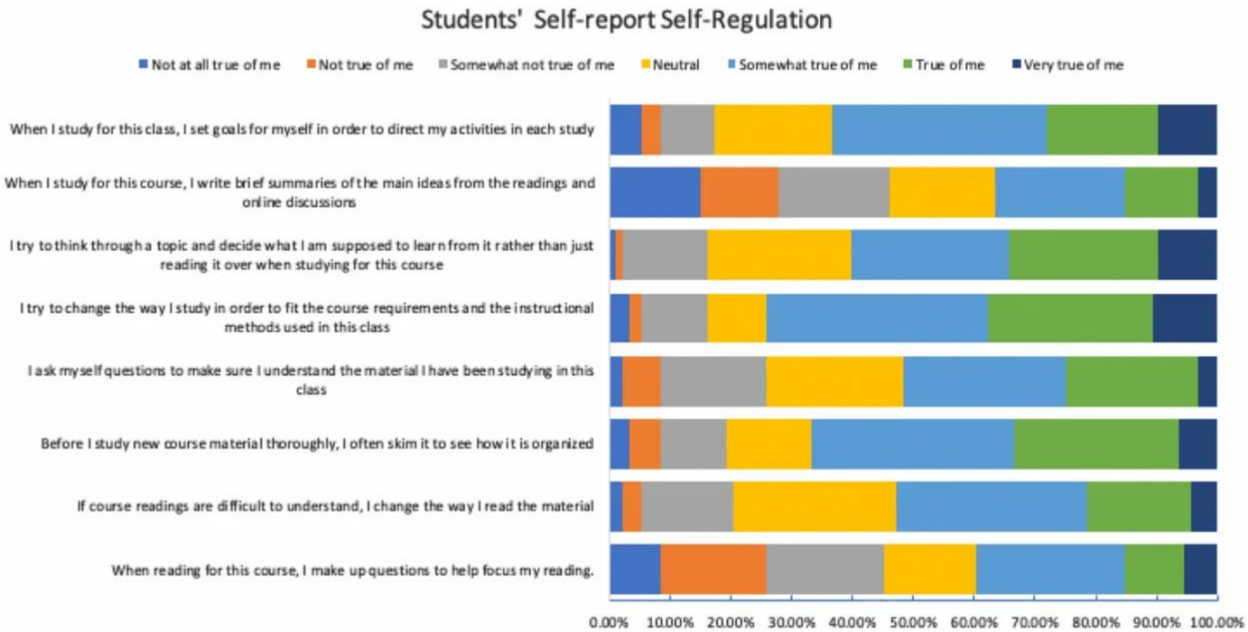
Note. Model of research questions

Figure 2.2



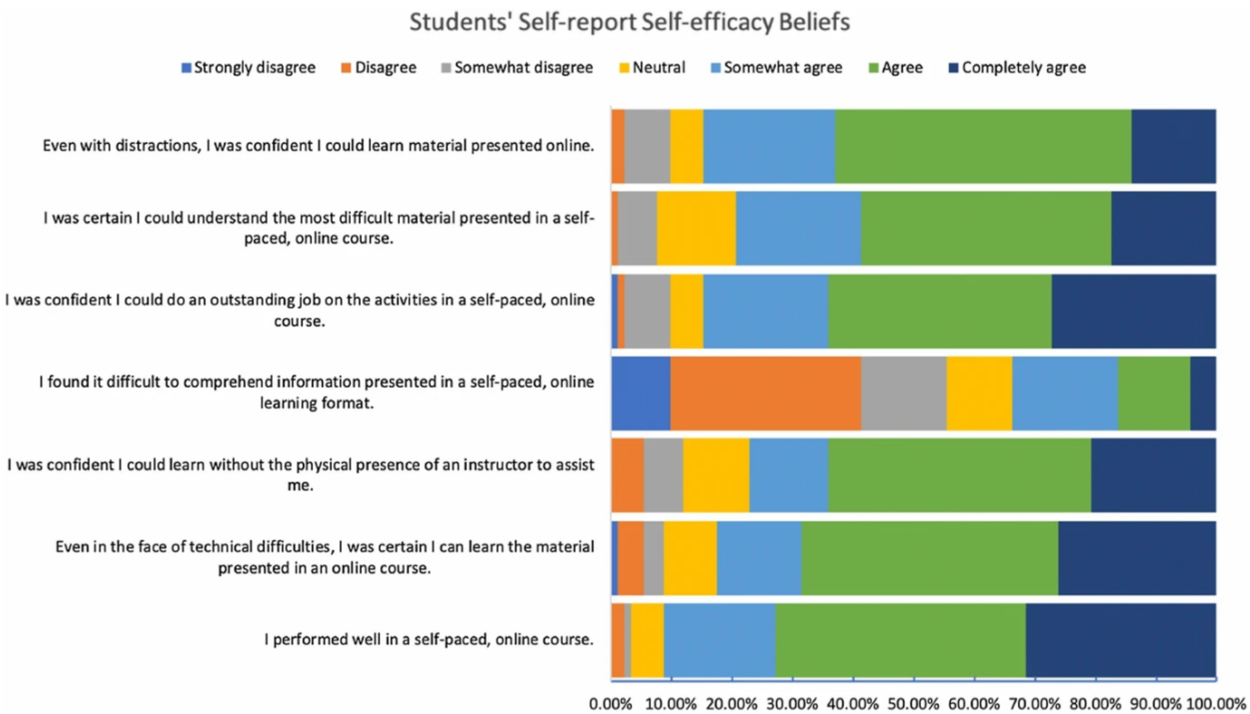
Note. Students' self-report task-value beliefs at the end of the academic quarter. Response values were normalized to percentages and stacked horizontally for visual representations

Figure 2.3



Note. Students' self-reported self-regulation at the end of the academic quarter. Response values were normalized to percentages and stacked horizontally for visual representations

Figure 2.4



Note. Students' self-reported self-efficacy at the end of the academic quarter. Response values were normalized to percentages and stacked horizontally for visual representations

CHAPTER 3: STUDY 3

Immediate vs. Delayed Questioning: Encouraging the Testing Effect through Embedded Video Questions to Support Students' Knowledge Outcomes and Learning Behaviors

Accepted for publication at *Technology, Knowledge, and Learning*

Wong, J. T., Richland, L., & Hughes, B. (2024) Immediate vs. Delayed Questioning: Encouraging the Testing Effect through Embedded Video Questions to Support Students' Knowledge Outcomes and Learning Behaviors. *Tech Know Learn* (2024).

Results from Study 1 suggested that students' mind-wandering mediated the relationship between students' self-efficacy, task value, and anxieties and their online engagement. Specifically, the data indicated that when students experienced higher levels of self-efficacy and perceived greater task value, they were less prone to mind-wandering, which in turn positively influenced their engagement in online activities. Conversely, heightened anxieties were associated with increased mind-wandering, leading to decreased online engagement. In Study 2, I conducted a comprehensive investigation into the impact of a self-paced asynchronous online course design with video scaffolds, deeply rooted in the principles of Learning Experience Design (LXD). This study aimed to explore how enhancements in students' self-efficacy, task value, and self-regulation could translate into improvements in their online learning experience. The results revealed that interventions aimed at boosting students' self-efficacy, enhancing their perception of task value, and improving their self-regulation skills led to notable enhancements in their engagement, elaboration of course materials, and development of critical thinking abilities. These findings underscore the importance of aligning course design with principles of cognitive psychology and learning theory to optimize student learning outcomes in online environments. Building upon the insights gained from Studies 1 and 2, Study 3 dives deeper into the exploration of LX course design elements that may enhance student learning experiences. This study tests the efficacy of an innovative approach involving the integration of embedded video questions within the course curriculum. The primary aim is to investigate whether this design modification could not only reduce instances of mind-wandering but also promote increased engagement, improved self-regulation, and reduced mind-wandering and cognitive load.

Drawing on established cognitive theories for multimedia learning, the use of embedded video questions aims to create interactive learning experiences that fostered deeper engagement and facilitated active information processing. By embedding questions directly within the video content, learners were encouraged to pause, reflect, and interact with the material, thereby promoting deeper encoding of information and enhancing retention through the testing effect. In the subsequent sections of this research, a thorough review of cognitive theories of multimedia learning, active information processing, and the testing effect is provided, with a specific focus on the potential impact of interactive embedded video questions on undergraduate learning experiences. Furthermore, I provide detailed descriptions of the experimental predictions tested, the materials and procedures employed, the analytic plan utilized for data analysis, and a comprehensive review of the findings. These insights lay the groundwork for further exploration and refinement of instructional strategies aimed at optimizing online learning environments for post-pandemic teaching and learning. This study is currently under review in the Journal of Technology, Knowledge, and Learning. In the following sections, I briefly review the study, materials and procedures, results, and discussion.

Introduction

A recurring concern in traditional in-person and online courses deployed is how best to maintain and sustain learners' engagement throughout the learning process. When considering the disruptions caused by the COVID-19 pandemic, these concerns are further exacerbated by competing introductions of "edtech" tools that were deployed in urgency to facilitate teaching and learning during a time of crisis learning context. That is not to say that introducing "edtech" tools did not aid in supporting students' learning trajectories during this period of time, but a major concern currently is a widespread deployment of "edtech solutions" without proper alignment with evidence-based pedagogical learning frameworks (Asad et al., 2020; Chick et al., 2020; Sandars et al., 2020) and whether or not the tools being deployed were having the intended supporting learning effect on students. Between 2020 and 2022, the United States government distributed $58.4 billion dollars through the Higher Education Emergency Relief Fund to public universities which spent more than $1.2 billion on distance learning technologies (EDSCOOP, 2023; O'leary & June, 2023). Educational technology spending by universities included expenditures on software licenses, hardware (such as computers and tablets), learning management systems (LMS), online course development tools, audio-visual equipment, digital content, and various technology-related services to name a few. In light of the considerable resources dedicated to distance learning in recent years, the need to discern how to employ these "edtech tools" in a manner that is meaningful, impactful, and grounded in evidence-based pedagogies has grown substantially.

Higher education has been grappling with a myriad of technologies to deploy in order to support the exponential increase of undergraduates enrolled in online courses. Data from the United States in the fall of 2020 indicate that approximately 11.8 million (75%) undergraduate students were enrolled in at least one distance learning course, while 7.0 million (44%) of undergraduates exclusively took distance education courses (National Center for Education Statistics [NCES], 2022). In the Fall of 2021 with the return to in-person instruction, about 75% of all postsecondary degree seekers in the U.S. took at least some online classes with around 30% studying exclusively online (NCES, 2022). In the aftermath of the pandemic, the proportion of students engaged in online courses has declined to 60%. Nevertheless, this figure remains notably higher than the levels seen in the pre-pandemic era (NCES, 2022). To meet the increasing demand, universities possess substantial opportunities to explore effective strategies for enhancing the online learning experiences of undergraduate students. However, it's important to note that merely introducing new tools into instructors' technological toolkit may not be enough to foster impactful teaching and learning.

To address these concerns, this study employs a quasi-experimental design, implementing embedded video questions into an asynchronous undergraduate Biology course, anchored in the Learning Experience Design (LXD) pedagogical paradigm. The objective is to assess the effectiveness of the embedded video question assessment platform, utilizing video technologies and employing design-based research (DBR) methodologies to evaluate practical methods for fostering active learning in online educational settings. While video content integration in education is recognized as valuable for capturing learners' attention and delivering complex concepts, passive consumption of videos may not fully harness their potential to promote active learning and deeper engagement (Mayer, 2017, 2019). Embedded video questions provide an avenue to transform passive viewing into an interactive and participatory experience (Christiansen et al., 2017; van der Meij & Böckmann, 2021). By strategically embedding thought-provoking questions within video segments, educators can prompt students to reflect on the material, assess comprehension, and immediately evaluate conceptual understanding. Additionally, analyzing the timing and placement of these questions within a video lesson may yield valuable insights into their effectiveness of facilitating the testing effect, a process in which implementing low-stakes retrieval practice over a period of time can help learners integrate new information with prior knowledge (Carpenter, 2009; Littrell-Baez et al., 2015; Richland et al., 2009). Understanding how variations in timing influence student responses and comprehension levels can inform instructional strategies for optimizing the use of interactive elements in educational videos in fostering engagement and enhancing learning performance.

This study aimed to compare students who received questions after watching a series of lecture videos with those who encountered questions immediately embedded within the video player. The objective was to identify differences in total weekly quiz scores, course engagement, as well as learning behaviors such as critical thinking and self-regulation over a span of 10 weeks. While previous studies have examined the efficacy of embedded video questions, few have considered the interrelation of these learning behaviors within the context of the Learning Experience Design (LXD) paradigm and the testing effect model for undergraduate science courses. These findings will contribute to a deeper understanding of evidence-based designs for asynchronous online learning environments and will help in evaluating the effectiveness of embedding video questions with regards to question timing within the LXD paradigm. Considering the increasing demand and substantial investment in online courses within higher education, this study aims to assess the effectiveness of a research-practice partnership in implementing embedded video questions into two courses. The ultimate aim is to determine whether this approach could serve as a scalable model for effectively meeting educational needs in the future.

Literature Review

Learning Experience Design

Learning Experience Design (LXD) encompasses the creation of learning scenarios that transcend the confines of traditional classroom settings, often harnessing the potential of online and educational technologies (Ahn, 2019). This pedagogical paradigm involves crafting impactful learning encounters that are centered around human needs and driven by specific objectives, aimed at achieving distinct learning results (Floor, 2018, 2023; Wong & Hughes, 2022; Wong et al., 2024). LXD differs from the conventional pedagogical process of "instructional design," which primarily focuses on constructing curricula and instructional programming for knowledge acquisition (Correia, 2021). Instead, LXD can be described as an interdisciplinary integration that combines principles from instructional design, pedagogical teaching approaches, cognitive science, learning sciences, and user experience design (Weigel, 2015). LXD extends beyond the boundaries of traditional educational settings, leveraging online and virtual technologies (Ahn, 2019). As a result, the primary focus of LXD is on devising learning experiences that are human-centered and geared toward specific outcomes (Floor, 2018; Wong & Hughes, 2022).

Practically, LXD is characterized by five essential components: Human-Centered Approach, Objective-Driven Design, Grounded in Learning Theory, Emphasis on Experiential Learning, and Collaborative Interdisciplinary Efforts (Floor, 2018). Taking a human-centered approach considers the needs, preferences, and viewpoints of the learners, resulting in tailored learning experiences where learners take precedence (Matthews et al., 2017; Wong & Hughes, 2022). An objective-driven approach to course design curates learning experiences that are intentionally structured to align specific objectives, making every learning activity purposeful and pertinent to support students' learning experiences (Floor, 2018; Wong et al., 2022). LXD also is grounded in learning theories, such that the design process is informed by evidence-based practices drawn from cognitive science and learning sciences (Ahn et al., 2019). Furthermore, LXD places a large emphasis on experiential learning where active and hands-on learning techniques, along with real-world applications, facilitate deeper understanding and retention (Floor, 2018, 2023; Wong et al., 2024). Lastly, LXD is interdisciplinary, bringing together professionals from diverse backgrounds, including instructional designers, educators, cognitive scientists, and user experience designers, to forge comprehensive and well-rounded learning experiences (Weigel, 2015). Each of these facets underscores the significance of empathy, where both intended and unintended learning design outcomes are meticulously taken into account to enhance learners' experiences (Matthews et al., 2017; Wong & Hughes, 2022). Consequently, LXD broadens the scope of learning experiences, enabling instructors and designers to resonate with learners and enrich the repertoire of learning design strategies (Ahn et al., 2019; Weigel, 2015), thus synergizing with the utilization of video as a powerful tool for teaching and learning online. In tandem with the evolving landscape of educational practices, LXD empowers educators to adapt and enhance their methodologies, fostering successful and enriched learning outcomes (Ahn, 2019; Floor, 2018, 2023; Wong et al., 2022), while also embracing the dynamic potential of multimedia educational technologies like video in delivering effective and engaging instructional content.

