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LEVERAGING VIRTUAL REALITY TO PROMOTE TRANSFORMATIVE EXPERIENCE: INVESTIGATING THE ROLE OF PRESENCE AND AGENCY

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Abstract

This study investigates the role of immersive virtual reality (IVR) in facilitating Transformative Experiences (TE) and enhancing everyday engagement with learning. Using the Teaching for Transformative Experiences in Science (TTES) model, this research integrates IVR's unique affordances—presence and agency—to examine how immersive learning environments can bridge classroom concepts and real-world applications. A convergent parallel mixed methods design was employed, involving both quantitative and qualitative analyses, to capture the nuanced impacts of IVR-supported instruction on TE. Findings reveal that IVR can deepen students' engagement by fostering a stronger sense of presence, contributing to meaningful and lasting changes in students' perspectives and interest in content beyond traditional educational settings. This research contributes significantly to both TE theory and the growing field of immersive learning, providing evidence-based insights that inform future instructional designs aimed at maximizing engagement, equity, and ecological validity in learning environments. Practical implications suggest that IVR, when integrated thoughtfully into instructional practices, can catalyze enduring interest and active engagement across a variety of educational contexts.

Keywords: immersive virtual reality, transformative experience, presence, agency, teaching for transformative experiences, mixed methods

Chapter 1: Introduction

Background of the study

Preparing learners with transferable skills for real-world applications presents a complex challenge due to the unpredictable nature of these experiences and the difficulty in capturing spontaneous moments (Tippett & Lee, 2019). Developing skills that students can apply in real-life situations requires opportunities for them to engage in experiences resonant with authentic, everyday contexts. Such engagement can lead to meaningful changes in their daily lives (Dewey, 1938; Kivinen & Ristela, 2003; Williams, 2017). Transformative Experience (TE) has been proposed as an integrative construct—comprising motivated use, expansion of perception, and experiential value—to enrich and expand complex everyday experiences. TE aims to transform students' daily experiences by motivating them to apply curricular concepts outside of the classroom while remaining precise enough for empirical study (Pugh, 2011, 2020).

Research has demonstrated that engaging with TE fosters deep learning (Pugh et al., 2017), increases interest (Heddy & Sinatra, 2017), elicits positive affect (Heddy et al., 2017), and promotes conceptual change (Heddy & Sinatra, 2013). The concept of TE stands apart from other forms of engagement due to its extension beyond the classroom boundaries (Pugh et al., 2017, p. 3). However, TE engagement does not typically occur naturally; it must be facilitated intentionally to make students aware and engaged (Pugh, 2011).

Various approaches can facilitate Transformative Experience (TE), with one notable model being the Teaching for Transformative Experiences in Science (TTES), specifically designed to foster TEs as an instructional method (e.g., Pugh et al., 2017; Pugh, 2020). Although initially developed for science learning, TTES has effectively increased engagement and interest across fields such as biology, psychology, social studies, and college-level engineering (e.g., Heddy & Sinatra, 2013; Heddy et al., 2023; Pugh, 2002, 2004; Pugh et al., 2010). However, challenges persist in developing and implementing methods to foster TEs, including shallow-level strategy application and disconnects from broader pedagogical activities (Pugh et al., 2017). Due to the unpredictable nature of TEs, effective implementation requires adaptable and flexible teaching approaches (Pugh et al., 2017).

These challenges, along with others inherent in fostering TEs in class, can limit students' meaningful engagement with content and affect learning. Recent studies increasingly address these challenges, examining TEs both within and beyond the classroom, though findings are sometimes mixed (Cropp, 2019; Heddy & Sinatra, 2017; Pugh, 2011, 2020). For instance, Pugh (2011) documented two years of design-based research where a cooperating teacher implemented TTES strategies with enthusiasm; however, results showed minimal impact on fostering TEs during the first year. Other recent studies have identified specific challenges, such as individual differences in readiness for TE (e.g., prior knowledge), the level of cognitive engagement with facilitative activities (e.g., shallow engagement), and difficulties in accurately assessing real-life TE episodes due to reliance on students' self-reports of these instances from memory (Heddy et al., 2023; Pugh, 2011; Pugh et al., 2023).

While these studies affirm TTES as an effective model for promoting TEs, they also underscore the need for further research to minimize or eliminate barriers to implementing strategies that foster TEs inside and outside educational settings. Identifying the root causes of these challenges in instructional methods and facilitating improvements through combined approaches is crucial in TE research to ensure students remain optimally engaged with learning content in meaningful ways beyond the classroom (Pugh, 2011; Pugh et al., 2017; Pugh et al., 2023).

Immersive Virtual Reality (IVR), which includes technologies like head-mounted displays, offers a unique and promising approach to addressing the challenges in promoting Transformative Experiences (TE). Positioned at the far-right end of the Reality-Virtuality Continuum, IVR represents a state of complete separation from physical reality (Milgram et al., 1991) and has the potential to transform classroom activities, introducing novel ways for students to experience and interact with learning content. This capability opens new pathways for immersing students in realistic or otherwise impossible scenarios (Radianti et al., 2020). As investments in IVR grow and its popularity rises among tech companies, its feasibility in educational environments increases (Lodge & Horvath, 2016), with continued improvements making it increasingly accessible for both learning and real-world applications (Mystakidis & Lympouridis, 2023). Consequently, immersive learning through IVR is gaining traction as a modern strategy that fosters meaningful engagement with academic content.

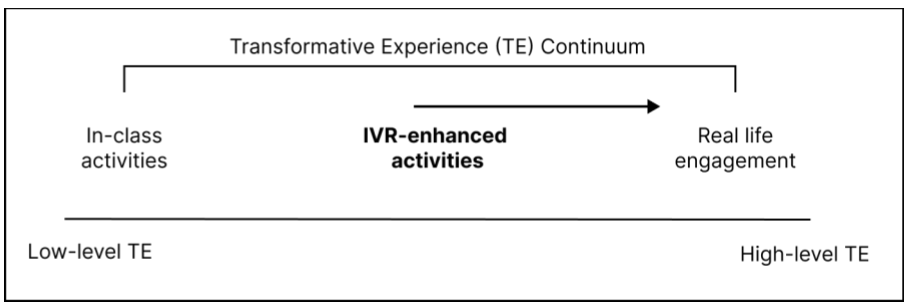
IVR can be a powerful tool for fostering TEs and supporting learning by allowing students to engage with material in a more immersive and interactive manner than is possible in lecture-based settings (Alshammari, 2019; Chen et