Video as a Tool for Teaching and Learning

Video and multimedia educational technologies have been broadly used as “edtech tools” tools for teaching and learning over the last three decades during in-person instruction and especially now with online learning modalities (Cruse, 2006; Mayer, 2019). Educational videos, also referred to as instructional or explainer videos, serve as a modality for delivering teaching and learning through audio and visuals to demonstrate or illustrate key concepts being taught. Multiple researchers have found evidence for the affordances of video-based learning, citing benefits including reinforcement in reading and lecture materials, aiding the development of common base knowledge for students, enhancing comprehension, providing greater accommodations for diverse learning styles, increasing student motivations, and promoting teacher effectiveness (Corporate Public Broadcasting [CPB], 1997, 2004; Cruse, 2006; Kolas, 2015; Yousef et al., 2014). Proponents in the field of video research also cite specific video design features that aid in specifically supporting students' learning experiences such as searching, playback, retrieval, and interactivity (Giannakos, 2013; Yousef et al., 2014; Wong et al., 2023). A study conducted by Wong et al. (2023) sheds light on the limitations of synchronous Zoom video lectures, based on a survey of more than 600 undergraduates during the pandemic. It underscores the advantages of the design of asynchronous videos in online courses, which better accommodate student learning needs when compared to traditional synchronous learning (Wong et al., 2023). Mayer's (2001, 2019) framework for multimedia learning provides a theoretical and practical foundation for how video-based learning modalities can be used as cognitive tools to support students' learning experiences. While some researchers have argued videos as a passive mode of learning, Mayer (2001) explains that viewing educational videos involves high cognitive activity that is required for active learning, but this can only occur through well-designed multimedia instruction that specifically fosters cognitive processing in learners, even though learners may seem or appear to be behaviorally inactive (Meyer, 2005, 2019). Following Mayer's (2019) principles, we designed multimedia lessons supporting students' cognitive processing through segmenting, pre-training, temporal contiguity, modality matching, and signaling, all implemented through asynchronous embedded video questions.

Embedded Video Questions

Embedded video questions are a type of educational technology design feature that adds interactive quizzing capacities while students engage in video-based learning. They involve incorporating formative assessments directly within online videos, prompting viewers to answer questions at specific points in the content. While a video is in progress, students viewing it are provided with questions designed to encourage increased engagement and deeper cognitive processing (Christiansen et al., 2017; Kovacs, 2016; van der Meij et al., 2021). This is similar to an Audience Response System (ARS) during traditional in-person lectures where an instructor utilizes a live polling system in a lecture hall such as iClickers to present questions to the audience (Pan et al., 2019). Yet, within the context of online learning, students are tasked with independently viewing videos at their convenience, and a set of on-screen questions emerges. This allows learners to pause, reflect, and answer questions at their own pace, fostering a sense of control over the learning process (Ryan & Deci, 2017). These questions serve to promptly recapitulate key concepts, identify potential misconceptions, or promote conceptual understanding of the subject matter. Studies suggest that embedded video questions can significantly improve student engagement compared to traditional video lectures (Chi & Wylie, 2014). Research on the use of embedded video questions has already shown promising empirical results in the field, such as stimulating students' retrieval and practice, recognition of key facts, and prompting behavioral changes to rewind, review, or repeat the materials that were taught (Cummins et al., 2016; Haagsman et al., 2020; Rice et al., 2019; Wong & Hughes et al., 2022). Embedded video questions have also been shown to transition learners from passively watching a video to actively engaging with the video content (Dunlosky et al., 2013; Schmitz, 2020), a critically important factor when considering the expediency from in-person to online instruction due to the pandemic. As a result, there are a myriad of affordances that showcase the potential effects of embedded video questions on student learning experiences –one of which is how embedded video questions can be intentionally leveraged with regards to question timing to support active information processing facilitated through the testing effect.

Testing Effect

Active information processing in the context of video-based learning is the process in which learners are able to encode relevant information from a video, integrate that information with their prior knowledge, and retrieve that information stored at a later time (Johnson & Mayer, 2009; Schmitz, 2020). This active learning process of retrieval, the learning strategy of rehearsing learning materials through quizzing and testing, is grounded in the cognitive process known as the testing effect. From a cognitive learning perspective, the testing effect is a process in which implementing low-stakes retrieval practice over a period of time can help learners integrate new information with prior knowledge, increasing long-term retention and memory retrieval in order to manipulate knowledge flexibly (Carpenter, 2009; Littrell-Baez et al., 2015; Richland et al., 2009). This shifts the narrative from looking at assessments as traditional high-stakes exams, but rather as practice learning events that provide a measure of learners' knowledge in the current moment, in order to more effectively encourage retention and knowledge acquisition of information not yet learned (Carrier & Pashler, 1992; Richland et al, 2009). The connection between retrieval and the testing effect represents sustained, continual, and successive rehearsal of successfully retrieving accurate information from long-term memory storage (Schmitzs, 2020).

The frequency of practice and the time allotted between practice sessions also play a role in memory retention. Equally as important, the timing and intentionality of when these questions might occur within a video may influence learner outcomes. As such, the more instances learners are able to retrieve knowledge from their long-term memory as practice, the better learners may recall and remember that information (Richland et al., 2009). This can come in the form of practice tests, which research has shown tremendous success in the cognitive testing literature (Carpenter, 2009; Roediger III & Karpicke, 2006), or in this study, embedded video questions to facilitate the testing effect. By doing so, we can provide students with an alternative interactive online modality to learning the material in addition to rereading or re-studying (Adesope et al., 2014; Roediger et al., 2006). Instead, learners are presented with opportunities to answer questions frequently and immediately as retrieval practice when watching a video. Active participation through answering questions keeps viewers focused and promotes deeper information processing (Azevedo, 2009). We can offer a focused medium for students to recall, retrieve, and recognize crucial concepts (Mayer et al., 2009; van de Meij et al., 2021). This approach aims to cultivate an active learning environment that engages learners' cognitive processing during online education. It assists students in discerning which aspects of the learning material they have mastered and identifies areas that require further attention (Agarwal et al., 2008; Fiorella & Mayer, 2015, 2018; McDaniel et al., 2011).

The Testing Effect on Student Learning Behaviors

Embedded video questions present a potential learning modality that operationalizes the theoretical model of the testing effect which may have tremendous benefits on the nature of student-centered active learning opportunities within an online course, particularly with student learning behaviors such as student engagement, self-regulation, and critical thinking. As such, leveraging the testing effect and the LXD pedagogical paradigm synergistically through the medium of embedded video questions may amplify student learning behaviors in online courses. The following sections review the literature on engagement, self-regulation, and critical thinking.

Student engagement in the online learning environment has garnered significant attention due to its crucial role in influencing learning outcomes, satisfaction, and overall course success (Bolliger & Halupa, 2018; Wang et al., 2013; Wong et al., 2023; Wong & Hughes, 2022). Broadly defined, student engagement can be characterized as the extent of student commitment or active involvement required to fulfill a learning task (Redmond et al., 2018; Richardson & Newby, 2010). Additionally, engagement can extend beyond mere participation and attendance, involving active involvement in discussions, assignments, collaborative activities, and interactions with peers and instructors (Hu & Kuh, 2002; Redmond et al., 2018; Wong et al., 2022). Within an online course, engagement can be elaborated as encompassing the levels of attention, curiosity, interaction, and intrinsic interest that students display throughout an instructional module (Redmond et al., 2018). This also extends to encompass the motivational characteristics that students may exhibit during their learning journey (Pellas, 2014). Several factors influence student online engagement, and they can be broadly categorized into individual, course-related, and institutional factors. Individual factors include self-regulation skills, prior experience with online learning, and motivation (Sansone et al., 2011; Sun & Rueda, 2012). Course-related factors encompass instructional design, content quality, interactivity, and opportunities for collaboration (Pellas, 2014; Czerkawski & Lyman, 2016). Institutional factors involve support services, technological infrastructure, and instructor presence (Richardson & Swan, 2003; Picciano, 2022). Furthermore, research has established a noteworthy and favorable correlation between engagement and various student outcomes, including advancements in learning, satisfaction with the course, and overall course grades (Bolliger & Halupa, 2018; Havlverson & Graham, 2019). Instructional designers argue that to enhance engagement, instructors and educators can employ strategies like designing interactive and authentic assignments (Floor, 2018), fostering active learning opportunities, and creating supportive online learning environments (Kuh et al., 2005; Wong et al., 2022). Thus, engaged students tend to demonstrate a deeper understanding of the course material, a stronger sense of self-regulation, and improved critical thinking skills (Fedricks et al., 2004; Jaggars & Xu, 2016; Pellas, 2018).

Self-regulation pertains to the inherent ability of individuals to manage and control their cognitive and behavioral functions with the intention of attaining particular objectives (Pellas, 2014; Vrugt & Oort, 2008; Zimmerman & Schunk, 2001). In the context of online courses, self-regulation takes on a more specific definition, encapsulating the degree to which students employ self-regulated metacognitive skills – the ability to reflect on one's own thinking – during learning activities to ensure success in an online learning environment (Wang et al., 2013a, 2013b; Wolters et al., 2013). Unlike conventional in-person instruction, asynchronous self-paced online courses naturally lack the physical presence of an instructor who can offer immediate guidance and support in facilitating the learning journey. While instructors may maintain accessibility through published videos, course announcements, and email communication, students do not participate in face-to-face interactions within the framework of asynchronous courses. However, the implementation of asynchronous online courses offers learners autonomy, affording them the flexibility to determine when, where, and for how long they engage with course materials (McMahon & Oliver, 2001; Wang et al., 2017). Furthermore, the utilization of embedded video questions in this course taps into Bloom's taxonomy, featuring both lower and higher-order thinking questions to test learners' understanding. This medium enables learners to immediately engage with and comprehend conceptual materials through processes such as pausing, remembering, understanding, applying, analyzing, and evaluating, negating the need to postpone these interactions until exam dates (Betts, 2008; Churches, 2008). While this shift places a significant responsibility on the learner compared to traditional instruction, embedded video questions contribute to a student-centered active learning experience (Pulukuri & Abrams, 2021; Torres et al., 2022). This approach nurtures students' self-regulation skills by offering explicit guidance in monitoring their cognitive processes, setting both short-term and long-term objectives, allocating sufficient time for assignments, promoting digital engagement, and supplying appropriate scaffolding (Al-Harthy et al., 2010; Kanuka, 2006; Shneiderman &

Hochheiser, 2001). Through this, students actively deploy numerous cognitive and metacognitive strategies to manage, control, and regulate their learning behaviors to meet the demands of their tasks (Wang et al., 2013a, 2013b). Due to the deliberate application of LXD principles, the course has the capability to enhance the development of students' self-regulation abilities in the context of online learning (Pulukuri & Abrams, 2021). Consequently, this empowers students to identify their existing knowledge and engage in critical evaluation of information that may need further refinement and clarification.

Leveraging the testing effect model through the integration of embedded video questions also yields notable advantages concerning students' critical thinking capabilities. Critical thinking involves students' capacity to employ both new and existing conceptual knowledge to make informed decisions, having evaluated the content at hand (Pintrich et al., 1993). In the context of online courses, critical thinking becomes evident through actions such as actively seeking diverse sources of representation (Richland & Simms, 2015), encountering and learning from unsuccessful retrieval attempts (Richland et al., 2009), and effectively utilizing this information to make informed judgments and draw conclusions (Uzuntiryaki-Kondakci & Capa-Aydin, 2013). To further elaborate, according to Brookfield (1987), critical thinking in the research context involves recognizing and examining the underlying assumptions that shape learners' thoughts and actions. As students actively practice critical thinking within the learning environment, the research highlights the significance of metacognitive monitoring, which encompasses the self-aware assessment of one's own thoughts, reactions, perceptions, assumptions, and levels of confidence in the subject matter (Bruning, 2005; Halpern, 1998; Jain & Dowson, 2009; Wang et al., 2013a, 2013b). As such, infusing embedded video questions into the learning process may serve as a strategic pedagogical approach that may catalyze students' critical thinking skills.

In the context of embedded video questions, students must critically analyze questions, concepts, scenarios, and make judgments on which answer best reflects the problem. As students engage with the videos, they're prompted to monitor their own thinking processes, question assumptions, and consider alternate perspectives—a quintessential aspect of metacognition that complements critical thinking (Bruning, 2005; Halpern, 1998; Jain & Dowson, 2009; Wang et al., 2013a, 2013b). Sometimes, students might get the answers wrong, but these unsuccessful attempts also contribute to the testing effect in a positive manner (Richland et al., 2009). Unsuccessful attempts serve as learning opportunities to critically analyze and reflect during the low-stakes testing stage so that learners are better prepared later on. Furthermore, cultivating students' aptitude for critical thinking also has the potential to enhance their transferable skills (Fries et al., 2020), a pivotal competency for STEM undergraduate students at research-intensive institutions (R1), bridging course content to real-world applications. In essence, the interplay between the testing effect model and the use of embedded video questions not only supports students' critical thinking, but also underscores the intricate relationship between engagement, self-regulation, and course outcomes (Wang et al., 2013).

Current Study

This study builds on the work of Wong and Hughes (2023) on the implementation of LXD in STEM courses utilizing educational technologies. Utilizing the same course content, course videos, and pedagogical learning design, this Design-Based Research (DBR) approach employs learning theories to assess the effectiveness of design and instructional tools within real-world learner contexts (DBR Collective, 2003; Siek et al., 2014). In this study, we utilized the same instructional videos and course materials as Wong & Hughes et al. (2023), but instead incorporated iterative design enhancements such as embedded video questions to assess their potential testing effect impacts on students' learning experiences. Therefore, this quasi-experimental research contrasts students who participated in a 10-week undergraduate science online course. Half of these students encountered low-stakes questions integrated directly within the video player (immediate condition), while the other half received questions following a series of video lectures (delayed condition). The aim is to assess how the timing of when low-stakes questioning occurs might beneficially influence learners' science content knowledge, engagement, self-regulation, and critical thinking. Additionally, we assessed students' learning analytics within the online course, including online page views and course participation, as a proximal measure of learners' online engagement. We then compared these findings with their self-report survey responses within the online course to corroborate the results. With the implementation of a newly iterated online course grounded in LXD paradigm and the testing effect model, this study is guided by the following research questions:

RQ1) To what extent does the effect of “immediate vs delayed low-stakes questioning” influence learners’ total quiz grades, online page views, and course participation rate?

RQ2) To what extent does the effect of “immediate vs delayed low-stakes questioning” influence learners’ engagement, self-regulation, cognitive load and mind-wandering?

RQ3) To what extent does the relationship between “immediate vs delayed low-stakes questioning” and learner’s total quiz grades vary depending on their levels of self-regulation, mind-wandering, and cognitive load?

Methodology

Ethical Considerations

This study, funded by the National Science Foundation (NSF), adheres to stringent ethical standards mandated by both the university and the grant funding agency. The university institution obtained approval from its Institutional Review Board (IRB) to conduct human subjects research, ensuring compliance with ethical guidelines. The research was categorized as IRB-exempt due to its online, anonymous data collection process, which posed minimal risk to participants. All participants were provided with comprehensive information about the study, including its purpose, procedures, potential risks and benefits, confidentiality measures, and their right to withdraw without consequences. Participant data was treated with utmost confidentiality and anonymity, and the study's questions, topics, and content were designed to avoid causing harm to students. The research protocol received formal approval from the university's ethics committee. All participants provided informed consent to participate in the study before any data collection procedures commenced. This ensured that participants were fully aware of the study's purpose, procedures, potential risks and benefits, confidentiality measures, and their right to withdraw without consequences.

Experimental Design

This research employed a design-based research (DBR) approach, leveraging learning theories to evaluate the effectiveness of design, instructional tools, or products in authentic, real-world settings (DBR Collective, 2003; Siek et al., 2014). The rationale for this research methodology is to assess instructional tools in ecologically valid environments and explore whether these tools enhance students' learning experiences (Scott et al., 2020). Our decision to adopt a DBR approach arises from the limited research on investigating the efficacy of the

Learning Experience Design (LXD) pedagogical paradigm with embedded video questions in online undergraduate science courses. We are also cognizant of previous research indicating that simply inserting questions directly into videos, without evidence-based pedagogical principles, intentional design, and instructional alignment, does not significantly improve learning outcomes (Deng et al., 2023; Deng & Gao, 2023; Mar et al., 2017). Thus, this DBR study utilizes a Learning Experience Design (LXD) approach to cultivate active learner engagement through the implementation of learning theories such as the testing effect model. We then compare the impact of embedded video questions on learning outcomes within the newly designed self-paced asynchronous online course (See Figure 3.1). Subsequently, we test these designs with learners and utilize the findings to iterate, adapt, and redeploy these techniques continually, aiming to enhance the efficacy and gradual evolution in our designs of embedded video questions on students' learning experiences.

[Insert Figure 3.1]

The study involved two equivalently sized classes within the School of Biological Sciences at an R1 university in Southern California, with students voluntarily enrolling in either one of these two classes. The two classes were taught by the same professor on the same topics of Ecology and Evolutionary Biology. This particular course was chosen to serve as a research-practice partnership (RPP), collaborating closely with the professor, educational designers, researchers, and online course creators to customize a course that aligns with the instructor's and students' needs returning from the COVID-19 remote learning environment.

The study spanned a 10-week period, allowing sufficient dosage for implementing our learning designs and effectively measuring their impact on students' learning experiences (See Figure 3.1). Selecting a quasi-experimental design allowed us to assess the impact of question timing and placement on students' comprehension and retention of the material presented in the videos. Following quasi-experimental design principles, the study involved two classes, each assigned to a different treatment condition. Students who experienced low-stakes questions after watching a series of videos were referred to as "Delayed Questioning," and students who experienced low-stakes questions immediately embedded within the video player were referred to as "Immediate Questioning." In the delayed questioning condition, students encountered low-stakes questions only after watching all assigned video lectures for the week, while in the immediate questioning condition, students faced questions directly embedded in the video player, time-stamped and deliberately synchronized with the presented conceptual content. The two treatment conditions, "Delayed" and "Immediate Questioning" were carefully designed to isolate the effect of question timing while keeping all other variables constant. As such, the low-stakes questions, quantity of videos, and the number of questions in both conditions were completely identical, with the only experimental manipulation involving the timing and placement of the questions across conditions.

Following the viewing of videos and answering of low-stakes questions, either embedded directly in the video or after watching all of the videos in the instructional unit, all students proceeded to take an end-of-week quiz, serving as a summative assessment released on Fridays. The end-of-week quiz was completely identical and released at the same time and day across both conditions. This comprehensive approach ensured equitable testing conditions and minimized potential confounding variables. Furthermore, this approach allowed for a controlled comparison between the two conditions, helping to determine whether embedding questions directly within the video player led to different learning outcomes compared to presenting questions after watching all of the videos. Selecting these carefully designed treatment conditions allowed for a controlled comparison, isolating the effect of question timing while keeping all other variables constant. This methodological rigor facilitated a robust analysis of the impact of question placement on students' learning experiences and outcomes.

Participants

The study encompassed a total of n=183 undergraduate students who were actively enrolled in upper-division courses specializing in Ecology and Evolutionary Biology. Participants were selected based on their voluntary self-enrollment in these upper-division courses during a specific enrollment period of Winter 2021. No exclusion criteria were applied, allowing for a broad sample encompassing various backgrounds and levels of experience in Ecology and Evolutionary Biology. These courses were part of the curriculum at a prominent R1 research university located in Southern California and were specifically offered within the School of Biological Sciences. Students were able to enroll in the upper division course so long as they were a biological sciences major and met their lower division prerequisites. Regarding the demographic makeup of the participants, it included a diverse representation with 1.2% identifying as African American, 72.0% as Asian/Pacific Islander, 10.1% as Hispanic, 11.3% as white, and 5.4% as multiracial. Gender distribution among the students consisted of 69.0% females and 31.0% males (See Table 3.1). Participants randomly self-select into one of two distinct course sections, each characterized by different approaches to course implementation: 1) The first condition featured questions placed at the conclusion of all video scaffolds (n = 92). 2) The second section incorporated questions that were embedded directly within the video scaffolds themselves (n = 91).

[Insert Table 3.1]

Learning Experience Design

Video Design The curriculum delivery integrated innovative self-paced video materials crafted with the Learning Experience Design (LXD) paradigm in mind (Wong et al., 2024). These videos incorporated various digital learning features such as high-quality studio production, 4K multi-camera recording, green screen inserts, voice-over narrations, and animated infographics (See Figure 3.2). Underpinning this pedagogical approach of the video delivery was the situated cognition theory (SCT) for e-learning experience design, as proposed by Brown et al. in 1989. In practice, the videos were structured to align with the key elements of SCT, which include modeling, coaching, scaffolding, articulation, reflection, and exploration (Collins et al., 1991; Wong et al., 2024). For instance, the instructor initiated each module by introducing a fundamental concept, offering in-depth explanations supported by evidence, presenting real-world instances demonstrating the application of the concept in research, and exploring the implications of the concept to align with the course's educational objectives. This approach emphasized immersion in real-world applications, enhancing the overall learning experience.

In the video design process, we adopted an approach where content equivalent to an 80-minute in-person lecture was broken down into smaller, more manageable segments lasting between five to seven minutes. This approach was taken to alleviate the potential for student fatigue, reduce cognitive load, and minimize opportunities for students to become distracted (Humphris & Clark, 2021; Mayer, 2019). Moreover, we meticulously scripted the videos to align seamlessly with the course textbook. This alignment served the purpose of pre-training students in fundamental concepts and terminologies using scientific visuals and simplified explanations, thereby preparing them for more in-depth and detailed textbook study. As part of our video design strategy, we strategically integrated embedded questions at specific time points during the video playback. These questions were designed to serve multiple purposes, including assessing students' comprehension, sustaining their attention, and pinpointing areas of strength and weakness in their understanding. In line with Meyer's (2019) principles of multimedia design, our videos were crafted to incorporate elements like pretraining, segmenting, temporal contiguity, and signaling (See Figure 3.2). These principles ensured that relevant concepts, visuals, and questions were presented concurrently, rather than sequentially (Mayer, 2003, 2019). This approach encouraged active engagement and processing by providing cues to learners within the video content.

[Insert Figure 3.2]

Question Design. Based on their respective conditions, learners would encounter questions either after watching 6 or 7 lecture videos or experience questions integrated directly within each of the videos. These questions served as opportunities for low-stakes content practice, retention, and reconstructive exercises, aiming to engage learners in the testing effect and enhance the development of their conceptual understanding (Richland et al., 2009). Using Bloom’s Taxonomy to ground our question development, the questions embedded in the videos consisted of both lower-order and higher-order thinking questions (See Figure 3.2). This meant that the lower-order thinking questions were designed to emphasize remembering, understanding, and applying the concepts in context (Bloom, 2001; Betts, 2008). On the other hand, higher-order thinking questions targeted applying and analyzing scenarios in ecology and evolutionary biology, requiring students to break down relationships and make judgments about the information presented (Bloom, 2001; Betts, 2008) (See Figure 3.1). Together, these strategic question design choices empower students to actively participate in constructive metacognitive evaluations, encouraging them to contemplate "how and why" they reached their conclusions

(See Figure 3.1). Research has indicated that such an approach promotes critical thinking and the utilization of elaborative skills among learners in online learning contexts (Tullis & Benjamin, 2011; Wang et al., 2013). Furthermore, by having students answer questions and practice the concepts immediately while watching the videos, our intentions were that students would be better prepared for the weekly quizzes due to the testing effect.

Course Design and Delivery. The course was implemented within the Canvas Learning Management System (LMS), the official learning platform of the university. The videos recorded for this course were uploaded, designed, and deployed using the Yuja Enterprise Video Platform software. Yuja is a cloud-based content management system (CMS) for video storage, streaming, and e-learning content creation. For this study, we utilized Yuja to store the videos in the cloud, design the embedded video questions platform, and record student grades. After uploading the videos, the questions were inputted into the Yuja system with the corresponding answer options based on specific time codes. These time codes were determined based on the concepts presented within the video. Typically, lower-order thinking questions (i.e. questions that required, remembering, understanding) were placed immediately after introducing a definition of a key concept. Then, higher-order thinking questions (i.e. analyzing, evaluating) were placed towards the end of the video for students to apply the concepts in context before moving on to the next video. Finally, each video was then published from Yuja to Canvas using the Canvas Learning Tools Interoperability (LTI) integration so that all student grades from the embedded video questions were automatically graded and directly updated into the Canvas grade book.

Data Collection and Instrumentation

Data collection for this study was conducted electronically during the Winter 2021 academic term. All survey measurement instruments were distributed online to the participating students through the Qualtrics XM platform, an online survey tool provided through the university. Students were granted direct access to the surveys through hyperlinks that were seamlessly integrated into their Canvas Learning Management System (LMS) course space, providing a user-friendly, FERPA compliant, and secure centralized data collection environment. Students filled out the surveys immediately after completing their last lesson during the last week of the course on Week 10. When responding to all of the surveys, students were asked to reflect on their learning experiences about the online course they were enrolled in specifically. Having students complete the survey right after their last lesson was an intentional research design decision in order to maintain the rigor, robustness, and quality of responses from students.

Survey Instruments

Five survey instruments were given to the participants: the Motivated Strategies for Learning Questionnaire, assessing critical thinking and self-regulation, Cognitive Load Questionnaire, Mind-wandering Questionnaire, and the Perceived Engagement Scale. We maintained the original question count and structure for reliability but made slight adjustments, such as replacing "classroom" with "online course" to align with the study's online math intervention context. This approach, supported by research (Hall, 2016; Savage, 2018), ensures effectiveness while preserving the survey instruments' reliability, particularly across different learning modalities.

The MLSQ instrument utilized in this study was originally developed by a collaborative team of researchers from the National Center for Research to Improve Postsecondary Teaching and Learning and the School of Education at the University of Michigan (Pintrich et al., 1993). This well-established self-report instrument is designed to comprehensively assess undergraduate students' motivations and their utilization of diverse learning strategies. Respondents were presented with a 7-point Likert scale to express their agreement with statements, ranging from 1 (completely disagree) to 7 (completely agree). To evaluate students in the context of the self-paced online course, we focused specifically on the self-regulation and critical thinking subscales of the MLSQ. Sample items in the self-regulation scale included statements such as "When studying for this course I try to determine which concepts I don't understand well" and "When I become confused about something I'm watching for this class, I go back and try to figure it out." Sample items for critical thinking include "I often find myself questioning things I hear or read in this course to decide if I find them convincing" and "I try to play around with ideas of my own related to what I am learning in this course." According to the original authors, these subscales exhibit strong internal consistency, with Cronbach alpha coefficients reported at 0.79 and 0.80, respectively. In this study, Cronbach's alphas for self-regulation and critical thinking were 0.86 and 0.85, respectively.

The Cognitive Load Questionnaire used in this study was originally developed by Klepsch and colleagues (2017). This 7-item survey contained questions that specifically measured three types of cognitive load including intrinsic, germane, and extraneous. Respondents conveyed their responses on a 5-point Likert scale, ranging from 1 (very low) to 7 (very high). Sample items in the scale included statements such as "For this task, many things needed to be kept in mind simultaneously" and "During this task, it was exhausting to find the important information." Klepsch et al. (2017) report that the internal consistency coefficient for this instrument was 0.86. In this study, Cronbach's alpha for the Cognitive Load Questionnaire was 0.897.

To determine students' levels of mind-wandering, the Mind-Wandering Questionnaire (MWQ), developed by Mrazek and colleagues (2013), was deployed to assess students' inattention while taking online courses. This instrument includes five items with response options designated on a 6-point Likert scale, 1 (almost never) to 6 (almost always). Sample items include “I mind-wander during lectures or presentations” and “I find myself listening with one ear and thinking about something else at the same time” (see Table 1.8). Mrazek et al. (2013) reported the internal consistency coefficient as 0.85 and was revalidated by Trigueros and colleagues (2019) with an internal consistency coefficient of 0.94. In this study, the Cronbach’s alpha of MWQ was 0.898.

To gauge students' perceptions of their online engagement, we employed a 12-item survey adapted from Rossing et al. (2012). This survey encompassed a range of questions probing students' views on the learning experience and their sense of engagement within the online course. Respondents conveyed their responses on a 5-point Likert scale, ranging from 1 (completely disagree) to 5 (completely agree). Sample items in the scale included statements such as "This online activity motivated me to learn more than being in the classroom" and "Online video lessons are important for me when learning at home.” Rossing et al. (2012) report that the internal consistency coefficient for this instrument was 0.90. Similarly, Wong et al. (2023) reported a coefficient of 0.88, further supporting the scale's reliability across online learning contexts. This instrument demonstrated robust internal consistency, with a Cronbach alpha coefficient reported at 0.89, indicating its reliability in assessing students' perceptions of online engagement.

Course Learning Analytics

Throughout the 10-week duration, individualized student-level learning analytics were gathered from the Canvas Learning Management System (LMS). These analytics encompassed various metrics, including total quiz grades, participation rates, and page views. The total quiz grades served as a summative assessment with 10 multiple choice questions. This aggregate metric was derived from the summation of weekly quiz scores over the 10-week period. Each student completed a total of 10 quizzes over the course of the study, with one quiz administered per week. It's noteworthy that the quizzes presented to students in both classes were completely identical in terms of length, question count, and answer choices. By standardizing the quizzes across both classes, we ensured uniformity in assessment across both classes, thereby enabling a fair comparison of learning outcomes between students who received embedded video questions and those who did not.

Pageviews and participation rates offered detailed insights into individual user behavior within the Canvas Learning Management System (LMS). Pageviews specifically monitored the total number of pages accessed by learners within the Canvas course environment, with each page load constituting a tracked event. This meticulous tracking provided a metric of the extent of learners' interaction with course materials (Instructure, 2024), enabling a close examination of learner engagement and navigation patterns within the online course. Consequently, page view data can serve as a reliable proxy for student engagement rather than a definitive measure, assisting in gauging the occurrence of activity and facilitating comparisons among students within a course or when analyzing trends over time. The total number of page views for both classes were examined and compared between students with and without embedded video questions.

Participation metrics within the Canvas LMS encompassed a broad spectrum of user interactions within the course environment. These included not only traditional activities such as submitting assignments and quizzes but also more dynamic engagements such as watching and rewatching videos, redoing low-stakes questions for practice, and contributing to discussion threads by responding to questions (Instructure, 2024). Each instance of learner activity was logged as an event within the Canvas LMS. These participation measures were comprehensive and captured the diverse range of actions undertaken by students throughout their learning journey. They provided invaluable insights into the level of engagement and involvement of each student within their respective course sections. By recording these metrics individually for each student, the Canvas LMS facilitated detailed analysis and tracking of learner behavior, enabling a nuanced understanding of student participation patterns and their impact on learning outcomes.

Data Analysis Plan

We conducted checks for scale reliability to assess the alpha coefficients for all the measurement instruments. Additionally, a chi-square analysis was performed to ensure that there were no disparities between conditions in terms of gender, ethnicity, and student-grade level statuses prior to treatment. Next, descriptive analyses were conducted to assess the frequencies, distribution, and variability across the two different conditions on learners total quiz grades, page views, and participation after 10 weeks of instruction (See Table 3.2). Then, a series of one-way Analysis of Variance (ANOVAs) were conducted to examine the differences between conditions on dependent variables separately. Next, two Multivariate Analysis of Variance (MANOVAs) were conducted to evaluate the difference between treatment conditions on multiple dependent variables. A MANOVA was chosen for analysis in order to access multiple dependent variables simultaneously while comparing across two or more groups. The first MANOVA compared the means of learners with and without embedded video questions on three dependent variables: (D1) quiz grades, (D2) pageviews, and (D3) participation. A second MANOVA compared the means of learners with and without embedded video questions on three dependent variables: (D1) engagement, (D2) self-regulation, and (D3) critical thinking skills. Lastly, multiple regression analyses were conducted to evaluate the effect of embedded video questions related to learners' quiz grades and whether this relation was moderated by learners' self-regulation and critical thinking skills.

Results

Descriptive Analysis

Table 3.3 displays the average weekly quiz grades for two instructional conditions, "Delayed Questioning" and "Immediate Questioning," over a ten-week period from January 4th to March 8th. Fluctuations in quiz grades are evident across the observation period for both conditions. For instance, on Week 1, the average quiz grade for "Delayed Questioning" was 95.65, while it was notably higher at 99.2 for students in the "Immediate Questioning" condition. Similarly, on Week 6, quiz grades decreased for both conditions, with "Delayed Questioning" at 93.35 and "Immediate Questioning" at 96.9 (See Figure 3.4). Comparing the average quiz grades between the two instructional conditions revealed consistent differences throughout the observation period. The "Immediate Questioning" condition consistently demonstrated higher quiz grades compared to "Delayed Questioning." Notably, this difference is particularly pronounced on certain dates, such as Week 3, where the average quiz grade for "Delayed Questioning" was 97.6, while it reached 99.6 for "Immediate Questioning." These descriptive findings suggest that embedding questions directly within the video content may positively influence learners' quiz performance, potentially indicating higher engagement and comprehension of the course material. However, further analysis is required to explore the significant differences in weekly quiz grades between the two instructional conditions.

Figure 3.5 presents the frequency of page views throughout the 10 week course, acting as an proximal indicator of learner engagement, across different dates for two instructional approaches: "Delayed Questioning" and "Immediate Questioning." Higher page view counts indicate heightened interaction with course materials on specific dates. For example, on Week 1, "Delayed Questioning" registered 9,817 page views, while "Immediate Questioning" recorded 12,104 page views, indicating peaks in engagement. Conversely, lower page view counts on subsequent dates may imply reduced learner activity or engagement with the course content. Fluctuations in page view counts throughout the observation period highlight varying levels of learner engagement under each instructional condition. Notably, a comparative analysis between the two instructional methods unveiled consistent patterns, with "Immediate Questioning" condition consistently exhibiting higher page view counts across most observation dates. This initial examination suggests that embedding questions directly within the video player may enhance learner engagement, evidenced by increased interaction with course materials.

Upon examination of the participation rates across the specified dates, it is evident that the "Immediate Questioning" condition consistently generated higher levels of engagement compared to the "Delayed Questioning" condition (See Figure 3.6). For instance, on Week 4, the participation rate for "Delayed Questioning" was recorded as 459, while it notably reached 847 for "Immediate Questioning." Similarly, on Week 7 participation rates were 491 and 903 for "Delayed Questioning" and "Immediate Questioning," respectively, indicating a substantial difference in participation rates between the two instructional approaches. Moreover, both conditions experienced fluctuations in participation rates over time, with instances where participation rates surged or declined on specific dates. For instance, on Week 10, the participation rate for "Delayed Questioning" dropped to 287, whereas it remained relatively higher at 677 for "Immediate Questioning." Overall, the descriptive analysis depicted in Figure

3.6 highlights the differences in participation rates across the two conditions and underscores how embedding video questions influences learners' online behaviors.

Multivariate Analysis of Variance on Dependent Variables

A MANOVA was conducted to compare the means of learners with and without embedded video questions on three dependent variables: (D1) quiz grades, (D2) pageviews, and (D3) participation (See Table 3.2). The multivariate test was significant, F (3, 150) = 188.8, $p <$ 0.000; Pillai's Trace = 0.791, partial $\eta^2 = 0.791$, indicating a difference between learners who experienced "Delayed" and "Immediate Questioning." The univariate F tests showed there was a statistically significant difference for total quiz grades F (1, 152) = 6.91; $p < 0.05$; partial η^2 = 0.043), pageviews F (1, 152) = 26.02; $p < 0.001$; partial $\eta^2 = 0.146$), and course participation rates F (1, 152) = 569.6; $p < 0.001$; partial $\eta^2 = 0.789$) between the two conditions. The results of the Bonferroni pairwise comparisons of mean differences for total quiz grades ($p < 0.05$), pageviews ($p < 0.001$), and course participation ($p < 0.001$) were statistically significantly different between the two conditions. Therefore, learners who experienced questions directly embedded within the video player had significantly higher total quiz grades, page views, and course participation across 10 weeks.

[Insert Table 3.3]

A second MANOVA compared the means of learners with and without video-embedded questions on three dependent variables: (D1) engagement, (D2) mind-wandering, (D3) cognitive load, and (D4) self-regulation. The multivariate test was significant for immediate condition, F (4, 177) = 5.09, $p < 0.001$; Pillai's Trace = 0.182, partial $\eta 2 = 0.182$, indicating a difference between learners by conditions. The univariate F tests showed there was a statistically significant difference between learners with and without embedded video questions for engagement F (1,

181) = 7.96; $p < 0.05$; partial $\eta 2 = 0.042$), mind-wandering F (1, 181) = 14.34; $p < 0.001$; partial η2 = 0.086), cognitive load F (1, 181) = 16.94; $p < 0.05$; partial $\eta 2 = 0.026$), and self-regulation F (1, 181) = 14.24; $p < 0.001$; partial $\eta 2 = 0.073$). The results of the Bonferroni pairwise comparisons of mean differences for engagement ($p < 0.05$), mind- wandering ($p < 0.001$), cognitive load ($p < 0.05$), and self-regulation ($p < 0.001$) showed a statistically significant difference across treatment conditions.

[Insert Table 3.4]

Moderation Analyses

The first multiple regression model investigated whether the association between learners' total quiz grades who experienced “Delayed” or “Immediate Questioning” depends on their levels of the accuracy of their low stakes questions. The results revealed that the main effect of condition significantly predicted the outcome variable ($\beta = 2.858$, $p < .001$), indicating that participants in the “Immediate Questioning” scored significantly higher on their total weekly quiz scores compared to those in the “Delayed” condition. Moreover, learner’s low-stakes questioning accuracy was also found to have a significant positive effect on learners total weekly quiz scores ($\beta = 0.807$, p < .001), suggesting that higher accuracy in low-stakes questions was associated with higher scores on the weekly quizzes. Furthermore, the interaction term between conditions and low-stakes question accuracy exhibited a significant effect on learner’s weekly quiz grades ($\beta = 2.890$, $p < .001$), indicating that the relationship between low-stakes question accuracy and the weekly quiz grades differed significantly between the two conditions. Specifically, the effect of low-stakes question accuracy on total weekly quiz grades was more pronounced in the immediate condition compared to the delayed condition. Overall, the predictor variables accounted for a significant portion of the variance in the outcome variable $R^2 = 0.845$, $F(3,175) = 323.7$, $p < .001$.

A second multiple regression model investigated whether the association between learners' total quiz grades who experienced ”Delayed” or “Immediate Questioning” depends on their levels of self-regulation, cognitive load, and mind-wandering (Table 3.4). The moderators for this analysis were learners’ self-report self-regulation, cognitive load, and mind-wandering, while the outcome variable was the learners’ total quiz grades after 10 weeks. Results show that learners’ who experienced “Immediate Questioning” ($\beta = 1.15$, $SE = 4.72$) were significantly predictive of their total quiz grades. The main effects of cognitive load ($\beta = -0.340$, $SE = 0.096$) and self-regulation ($\beta = 0.448$, $SE = 0.063$) were also significant, while mind-wandering ($\beta = -0.121$, $SE = 0.185$) was not statistically significant. The interactions between conditions and self-regulation ($\beta = 0.747$, $SE = 0.099$) and between conditions and cognitive load ($\beta = 0.564$, $SE = 0.150$) were significant, suggesting that the effect of condition on quiz grades is dependent on the level of learners’ self-regulation and cognitive load. Together, the variables accounted for approximately 27.1% of the explained variance in learners’ quiz grades, $R^2 = 0.271$, $F(5,158) = 9.08$, $p < .001$.

Discussion

The current study is part of a large-scale online learning research effort at the university that examines undergraduate learning experiences with the intentional design and implementation of pedagogically grounded educational technologies. More specifically, this study implements learning experience design, the testing effect model, and “edtech tools” aligned with evidence-based learning theories with the goals of increasing student knowledge outcomes, online engagement, and transferable skills such as self-regulation and critical thinking.

In addition, one of the primary goals of this study is to leverage design-based research methodologies to evaluate students at the same university where instructors are implementing these evidence-based practices in ecologically real-world settings. Doing so in turn may help higher education administrators determine if the large investments universities have made in purchases towards educational technologies are actually supporting students' learning experiences. Furthermore, the results and impacts of these designs may inform the continual evolution and iteration of best practices of educational technologies at scale across the university.

As mentioned previously, the demand for online learning experiences has increased exponentially during the pandemic, and student interest in online learning in this post-pandemic era of teaching and learning has continued to increase. Thus, the present study aimed to investigate the impact of embedded video questions within an asynchronous online Biology course grounded in the Learning Experience Design (LXD) paradigm on learners' engagement, self-regulation, critical thinking, and quiz performance. By comparing learners who experienced "Immediate Questioning" versus "Delayed Questioning," this research contributes to our understanding of how the integration of embedded video questions and the timing of when questions appear may influence the efficacy of online learning experiences by encouraging the utilization of testing effect strategies. The discussion will interpret and contextualize the study's findings within the broader landscape of online education, technology integration, and pedagogical design.

Impact on Student Course Outcomes

The findings presented in Tables 2 and 3 shed light on the general descriptive trends of the two distinct instructional methodologies, "Delayed Questioning" and "Immediate Questioning," implemented over a ten-week period from January 4th to March 8th. This period allowed for a comprehensive examination of learners' engagement and summative learning performance within the educational context. Analysis of the average weekly quiz grades indicates notable fluctuations across the observation period, with those in the "Immediate Questioning" condition consistently yielding higher grades compared to the "Delayed Questioning" condition. This trend aligns with van Der Meij (2020) and Deng et al. (2023) who found that learning performance was significantly higher for students who experienced embedded video questions compared to their counterparts in their respective studies. Concurrently, Figure 5 presents a detailed portrayal of the frequency of page views, serving as a proximal measure of learner engagement with course materials over time. Notably, students who received "Immediate Questioning" consistently demonstrated heightened interactivity and engagement within the course, evident from higher page view counts across most observation dates. Moreover, examination of participation rates further supports the efficacy of embedding questions directly within the video content, revealing sustained higher levels of engagement compared to the alternative approach. These initial descriptive findings begin to suggest and align with previous scholars that embedding questions immediately within the video player fosters enhanced learner engagement and positively influences learning outcomes (Deng et al., 2023; Kestin & Miller, 2022; Torres et al., 2022)

The results from the first MANOVA of the study demonstrated that learners who experienced the "Immediate Low-stakes Questioning" showed significant positive effects on learners' summative quizzes scores across 10 weeks compared to "Delayed Low-stakes condition." Importantly, these weekly summarized quizzes were made available to students in both conditions at the same time with the same deadlines at the end of each week on fridays. This meant that both conditions had an equal amount of instructional preparation time to watch the lecture videos in their respective conditions. This suggests that the timing of the low-stakes questions synchronized to the instructional unit as well as the interactive nature of embedded video questions that aimed to foster the testing effect paradigm contributed to increased learner activity and participation (Richland et al., 2009). Interestingly, the observed trends in the "Immediate Questioning" group, characterized by notably higher weekly quiz scores, might be attributed to the student-centered active learning facilitated by the concurrent processing of concepts through answering questions while watching the lecture videos. While videos have been used broadly as an educational tool to facilitate online learning (Mayer, 2017, 2019; Wong et al., 2024), immediate questions embedded directly in the offers a technological medium that fosters an active learning environment, captures students' attention, and engages learners differently than passive modes of learning (Mayer, 2021; van der Meij et al., 2021). It also allows learners to recall and practice important information immediately, rather than waiting for all of the videos to conclude. As a result, learners are presented with guided learning opportunities to think about the core concepts immediately, reflect on what they know, and then validate their accuracies or improve upon their mistakes (Cummins et al., 2016; Haagsman et al., 2020). The timing of the questions synchronized to the specific instructional topics afforded students the opportunities to recognize, reflect, and decipher what they know and what they don't know. As a result, students are apt to approach their weekly quizzes with greater readiness, given that the strategically positioned embedded video questions foster enhanced cognitive engagement, thanks to their intentional timing, placement, and deliberate use of low-stakes questioning (Christiansen et al., 2017; Deng & Gao, 2023). Thus, the results of the study are in line with those in the literature, that interactive low-stakes quizzing capacities through intentionally timed questions with video-based learning are an effective means to simulate the testing effect paradigm to foster retrieval practice over a period of time (Littrell-Baez et al., 2015; Richland et al., 2009).

Additionally, learners in the “Immediate Questioning" condition showed significantly higher participation rates and page views within the course (Table 3.2). Page views in the course were recorded at the individual student level as the total number of pages viewed by the learner which includes watching a video, rewatching a video, viewing an assignment, and accessing or downloading the course textbook. This means that students in the “Immediate Questioning" condition, on average, were more likely to watch the lecture videos, reassess the videos, and access a variety of course materials to further support their learning in preparation for the weekly quiz. In terms of participation rates, we see that learners in the “Immediate Questioning" condition participated more in the course when compared to their counterparts (Table 3.2).

Participation was recorded as the total number of events where a learner takes an action within the Canvas LMS course such as submitting assignments, watching videos, rewatching a video, downloading the course textbook, accessing additional course study materials, responding to questions in a discussion thread, and submitting quizzes. In particular, we noticed that learners who experienced “Immediate Questioning" were more likely to post their questions, thoughts, and confusion about the embedded video questions they came across. Furthermore, these students also tended to respond to other students in the course discussion posts engaging in discourse. Moreover, we see a general trend of students revisiting instructional videos based on page views Research on embedded video questions has also been shown to prompt positive behavioral learning changes during the student learning process such as rewinding, reviewing, or repeating course materials that were taught (Cummins et al., 2016; Haagsman et al., 2020; Rice et al., 2019; Wong et al., 2022). Collectively, these learning analytics data offer insights into the behavioral shifts observed in student interactivity within the course. This is attributed to the integration of questions directly within the video player, providing a glimpse into how students experienced heightened engagement indicated by increased page views and course participation.

Impacts on Student Learning Behaviors

In addition to learning analytics, we captured data on students' self-reported online engagement. Firstly, students in the "Immediate Questioning" condition experienced higher levels of self-reported engagement than their counterparts. These trends might be attributed to the anticipation of upcoming questions fostering a sense of attention, participation, and interaction. This heightened awareness can positively impact students' knowledge engagement, retrieval, and understanding, as students mentally prepare for the questions presented (Dunlosky et al., 2013; Schmitz, 2020). Moreover, the presence of questions directly embedded within the video encourages students to thoughtfully engage with the material they may not have fully comprehended initially, amplifying the benefits of the testing effect with repeated low-stakes testing in preparation for their weekly assessment (Kovacs, 2016; Richland et al., 2009). In this study, we manipulated the timing of when these questions appear based on the content of the lecture to encourage the saliency of the testing effect paradigm. Our intentions in pedagogical and learning experience design with embedded video were to utilize the synchronized timing of instructional content and the interactivity offered by the platform within an online course. This aimed to craft a learning experience that transitions learners from passive to active participants, while also offering opportunities to interact with lecture videos in a novel manner conducive to fostering deeper conceptual understanding. When corroborating the first and second MANOVA results together, we see that learners' in the "Immediate Questioning" not only showed significant differences in their participation and page views in the online course, but corroborating their self-report data also revealed that these learners also experienced significantly higher engagement than those in the "Delayed Questioning" condition. Thus, our study results aligned with previous research on the affordances of interactive learning activities grounded in the LXD paradigm while implementing "edtech tools" in promoting student engagement in online courses (Wong et al., 2022; Wong et al., 2024). We employed the same instructional videos from Wong and Hughes (2022), but our study was informed by the design constraints students identified regarding limited interactivity, practice opportunities, and guided learning in asynchronous settings. By integrating embedded video questions to address these concerns, we were able to refine their previous designs and offer students a more engaging and interactive learning experience. Further, the findings indicate that embedding questions directly within videos may serve as an effective strategy for enhancing learners' engagement and participation within the online course. Moreover, our results add to the literature by comparing both self-report data alongside behavioral course data as a proxy for engagement in online courses that shed light on the beneficial impacts of embedded video questions.

Secondly, the increase in self-regulation and critical thinking skills among learners who experienced questions immediately embedded directly in video signified the value of this pedagogical approach. The act of engaging with questions intentionally timed, interspersed, and aligned to the instructional content requires learners to monitor and regulate their cognitive processes, encouraging metacognitive awareness and self-regulated learning (Jain & Dowson, 2009; Wang et al., 2013a, 2013b). Similarly, the cognitive effort exerted to critically analyze, metacognitive reflect, and then concurrently respond to these questions immediately within the video fosters critical thinking skills, as learners might be compelled to evaluate and apply their understanding in real-time contexts. Through our intentional LXD, our hopes with aligning the

“Immediate Questioning” condition to facilitate a greater saliency of the testing effect model were to catalyze students' “thinking about their own thinking" through formative assessments and offer opportunities to further crystalize their conceptual understanding of the science concepts prior to taking their summative assessments (Richland & Simms, 2015). By repeatedly presenting opportunities for learners to metacognitively reflect, react, and regulate their learning, students are able to further make judgements to evaluate whether or not that truly understand the subject matter (Wang et al., 2017; Wong & Hughes 2022; Wong et al., 2022). This reflective process empowers students to gauge their own comprehension, identify areas that require further exploration, and actively manage their own learning progress.

Thirdly, the findings suggest that immediate questioning compared to delayed questioning can facilitate the development of higher-order cognitive skills such as critical thinking, with students in the “Immediate Questioning” conditions experiencing significantly higher critical thinking than their counterparts. Just as self-regulation is critical in actively managing their own learning progress, building students’ critical thinking skills are equally important. Within the context of questions immediately embedded within the video player, critical thinking can be evident through actions like exploring varied sources of representation (Richland & Simms, 2015), experiencing unsuccessful retrieval attempts (i.e. seeing failure as an opportunity to learn) (Richland et al., 2009), and utilizing this data to make inferences and reach deductions (Uzuntiryaki-Kondakci & Capa-Aydin, 2013). The timing of when students encounter these questions may influence the occurrence of critical thinking. For students who encountered questions immediately within the video, these questions prompted consideration of key concepts, assessed understanding, and required learners to make judgments by selecting the appropriate answers immediately (Jain & Dowson, 2009; Wang et al., 2013a, 2013b).

Conversely, their counterparts did not have this guided learning experience, where the questions were delayed and not directly synchronized with the instructional content provided opportunities for critical thinking. This necessitates learners to retain the information for a longer duration in their working memory, simultaneously mitigating distractions from mind-wandering, as learners await a delayed opportunity to actively retrieve and practice the information gleaned from the videos (Richland et al., 2099; Richland & Simms, 2015; Wong et al., 2023). Therefore, the findings suggest that promptly answering low-stakes questions, directly embedded within the video while simultaneously engaging with course content, may enhance learners' critical thinking and engagement with instructional content.

In order to build in more learning moments for students to engage in critical thinking, we intentionally curated the low stakes questions utilizing Bloom’s Taxonomy to guide our question development. Employing Bloom's Taxonomy as a foundation for shaping our question construction, this entailed that the lower-order questions were formulated to underscore the tasks of remembering, comprehending, and applying concepts in specific contexts (Bloom, 2001; Betts, 2008). Conversely, the higher-order questions were tailored to provoke the application and analysis of real-world scenarios in the field of ecology and evolutionary biology, requiring students to deconstruct relationships and evaluate patterns on the information presented (Bloom, 2001; Betts, 2008). In combination, these choices in question design provide students with the opportunity to engage in a critical evaluation of course concepts, prompting them to make inferences, inquire, and judge complex problems as they formulate their solutions. This high-order thinking approach has been found to nurture learners' critical thinking skills and enhance their ability to elaborate on ideas within the online learning environment (Richland & Simms, 2015; Tullis & Benjamin, 2011; Wang et al., 2013). When considering the timing of these low-stakes questions for students in the "Immediate Questioning" condition, we can strategically employ the impacts of higher-order thinking question design in conjunction with the testing effect paradigm at precise learning moments aligned with instructional content to emphasize students' critical thinking skills. In this way, the cultivation of critical thinking skills also holds the potential to bolster students' transferable skills that can be applied across various contexts (Fries et al., 2020), which is a crucial competency for undergraduate students in STEM disciplines (Wong et al., 2023).

Interplay Between Student Knowledge Outcomes and Learning Behaviors

The results of the multiple regression analysis provided valuable insights into the relationship between learners' quiz performance, the timing of questioning (immediate vs. delayed), and the accuracy of low-stakes questions. Consistent with our hypothesis of the testing effect paradigm, the main effect of condition emerged as a significant predictor of total weekly quiz scores. As such, participants in the "Immediate Questioning" condition outperformed those in the "Delayed" condition, indicating that immediate questioning positively influences subsequent quiz performance. This finding underscores the importance of the beneficial impacts and affordances embedded video question modality may have in enhancing student academic performance (Ge et al., 2022; Torres et al., 2022; van der Meij, & Böckmann, 2021). Furthermore, the accuracy of low-stakes questions also exerted a significant positive effect on total weekly quiz scores. This result highlights the role of low-stakes assessments while watching lecture videos in enhancing learner’s summative assessments later on (Casselman, 2021; Dimick Gray, 2020). As a result, learners who demonstrated higher accuracy in answering low-stakes questions tended to achieve higher scores on their weekly quizzes, suggesting a positive relationship between question accuracy and overall understanding of the material.

Interestingly, the interaction between conditions and low-stakes question accuracy yielded a significant effect on quiz grades, indicating that the impact of low-stakes question accuracy on quiz performance varied depending on the timing of questioning. Specifically, the effect of low-stakes question accuracy was more pronounced in the immediate questioning condition compared to the delayed condition. This suggests that the benefits of accurately answering low-stakes questioning may be amplified when answering questions immediately in the video player, aligning with Pan et al. (2020). This result highlights the advantage in the course design intention as those in the immediate conditions received their low-stakes questions synchronized to the instructional content, leading to enhanced retention and conceptual understanding (Deng & Gao, 2023; Fan et al., 2018). Where the results of this study differs from previous research is that we gave both conditions low-stakes questions, but manipulated the timing, rather than having a traditional control and treatment groups. This allowed us to test the difference of the timing of the low-stakes questions and how the placement of when students encounter low-sateks questions might yield enhanced performance. This suggests that the combination of timing of questioning and accuracy of low-stakes questions significantly contributes to explaining differences in quiz performance among learners. These findings have important implications for educational practice. Incorporating immediate questioning and promoting accuracy in low-stakes assessments can be effective strategies for improving student learning outcomes. Additionally, educators should consider the interplay between timing of questioning and question accuracy when designing instructional interventions aimed at enhancing learning and retention. To further explain the potential underlying mechanisms driving these effects, we evaluated students' self-reported learning behaviors in the online course.

The results of the second multiple regression model shed light on the complex interplay between timing of low-stakes questioning, individual differences in self-regulation and cognitive load, and their combined influence on learners' quiz performance. These findings contribute to our understanding of how various cognitive and metacognitive factors interact to shape learning outcomes in educational settings. Consistent with previous research, the main effect of timing of questioning emerged as a significant predictor of total quiz grades. Participants who experienced "Immediate Questioning" exhibited higher quiz performance compared to those in the "Delayed" condition. This finding aligns with literature emphasizing the importance of timely feedback and active engagement in promoting learning and retention. Moreover, the main effects of cognitive load and self-regulation were also significant predictors of quiz grades. Higher levels of self-regulation were associated with better quiz performance, highlighting the importance of metacognitive skills in academic achievement. Conversely, increased cognitive load was associated with lower quiz scores, indicating that excessive mental workload may impede learning and cognitive performance. These results are consistent with theories proposing that effective self-regulation and cognitive resources play crucial roles in learning processes.

Interestingly, the interaction effects between timing of questioning and individual differences in self-regulation and cognitive load were also significant. As such, this pattern begins to delve into the potential mechanism that self-regulation and cognitive load plays when considering the testing effect (Peng et al., 2019; Sotola & Crede, 2021). This suggests that the impact of timing of questioning (immediate vs. delayed) on quiz grades varies depending on learners' levels of self-regulation and cognitive load. Specifically, the positive effect of immediate questioning on quiz performance was more pronounced for learners with higher levels of self-regulation and lower cognitive load. In other words, higher self-regulation enhances the positive effect of immediate questioning, while lower cognitive load strengthens this effect. This underscores the importance of considering individual differences in cognitive and metacognitive factors when designing instructional interventions aimed at optimizing learning outcomes. The timing of the conceptually synchronized questions embedded directly into the video player can serve as a metacognitive reflective learning opportunity that empowers students to gauge their own comprehension, identify areas that require further exploration, and actively manage their own learning progress to improve their learning outcomes (Delen et al., 2014; Wang et al., 2013; Wong & Hughes, 2023). This in turn may reduce the cognitive load students are experiencing as the amount of information dealt with in the immediate moment is targeted and intentionally limited for students in the immediate condition. As one could imagine, the delayed condition would need to hold all of the information from the instructional unit in their working memory, rather than be scaffolded and guided by questions interspersed within the video. Moreover, one of the many benefits of the testing effect paradigm is acknowledging errors during low-stakes questions which can offer learners an opportunity to self-regulate by embracing mistakes, reassessing their initial understandings, and fostering conceptual comprehension (Richland et al., 2009; Iwamoto et al., 2017; Sotola & Crede, 2021).

It is noteworthy that mind-wandering did not emerge as a significant predictor in this analysis. While unexpected, we did find that mind-wandering was lower for those in the immediate condition and that engagement levels were higher. This aligns with Pan et al. (2020) where they found strong evidence on how pre-testing reduces mind-wandering and enhances learning outcomes for students learning through online modalities. However, further research exploring the relationship between mind-wandering and learning outcomes in educational contexts is warranted to provide a more comprehensive understanding of its role in academic achievement. Overall, the variables included in the model accounted for a significant portion of the variance in quiz grades, indicating that timing of questioning, self-regulation, and cognitive load collectively contribute to explaining differences in learners' performance. Nurturing students' ability in employing metacognitive learning techniques, like self-regulation and intentional designing course to reduce learners' cognitive load, holds the potential to enrich students' skills that can be applied not only within this course but also in various contexts like other courses taken, workforce training, and time management (Barak et al., 2016; Fisher & Baird, 2005; Fries et al., 2020). This is a critical proficiency that the questions embedded directly into the video player can help nurture (Delen et al., 2014; Moo & Bonde, 2016), especially for STEM undergraduates at research-intensive institutions (R1), as it links the course content with real-world applications to foster transferable skills. In essence, the result of the study highlights the interplay between the LXD, testing effect model, and the use of immediate questioning embedded directly in the video not only supports students' cognitive load, but also underscores the intricate relationship between engagement, self-regulation, and science knowledge outcomes. These findings underscore the importance of considering individual differences and instructional strategies in educational practice to enhance learning outcomes effectively.

Alignment with Learning Experience Design and Learning Theories

The positive outcomes of this study also resonate with the principles of Learning Experience Design. LXD emphasizes human-centered, experiential, and evidence-based design to create meaningful and effective learning encounters (Floor, 2018). The incorporation of embedded video questions exemplifies how LXD principles can be applied intentionally to empathize with learner's needs in online learning experiences (Wong & Hughes, 2023; Wong et al., 2023). By incorporating interactivity through embedded video questions, the video lessons promoted active learning, where learners' needs and behaviors in the course were considered. This design choice transformed passive video consumption into an interactive and participatory experience, aligning with LXD's focus on fostering engagement through experiential learning techniques (Floor, 2018). Additionally, the alignment of the study's findings with LXD underscores the value of interdisciplinary with the implementation of educational technologies at scale. To make this study possible, we worked alongside the university instructor, an instructional designer, and a researcher in order to consider the integration of instructional design, learning sciences, theories of learning, and user experience design (Weigel, 2015). In doing so, we were able to ensure that the course was properly aligned to the LXD paradigm, grounded in learning theories such as the testing effect and Bloom's Taxonomy, and deployed with an empathic lens to promote students' active learning behaviors in online learning settings. Thus, our efforts led to the implementation of a technology-enhanced online learning experience that effectively supported learners' quiz grades, engagement, self-regulation, and critical thinking.

Implications for Practice and Future Directions

The implications of this study for educators, instructional designers, and higher education administrators are significant. Firstly, the incorporation of immediate low-stakes questioning directly within video content offers a promising avenue for enriching online learning experiences rooted in the Learning Experience Design (LXD) paradigm and the testing effect model. Educators can integrate these strategies and technological modality into their course designs to foster active learning and deepen learners' engagement with course material. Instructional designers, drawing on LXD principles, can create meaningful learning experiences that incorporate evidence-based pedagogical strategies, such as embedding low-stakes questions within instructional content. Facilitating the testing effect with low-stakes questioning can extend beyond videos and be incorporated into readings, assignments, and course activities. Moreover, higher education administrators and institutions should recognize the importance of integrating technology in line with evidence-based pedagogies. While the rapid introduction of educational technology (edtech) tools during the COVID-19 pandemic facilitated emergency remote learning, our study underscores the necessity of aligning these tools with pedagogical frameworks to optimize their effectiveness. By investing in the development and implementation of technologies that promote active learning and enhance learners' engagement, self-regulation, and critical thinking, institutions can better equip students for success in online learning environments while capitalizing on existing edtech resources. An essential aspect of our study is to raise awareness about the range of tools already available to and supported by universities. Ensuring accessibility for instructors, designers, researchers, and students is imperative, enabling effective adoption of these tools while employing evidence-based strategies. We aspire for this study to serve as an example of how university investments in tools can positively impact students' learning experiences, encouraging others to adopt similar approaches as we continue to refine our support for students' needs.

Limitations

Further research is needed to thoroughly assess the long-term benefits of incorporating embedding low-stakes questions directly into videos in online undergraduate courses. During this study, participants in both groups were presented with low-stakes questions throughout the course. Students in the immediate condition encountering questions embedded within the video player experienced automatic triggering of questions, synchronized with instructional content. In contrast, those in the delayed condition faced identical questions after viewing all of the lecture videos in the instructional unit. While the timing of the questions served as a deliberate experimental manipulation between the two groups, determining whether the testing effect was more pronounced in either condition poses a limitation of the study. Despite high weekly quiz grades ranging from mid to upper 90% for both conditions, quiz scores were significantly higher for those who experienced questions directly embedded in the video. However, it's important to note that scores remained consistently high across both conditions, suggesting that the testing effect may manifest regardless of question timing or that the question difficulty may need to be adjusted. This highlights the need for further exploration of how the testing effect operates in various instructional courses, topics, and learning contexts. Future research could involve a quasi-experimental study comprising a traditional control group without questions and treatment conditions integrating embedded video questions, utilizing larger sample sizes across STEM courses could reveal the true advantages of the testing effect. Moreover, future research could consider controlling for additional learning analytics, such as video completion rates, assignment submission times, and accuracy of low-stakes questioning, as predictors for learners' course performance and learning outcomes. Understanding these dynamics can refine instructional strategies for optimizing learning outcomes in online education settings. We deliberately refrained from introducing additional learning opportunities between groups to ensure equal access to course content. Our aim was to evaluate the timing and integration of questions within or following video content, scrutinizing the effectiveness and benefits of implementing the embedded video questioning platform within the framework of LXD.

As a future direction, we plan to investigate the long-term impacts of embedded video questions on knowledge retention and transferable skills. Additionally, analyzing various question types, number, and difficulty, along with on-demand feedback and spacing intervals within videos, could inform optimal design choices for promoting knowledge outcomes and student learning behaviors. Enhancing the designs might include direct feedback for each of the low-stakes questions, adjusting the quantity of low-stakes questions learners encounter, and refining the difficulty level to better cater to individual learning needs. Further research is warranted to explore underlying mechanisms, optimal design, and factors influencing cognitive aspects such as affect, cognitive load, and mind-wandering. Structural equation modeling, pending sample sizes, could provide insights into intricate mechanisms exhibited by students. Lastly, exploring the scalability of this approach across different subject domains and learner populations could enhance understanding of its generalizability and benefits of operationalizing the testing effect through embedded video within the LXD paradigm.

Conclusion

The integration of low-stakes questioning embedded directly into the video player within an asynchronous online course grounded in the Learning Experience Design (LXD) paradigm showcased significantly positive effects on learners' engagement, self-regulation, and critical thinking compared to their counterparts. In addition, results showed that learners in the immediate condition had significantly higher quiz grades, pageviews, and course participation after 10 instructional weeks. Furthermore, findings also revealed that one potential mechanism underpinning learners’ increased quiz grades might be attributed to students’ levels of self-regulation when experiencing embedded video questions. As evidenced by students learning analytics and self-reported online engagement, learners are more actively involved in the learning process, with the timing of the embedded questions activating students' awareness to reflect on “what, how, and why” before critically deciding on answer choices to the conceptual questions. We suspect that learners might be experiencing more of the benefits of the testing effect given our LX design decisions, the placement of the questions given the timing of when these questions appeared, and how the questions were designed when deploying the low-stakes questioning. Thus, results suggest that the implementation of an LX-designed self-paced online course deployed with low-stakes questions directly embedded in video are efficacious for students' science learning outcomes and may have practical implications for the sustainability and rigor of undergraduate science distance learning. As a result, this study contributes to the growing body of literature on technology-enhanced pedagogical strategies for online learning and underscores the importance of aligning "edtech" tools with evidence-based frameworks. By fostering active learning through embedded low-stakes video questions, educators and instructional designers create online learning experiences that are more engaging, meaningful, and effective, ultimately enhancing students' academic outcomes and transferable skills in digital learning environments. As institutions continue to invest in educational technology, the collaborative integration of expertise from diverse fields will be pivotal in designing and implementing effective and engaging online learning environments.

Appendix

Table 3.1
Sociodemographic Characteristics of Participants

Variable	N	Percent (%)
Gender		
Female	116	30.952
Male	52	69.1
Ethnicity		
African American	2	1.19
Asian	121	72.0
Hispanic	42	46.7
Other	9	5.35
White	19	11.6
Conditions		
Immediate	91	50.2
Delayed	92	49.7
First Generation		
Yes	82	49.1
No	85	50.9

Note. Table 3.1 displays participant demographics, including gender, ethnicity, cohort, and first-generation status, presenting counts (N) and corresponding percentages for each category.

Table 3.2

Descriptive Statistics

	Page Views		Participation		Total Quiz Grades	
	Delayed	**Immediate**	**Delayed**	**Immediate**	**Delayed**	**Immediate**
Valid	92	91	92	91	92	91
Mean	788.138	971.738	46.607	88.380	94.943	98.426
Std. Deviation	276.168	381.170	3.745	16.686	2.701	1.531
Minimum	81.000	412.000	42.000	1.000	87.690	93.310
Maximum	1958.000	3260.000	66.000	127.000	100.000	100.000

Note. Descriptive of student analytics and quiz grades.

Table 3.3

Descriptive Statistics of Course Analytics

	Page Views		Participation		Low-stakes Accuracy		Quiz Accuracy	
	Delayed	Immediate	Delayed	Immediate	Delayed	Immediate	Delayed	Immediate
Valid	92	91	91	91	92	91	92	91
Mean	788.138	971.738	46.607	88.380	96.029	99.847	92.152	94.643
Std. Deviation	276.168	381.170	3.745	16.686	6.051	0.799	8.668	5.366
Minimum	81.000	412.000	42.000	1.000	66.452	94.770	62.357	77.400
Maximum	1958.000	3260.000	66.000	127.000	100.000	100.000	100.000	100.000

Note. Means descriptive table of page views, participation, low-stakes accuracy, and quiz accuracy.

Table 3.4

Weekly Descriptive Statistics of Students Quiz Grades and Low-stakes Accuracy

Average of Weekly Quiz Grades	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Delayed	95.6	96.8	97.6	91.9	91.9	93.35	96.8	95.6	96.6	93.2
Immediate	99.2	98.9	99.6	97.9	98.6	96.9	97.8	98.6	97.9	98.5

Average of Weekly Low-stakes Questioning Accuracy	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Delayed	97.8	88.3	93.8	90.7	91.8	92.4	93.8	95.2	92.5	88.0
Immediate	97.8	93.3	97.4	95.3	95.7	94.3	98.0	97.4	95.9	92.5

Note. Weekly average breakdown of student accuracy on low-stakes questions and summative quizzes by condition.

Table 3.5

Multivariate Analysis of Variance on Quiz Grades, Page Views, and Participation

MANOVA: Pillai Test

Cases	df	Approx. F	$Trace_{Pillai}$	Num df	Den df	p
(Intercept)	1	103225.163	1.000	3	147.000	< .001
Section	1	182.578	0.788	3	147.000	< .001
Residuals	149					

ANOVA

ANOVA: Overall Quiz Grades

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	$1.445 \times 10^{+6}$	1	$1.445 \times 10^{+6}$	310193.552	< .001
Section	70.600	1	70.600	15.159	< .001
Residuals	693.949	149	4.657		

ANOVA: Page Views

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	$1.226 \times 10^{+8}$	1	$1.226 \times 10^{+8}$	1350.412	< .001
Section	$2.027 \times 10^{+6}$	1	$2.027 \times 10^{+6}$	22.328	< .001
Residuals	$1.353 \times 10^{+7}$	149	90775.097		

ANOVA: Participation

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	709968.980	1	709968.980	5626.645	< .001
Section	69046.229	1	69046.229	547.205	< .001
Residuals	18800.790	149	126.180		

Note. The table presents the results of a MANOVA analysis comparing learners with and without embedded video questions on three dependent variables: quiz grades, pageviews, and course participation, indicating statistically significant differences between treatment conditions.

Table 3.6

Multivariate Analysis of Variance on Students' Self-reported Engagement, Cognitive Load, Mind-wandering, Self-regulation

MANOVA: Pillai Test

Cases	df	Approx. F	Trace$_{Pillai}$	Num df	Den df	p
(Intercept)	1	1543.279	0.963	3	179.000	< .001
Section	1	5.094	0.079	3	179.000	0.002
Residuals	181					

ANOVA

ANOVA: Engagement

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	349639.350	1	349639.350	4095.755	< .001
Section	634.355	1	634.355	7.431	0.007
Residuals	15451.295	181	85.366		

ANOVA: Cognitive Load

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	349639.350	1	349639.350	4095.755	< .001
Section	634.355	1	634.355	7.431	0.007
Residuals	15451.295	181	85.366		

ANOVA: Mind-wandering

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	96072.399	1	96072.399	2208.226	< .001
Section	293.907	1	293.907	6.755	0.010
Residuals	7874.694	181	43.507		

ANOVA: Self-regulation

Cases	Sum of Squares	df	Mean Square	F	p
(Intercept)	254240.661	1	254240.661	1578.669	< .001
Section	2310.754	1	2310.754	14.348	< .001
Residuals	29149.585	181	161.047		

Note. The table presents the results of a MANOVA analysis comparing learners with and without embedded video questions on three dependent variables: engagement, critical thinking, and self-regulation, indicating statistically significant differences between treatment conditions.

Table 3.7

Regression Interaction of Low-stakes Questions on Total Quiz Grades

Model		B	Standard Error	*ß*	**t**	**p**
H_1	(Intercept)	-6.218	5.424		-1.146	0.253
	Condition	110.961	9.469	2.858	11.718	< .001
	LowStakesQuestionAccuracy	0.853	0.032	0.807	26.587	< .001
	Condition * LowStakesQuestionAccuracy	0.780	0.066	2.890	11.814	< .001

Note. The regression table displays the coefficients, standard errors, standardized coefficients, and t-values for two models (H_0 and H_1) with multiple predictors, illustrating the relationships between the predictors and the dependent variable, total quiz scores.

Table 3.8

Regression Interaction of Student Learning Behaviors on Total Quiz Grades

Model		B	Standard Error	*ß*	t	p
H_1	(Intercept)	79.614	2.838		28.057	< .001
	Condition	19.381	4.715	1.146	4.110	< .001
	Mind-wandering	-.184	0.185	-.121	1.347	<.001
	Cognitive Load	.288	.153	.222	1.874	.043
	Self-regulation	.296	.163	.448	1.856	<.001
	Section ✻ Mind-wandering	.192	.234	.236	1.986	.055
	Section ✻ Cognitive Load	.362	.150	.564	1.509	.035
	Section ✻ Self-regulation	.238	.120	.608	1.986	<.001

Note. The regression table displays the coefficients, standard errors, standardized coefficients, and t-values for two models (H_0 and H_1) with multiple predictors, illustrating the relationships between the predictors and the dependent variable, total quiz scores.

Figure 3.1

Quasi-experimental research design.

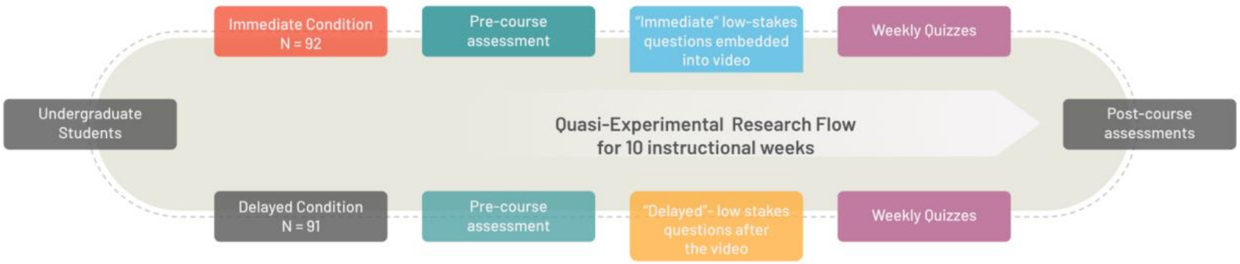
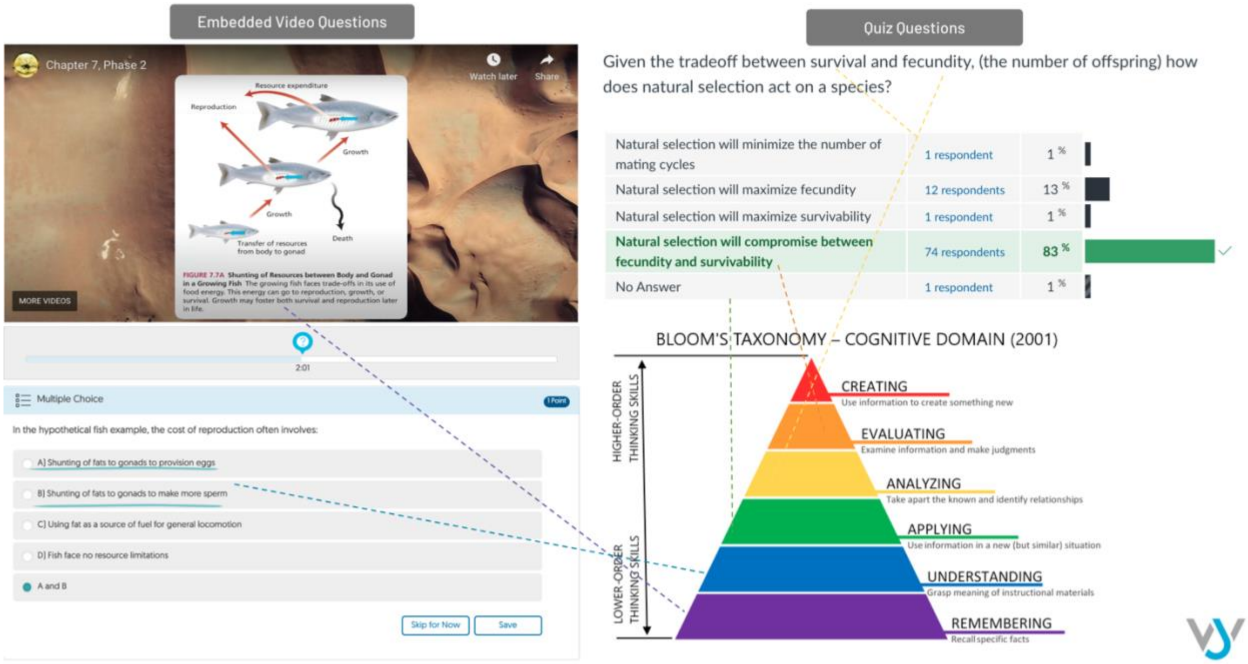


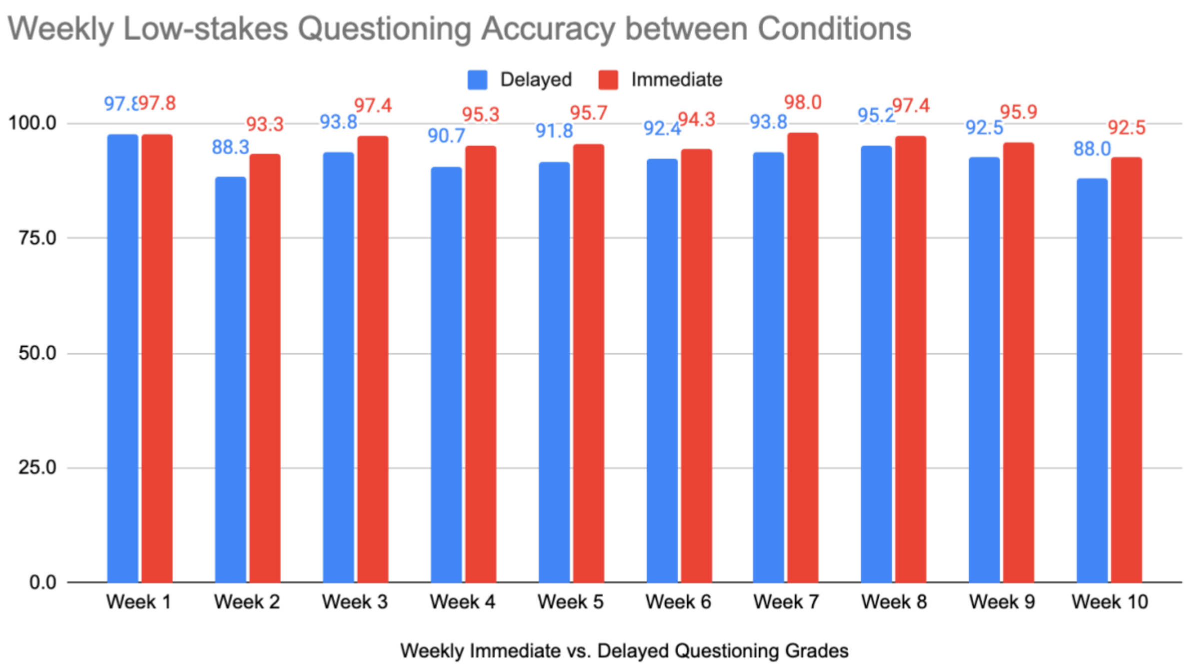
Figure 3.2

Embedded Video Question Platform



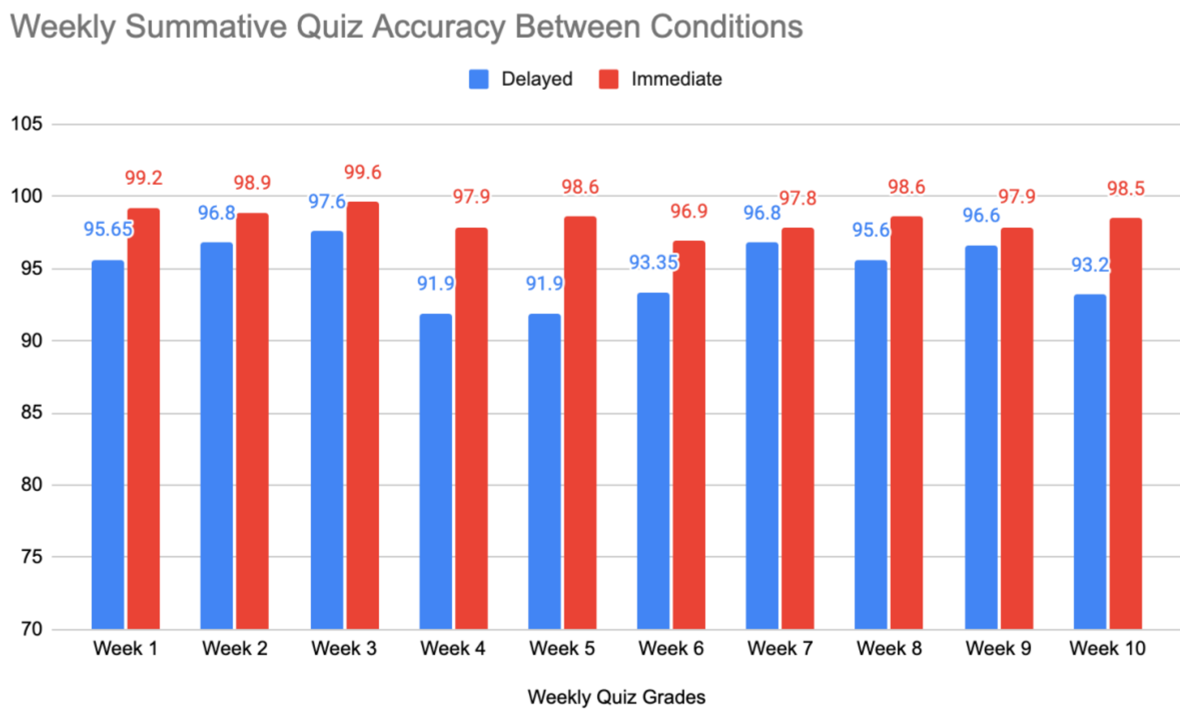
Note. This figure visually depicts the embedded video question interface alongside the Bloom's Taxonomy pyramid, illustrating the connection between the video questions and the quiz questions for the week, specifically emphasizing the testing effect.

Figure 3.3



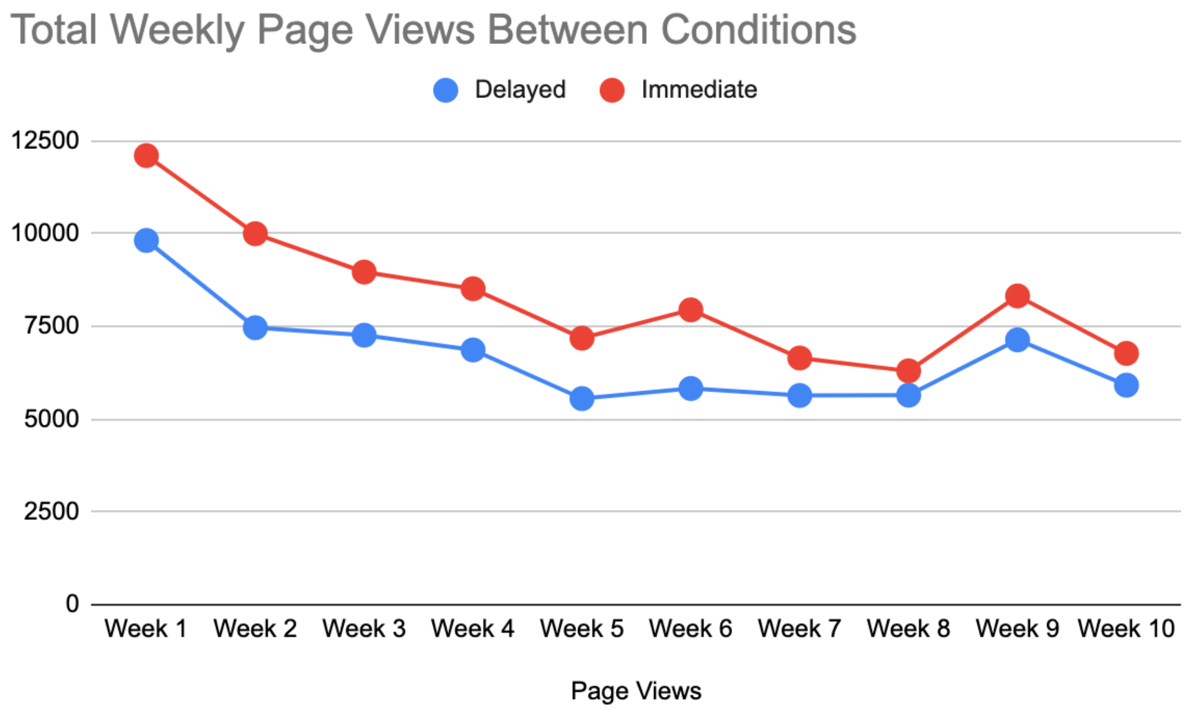
Note. Descriptive comparison of students' weekly low-stakes question accuracy by condition.

Figure 3.4



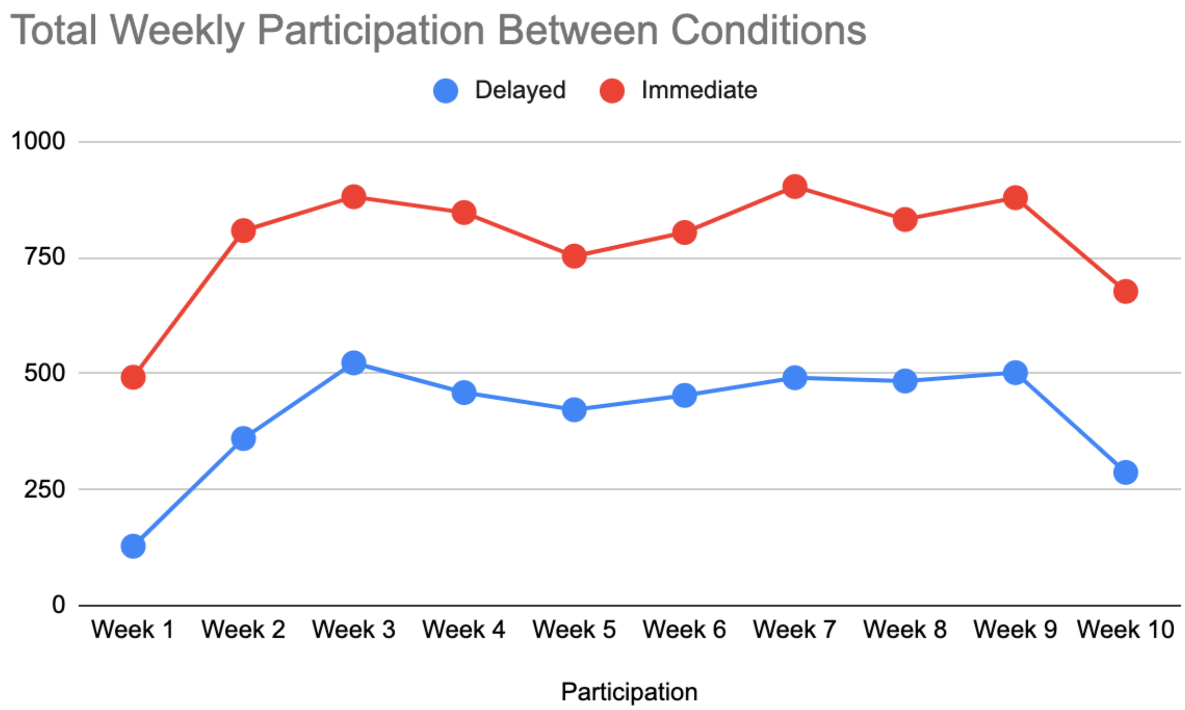
Note. Descriptive comparison of students' weekly summative quiz by condition.

Figure 3.5



Note. This figure presents the frequency of page views throughout the 10-week course.

Figure 3.6



Note. This figure presents the frequency of participation throughout the 10-week course.

General Discussion

My dissertation aimed to explore how students' social, cognitive, and behavioral factors impact their distance learning experiences during and after the pandemic. It investigated social cognitive learning theories (Bandura 1986, 1977) influencing learners' engagement in distance learning and proposed strategies based on Learning Experience Design (Floor, 2018) to create effective online courses informed by these insights. To this end, I initially examined undergraduates' synchronous learning via Zoom to establish a model of factors influencing engagement in Chapter 1. Then, in Chapters 2 and 3, I used design-based research to develop an asynchronous online course aligned with the learning experience design framework, specifically tailored for upper-division biological sciences undergraduates during the pandemic. Chapter 2 evaluated the social, cognitive, and behavioral impacts on students resulting from our course designs informed by Chapter 1. Lastly, Chapter 3 details the iterative improvements based on student feedback from Chapter 2, such as incorporating embedded video questions to enhance digital learning interactions and stimulate cognitive processes like the testing effect.

In Chapter 1, I delved into the dynamics of undergraduates' synchronous learning via Zoom, focusing on the social, cognitive, and behavioral factors influencing their engagement. Mind-wandering, considered as a lapse in attention during learning, was a key aspect of this investigation (Desideri et al., 2019;McVay & Kane, 2012; Smallwood, 2013). Factors such as anxieties, task-value, and self-efficacy were identified as sources of mind-wandering, all of which impacted students' engagement levels (Hartanto & Yang, 2020; Son et al., 2020). By simultaneously measuring these characteristics in the evolving context of Zoom-based online learning, I aimed to provide insights into how students' social environment and learning behaviors intersect to shape their learning experiences during the pandemic. To this end, Chapter 1 of the dissertation introduced a structural equation model (SEM) rooted in social cognitive learning theories, aiming to explore how students' self-efficacy, task-value, and trait anxiety influence mind-wandering and subsequently impact engagement during synchronous Zoom learning sessions. The transition to emergency remote distance learning via Zoom, driven by the COVID-19 pandemic, presented both opportunities and challenges (Hodges, 2020; Son et al., 2020). While it provided flexibility and continuity, it also brought forth issues such as unfamiliarity, lack of confidence, anxiety, and distractions for both instructors and students (Mesghina et al., 2022; Wong et al., 2023). Through analysis within this unique context, robust evidence was uncovered supporting the mediation of engagement by mind-wandering frequency during synchronous Zoom lectures. Additionally, sources of mind-wandering, particularly students' self-efficacy and trait anxiety, emerged as significant predictors within the online course environment. Individuals with higher levels of self-efficacy and lower levels of trait anxiety were observed to experience less mind-wandering and demonstrate greater engagement in online courses (McVay & Kane, 2010; Bandura, 2000). Interestingly, the anticipated impact of task-value on the frequency of mind-wandering was found to be insignificant (Artino Jr & McCoach, 2008), suggesting that factors beyond perceived importance may play a greater role in influencing students' cognitive engagement during online learning. This underscores the significance of self-efficacy and trait anxiety in shaping mind-wandering (i.e. cognitive focus) and engagement levels in the online learning environment. Unlike previous studies conducted in traditional classroom settings, this research evaluated these relationships within the online learning landscape prompted by the pandemic. The intricate interplay of students' social environments and motivations influencing their behavioral outcomes offered valuable insights into designing courses that instructors, designers, and educators can utilize to enhance student engagement. Overall, this study contributes to understanding the social, cognitive, and behavioral impacts of synchronous Zoom learning, offering strategies to mitigate mind-wandering and enhance engagement in online courses. Furthermore this model emphasizes the necessity for further exploration in designing online courses focused on reducing mind-wandering and maximizing student engagement.

In response to the mechanism evaluated from Chapter 1 and the recommendations for online course design explicated, Chapter 2 involved the creation of an online asynchronous undergraduate biology course informed by the social, cognitive, and learning behavioral patterns uncovered from Study 1. Recognizing the significant impact of students' self-efficacy and task-value on learner engagement in synchronous online learning, I re-evaluated these constructs while incorporating various technological affordances offered by asynchronous learning modalities. Employing an in situ design-based research (DBR) approach, Study 2 investigated two upper-division biology courses on the implementation of the LXD paradigm, incorporating asynchronous 4K videos, interactive course dashboards, and enhanced user experience design. Drawing on learning theories such as Brown et al.'s (2001) Situated Cognition Theory and Mayer's (2019) multimedia video principles, I implemented these design practices to ensure the quality of instructional and pedagogical design for effective online learning experiences. This course design operationalized SCT by incorporating practical elements such as modeling, coaching, scaffolding, articulation, reflection, and exploration (Collins et al., 1991). Specifically, the 80-minute lessons were segmented into smaller, three to five-minute scaffolded video phases instead of a continuous stream, aiming to reduce fatigue, cognitive load, and instances of student mind-wandering (Mayer, 2019). These video segments were designed to pre-train students to general concepts and terminologies using scientific visuals and simplified explanations to facilitate temporal contiguity before proceeding to more in-depth study with a textbook reader.

To accommodate for the accessibility of navigating the abundance of course videos, course dashboards were created as a one-stop-shop where students every week would be able to access all of their course materials for that instructional unit from one centralized location. Furthermore, the affordances of asynchronous self-paced videos enabled students to pause, play, rewind, speed up, and enable closed captioning to enhance their learning experiences based on their own personal learning preferences. Through these design enhancements, a significant relationship emerged between motivational factors (self-efficacy, task-value) and cognitive factors (self-regulation), indicating their collective impact on students' course engagement, usage of elaboration, and critical thinking skills. In our analysis, self-efficacy, task-value, and self-regulation collectively accounted for 31% of the variance in engagement, 47% in critical thinking skills, and 57% in the usage of elaboration. Particularly noteworthy was the significant contribution of task-value beliefs to each model, surpassing that of self-efficacy and self-regulation. While task-value did not directly predict learners' mind-wandering in Study 1, compelling evidence emerged for its significant association with online engagement. This underscores the importance of students perceiving tasks and activities as meaningful and valuable, which in turn drives active participation in the online learning environment. This trend aligns with our findings in Study 2, reaffirming the crucial role of task-value in shaping students' online learning behaviors, including engagement, critical thinking, and elaboration.

Task-value, as defined in our study, refers to students' perception of the importance and relevance of tasks and activities presented in online courses (Artino & McCoach, 2008; Eccles & Wigfield (2002). Our findings underscore its significance in motivating students to actively engage with course content and apply critical thinking skills, emphasizing the importance of intentionally designing online courses to emphasize the importance and relevance of course content and activities (Hodges et al., 2020; Son et al., 2020). This intentional approach promotes deeper engagement and ultimately leads to improved learning outcomes in the online learning environment. Moreover, our research underscores the potential of asynchronous learning modalities to accommodate diverse learning preferences and promote self-directed learning. The segmented video phases, interactive dashboards, and customizable video functionalities empower students to engage with course content at their own pace and according to their individual learning styles, reducing cognitive load and mind-wandering (Meyer, 2019; Wong & Hughes, 2023) while fostering a sense of agency and ownership over the learning process. Ultimately, our study offers actionable insights for educators seeking to optimize online learning experiences and improve student outcomes by prioritizing task-value, leveraging instructional design principles grounded in learning theories, and harnessing the affordances of technology to foster a culture of active engagement, critical inquiry, and deep learning in asynchronous online courses, thereby laying the foundation for students in developing successful academic learning outcomes.

In study 3, we conducted a replication of Study 2, iterating on the design limitations and constraints documented from student qualitative feedback to examine the effects of our LXD on student learning knowledge outcomes. Through the qualitative analysis, students documented the lack of active learning opportunities typically afforded through an in-person classroom lecture, mentioning how they wanted more opportunities to interact and engage with the course materials while watching the video scaffolds. Drawing on the cognitive theories for multimedia learning (Mayer, 2019, 2021), I compared the use of embedded video questions as a modality to facilitate opportunities for digital learning interactions with the video in order to foster greater instances of the cognitive process of the testing effect. That is, the phenomenon in which attempting or even failing to reproduce the correct answer through low stakes testing during a learning event improves students' learning outcomes (Carpenter, 2009; Roediger III & Karpicke, 2006). As such, I conducted a quasi-experimental design-based research study over a period of 10 weeks, during which half of the students encountered questions immediately embedded within the video player, while the remaining half received the same questions after viewing all the instructional videos within the unit, prompting delayed questioning. Consequently, this study experimentally manipulated the timing of the questions across the two class conditions. These questions functioned as opportunities for low-stakes content practice and retention, designed to encourage learners to experience testing effect and augment the formation of their conceptual understanding.

In this Study 3, I examined the impact of embedded video questions on various aspects of student performance and engagement. We analyzed differences in total weekly quiz grades, page views, and course participation across both conditions. Additionally, we assessed self-reported engagement, self-regulation, and critical thinking. Our findings revealed that students exposed to immediate questioning demonstrated significantly higher quiz scores, increased page views, and greater participation in the course. Moreover, they exhibited heightened levels of online engagement, self-regulation, and critical thinking. Furthermore, our analysis delved into the complex relationship between treatment conditions, low-stakes question accuracy, self-regulation, critical thinking, and quiz grades. We found strong evidence indicating that the interaction between immediate questioning and self-regulation significantly influenced quiz grades. Additionally, there was a notable strengthening of the relationship between low-stakes question accuracy and total quiz accuracy for students in the immediate questioning condition. This suggests that students who scored higher on low-stakes questions tended to perform better on weekly summative quizzes compared to their counterparts. By maintaining consistency in instructional materials, instructor, and assignment deadlines across conditions, we isolated the effects of question timing implementing embedded video questions through the LXD paradigm. This allowed us to observe how students differed in their learning behaviors, including engagement, mind-wandering, self-regulation, and knowledge outcomes. Importantly, accurate performance on lower-order thinking questions in Bloom's taxonomy was associated with better performance on higher-order thinking questions, along with increased engagement, self-regulation, and critical thinking, and reduced mind-wandering. These findings underscore the multifaceted impact of embedded video questioning on learning behaviors and outcomes. The implications of our findings extend beyond mere performance metrics, delving into the broader landscape of educational psychology and instructional design. By leveraging immediate questioning within the context of embedded video content, we not only observed tangible improvements in quiz scores, page views, and course participation but also uncovered deeper insights into students' cognitive engagement and metacognitive processes. The significant interaction between immediate questioning and self-regulation underscores the importance of individual differences in learning approaches and highlights the potential for tailored interventions to enhance learning outcomes. Moreover, the heightened relationship between low-stakes question accuracy and overall quiz performance within the immediate questioning condition emphasizes the nuanced dynamics at play, wherein active retrieval and comprehension of foundational concepts catalyze higher-order cognitive processes (Littrell-Baez et al., 2015; Karpicke & Blunt, 2011; Schmitz, 2020). This not only elucidates the efficacy of incorporating spaced retrieval practice but also underscores the role of technology-enhanced learning environments in facilitating deeper engagement and critical thinking skills development

(Adesope et al., 2017). Ultimately, our study underscores the multifaceted impact of embedded video questioning on learning behaviors, paving the way for more targeted instructional strategies that leverage cognitive science principles to optimize educational outcomes in diverse learning contexts.

Overall, students' social, cognitive, and behavioral impacts significantly influence their online learning experiences, as demonstrated by the SEM model in Chapter 1 focusing on synchronous online Zoom learning, and the redesign of an asynchronous online course in Chapters 2 and 3. This dissertation extends the scope of Social Cognitive Learning Theory beyond traditional classroom settings, integrating it as a foundational framework with specific measurable variables to comprehend and address the complexities of student engagement in distance learning environments. Rooted in Bandura's Social Cognitive Theory of reciprocal determinism (Bandura, 1977; 1989), the research examines how individuals' social interactions, cognitive processes, and behavioral patterns mutually influence each other within the unique context of pandemic teaching and learning (Schunk, 2012). The COVID-19 pandemic prompted a rapid transition in course delivery methods, with in-person instruction suspended due to nationwide social distancing mandates (Agarwal & Kaushik, 2020; Ferrel & Ryan, 2020). With approximately 11.8 million (75%) undergraduate students enrolled in at least one distance learning course and 7.0 million (44%) exclusively participating in distance education courses in the U.S. (National Center for Education Statistics [NCES], 2022), educational institutions, including higher education, swiftly adopted internet-mediated educational technology platforms to facilitate teaching and learning (Asad et al., 2020; Chick et al., 2020; Sandars et al., 2020). Given the large dependence between learners' attention and academic achievement (Kane et al., 2017; Wammes et al., 2019; Wammes & Smilek, 2017), it has been increasingly important to identify ways in which learners' attentional engagement might be sustained, free from distractions that may hinder the learning experience.

As such, Chapter 1 applies Social Cognitive Learning Theory to analyze students' engagement during synchronous Zoom sessions, considering factors such as self-efficacy, task-value, and trait anxiety as key determinants of cognitive focus and engagement levels. By drawing on this theoretical lens, the study elucidates the mechanisms through which students' beliefs in their own capabilities (self-efficacy), perceived importance of tasks (task-value), attention in the moment (mind-wandering, and emotional responses (trait anxiety) impact their engagement behaviors. In Chapter 2, the development of an asynchronous online course is guided by Social Cognitive Learning Theory principles, integrating elements such as modeling, coaching, and scaffolding to facilitate learning experiences that align with students' cognitive and motivational processes. Furthermore, the incorporation of multimedia design principles grounded in Social Cognitive Learning Theory, as evidenced in Chapter 3 through the implementation of embedded video questions, aimed to promote active learning and cognitive engagement by providing opportunities for self-regulation and metacognitive reflection.

By applying Social Cognitive Learning Theory across all phases of the research, my dissertation not only advances our understanding of the social, cognitive, and behavioral factors influencing student engagement in distance learning but also offers practical insights into designing effective online courses that foster meaningful learning experiences aligned with Social Cognitive Learning theories and Learning Experience Design principles. The implication here is profound, as it sheds light on the transformative potential of intentional online course design informed by cognitive and learning theories. By synthesizing insights from Chapter 1 with the practical implementation of the LXD paradigm in Chapters 2 and 3, we've demonstrated how strategic integration of technology and pedagogy can enhance student engagement, self-regulation, critical thinking, mind-wandering, and even knowledge outcomes in distance learning environments. The emphasis on self-efficacy, task-value, and self-regulation as pivotal motivational and cognitive factors underscores the importance of addressing both intrinsic and extrinsic motivators in course design. While Chapter 1 did not show show a significant relationship between task-value and mind-wandering, notably in Chapter 2, our findings highlighted the outsized influence of task-value beliefs in driving student engagement and learning behaviors, emphasizing the need for educators to cultivate a sense of purpose and relevance in course materials and activities.

Moreover, in Chapter 3, we provide evidence demonstrating how the manipulation of embedded video questions and their timing – whether they appear immediately within the video or after watching the entire instructional unit– reduces instances of mind-wandering and fosters higher levels of engagement. Finally, we document the saliency of the testing effect as a potential mechanism where low stakes testing while learning leads to greater accuracy in higher-stakes examination. The testing effect, a well-established phenomenon in cognitive psychology, suggests that actively retrieving information through testing or quizzing enhances long-term retention and improves subsequent recall of that information during later assessments (Carpenter, 2009; Littrell-Baez et al., 2015; Richland et al., 2009). This effect is rooted in the concept of retrieval practice, wherein the act of recalling information from memory strengthens memory traces, making it easier to recall the information in the future. By incorporating low-stakes testing within the instructional materials, such as the embedded video questions in our study, students engage in repeated retrieval attempts, reinforcing their learning and improving their ability to recall the material accurately. Thus, across all three studies, we document how when technology is intentionally designed with evidenced-based learning theories and pedagogical practices, students' social (self-efficacy, task-value), cognitive (self-regulation, trait-anxiety, mind-wandering), and behavioral (engagement, critical thinking, knowledge outcomes) factors can greatly enhanced.

Overall, the current studies support the notion that social cognitive learning theory aligns with the amalgamation of learning experience design for deploying asynchronous online courses, but also emphasize the importance of considering the specific nuances and contexts of distance learning environments. By integrating social cognitive learning theory principles into the design and implementation of online courses, educators can create learning experiences that not only address the immediate challenges posed by the transition to online learning but also promote deeper engagement, critical thinking, and knowledge acquisition among students. The findings underscore the need for a holistic approach to course design that accounts for both the social and cognitive dimensions of learning, as well as the interplay between individual learner characteristics and instructional strategies. Furthermore, the documented effectiveness of interventions such as embedded video questions highlights the potential of technology-enhanced learning environments to support and enhance traditional pedagogical practices. Moving forward, ongoing research in this domain can deepen our comprehension of how to effectively utilize technology, learning theories, and LXD to optimize students' social, cognitive, and behavioral outcomes across various educational settings at scale, including online, in-person, and hybrid environments.

Limitations

While the research presented in this dissertation offers valuable insights into the dynamics of student engagement and learning experiences in online environments, it is essential to acknowledge certain limitations that may impact the generalizability and interpretation of the findings. One of the key limitations for Chapter 1 when conducting the SEM model was that data was collected in three waves. Since the survey questionnaires were deployed and collected in three different waves, there is a possibility that research participants may differ between groups due to the time variance of survey assessment. This was not accounted for in the published analysis for Chapter 1, which may constitute bias in the study results. However, one of the primary goals of this study was to test a hypothesized model for factors influencing students' online engagement and the role of mind-wandering during the entire year long period higher education institutions were in remote instruction to provide generalizable findings. Future analysis will include nested model comparisons in SPSS AMOS. Conducting a multiple group analysis in structural equation modeling will afford the comparison of the same measurements between multiple population samples collected at different points in time (Deng & Yuan, 2015). This method will then allow the researchers to test the assumptions of whether the groups examined are equal by examining if the different sets of path coefficients are invariant (Loehlin, 2004). Alternatively, we might also consider using fixed-effects modeling to test the relationship between the predictor and outcome variables varying over time. Controlling for the time-invariant characteristics affords researchers to test the net effect of the predicted outcome variables, as the assumption that time may be a biasing factor may be accounted for (Torres-Reyna, 2007).

In Chapter 2, one of the primary constraints of this design-based research was the lack of an equivalent comparison group to test the efficacy of our course designs' impact on student learning experiences. Despite this limitation, our study involved a collaborative effort between the instructor, designer, and researcher to redesign the upper-division ecology and evolutionary biology course, ensuring an equitable experience for all students amid the challenges of pandemic teaching and learning. This marked the initial phase of a multi-year implementation project grounded in LX design principles. To identify whether our new course designs are more effective, it will be essential to incorporate experimental manipulations of LXD-based courses to validate and scale the effectiveness of asynchronous online learning environments. Secondly, the reliance on self-report measures for assessing constructs such as self-efficacy, task-value, and trait anxiety may introduce biases or inaccuracies in the data due to issues such as social desirability or response bias. While efforts were made to mitigate these concerns through the use of validated scales and anonymous survey protocols, future studies could benefit from employing objective measures or complementary methodologies to corroborate self-reported data. However, this is where the qualitative feedback and the deductive thematic analysis afforded clear explanations on "how and why" students felt positively or negatively about the new course designs. This proved to be extremely useful when considering the design iterations implemented and retested in Chapter 3. Additionally, while our study relied on self-reported measures, leveraging learning analytics data from platforms like Canvas LMS in subsequent studies will provide objective insights into student interactions and behaviors. Furthermore, future research endeavors should integrate objective measures of student engagement and learning outcomes, such as performance on quizzes, exams, or assignments, to offer a more comprehensive evaluation of course effectiveness. Moving forward, Chapter 3 builds upon the insights gained from Chapter 2 to refine our approach and better address students' learning outcomes.

In Chapter 3, a significant limitation of the study lies in the inability to thoroughly evaluate the long-term benefits of integrating embedded video questions into online undergraduate courses. Although the intervention spanned 10 instructional weeks, covering the duration of one academic term, the study did not extend its assessment beyond this specific course to evaluate how these learning behaviors might transfer to other courses or impact students' overall retrieval skills. Future research endeavors employing experimental designs or longitudinal assessments could offer more robust evidence regarding the causal relationships and underlying mechanisms of student engagement in online learning environments. During the study, participants in both groups encountered questions throughout the course. Students who experienced questions embedded within the video player were automatically prompted with low-stakes questions synchronized with instructional content. Conversely, those in the alternative condition faced identical low-stakes questions after viewing all lecture videos in the instructional unit. While the deliberate manipulation of question timing served as a key experimental variable, determining whether the testing effect differed significantly between the two conditions poses a limitation. Despite consistently high weekly quiz grades ranging from mid to upper 90% for both groups, quiz scores were notably higher for students who encountered questions directly embedded in the video. However, it's crucial to acknowledge that scores remained consistently high across both conditions, suggesting that the testing effect may manifest regardless of question timing or indicating a potential need for adjusting question difficulty. This underscores the necessity for further exploration of how the testing effect operates within various instructional contexts. Furthermore, one aspect that warrants investigation in future research is controlling for individual differences in the timing of task completion. While efforts were made to regulate the release of weekly videos and establish deadlines for completing low-stakes questions and quizzes, the study did not assess or control for variations in the time duration between when students completed low-stakes questions and when they took their weekly quizzes. Consequently, some students may have completed both tasks immediately in sequence, while others may have allowed for additional time between completing low-stakes questions and taking the quiz, potentially influencing practice, consolidation, or delayed retrieval processes. These ecological factors, which reflect students' day to day learning habits, were not specifically controlled in this study. Consequently, the data from this study provided ecologically valid results that accurately represent the heterogeneous nature of students' behaviors in an asynchronous online course. Similarly, a synchronous online course may run into challenges regarding maintaining consistent engagement, accommodating diverse learning behaviors, and ensuring that all students can participate equally despite potential differences in time zones and personal commitments. Addressing these aspects of ecological validity with greater experimental control over the time allocated for low-stakes questioning, the time interval between low-stakes questions and weekly quizzes, and the number of practice attempts could provide valuable insights into how timing impacts the efficacy of learning interventions in online courses.

Conclusion

Throughout the process of my dissertation, I have attempted to explain undergraduate student learning experience through the *framing* of social cognitive learning theories and learning experience design, and educational technologies As such, Chapter 1 applies Social Cognitive Learning Theory to analyze students' engagement during synchronous Zoom sessions, considering factors such as self-efficacy, task-value, and trait anxiety as key determinants of cognitive focus and engagement levels. By drawing on this theoretical lens, the study elucidates the mechanisms through which students' beliefs in their own capabilities (self-efficacy), perceived importance of tasks (task-value), attention in the moment (mind-wandering), and emotional responses (trait anxiety) impact their engagement behaviors. In Chapter 2, the development of an asynchronous online course is guided by Social Cognitive Learning Theory principles, integrating elements such as modeling, coaching, and scaffolding to facilitate learning experiences that align with students' cognitive and motivational processes. Furthermore, the incorporation of multimedia design principles grounded in Social Cognitive Learning Theory, as evidenced in Chapter 3 through the implementation of embedded video questions, aimed to promote active learning and cognitive engagement by providing opportunities for self-regulation and metacognitive reflection. By applying Social Cognitive Learning Theory across all phases of the research, my dissertation not only advances our understanding of the social, cognitive, and behavioral factors influencing student engagement in distance learning but also offers practical insights into designing effective online courses that foster meaningful learning experiences aligned with Social Cognitive Learning theories and Learning Experience Design principles. The implication here is profound, as it sheds light on the transformative potential of intentional online course design informed by cognitive and learning theories. By synthesizing insights from Chapter 1 with the practical implementation of the LXD paradigm in Chapters 2 and 3, we've demonstrated how strategic integration of technology and pedagogy can enhance student engagement, self-regulation, critical thinking, mind-wandering, and even knowledge outcomes in distance learning environments. The emphasis on self-efficacy, task-value, and self-regulation as pivotal motivational and cognitive factors underscores the importance of addressing both intrinsic and extrinsic motivators in course design. While Chapter 1 did not show a significant relationship between task-value and mind-wandering, notably in Chapter 2, our findings highlighted the outsized influence of task-value beliefs in driving student engagement and learning behaviors, emphasizing the need for educators to cultivate a sense of purpose and relevance in course materials and activities. Moreover, in Chapter 3, we provide evidence demonstrating how the manipulation of embedded video questions and their timing – whether they appear immediately within the video or after watching the entire instructional unit – reduces instances of mind-wandering and fosters higher levels of engagement. Finally, we document the saliency of the testing effect as a potential mechanism in which low-stakes testing while learning leads to greater accuracy in higher-stakes examination (Carpenter, 2009; Littrell-Baez et al., 2015; Richland et al., 2009). This aligns with broader educational psychology literature, affirming the importance of fostering students' perceptions of meaningfulness and value in their learning experiences. Through this comprehensive exploration in my dissertation, the integration of Social Cognitive Learning Theory and Learning Experience Design emerges as a powerful framework for creating effective and engaging distance learning environments, with implications for pedagogical practice, deploying evidence-based “edtech tools,” and future research for educational implementation at scale.

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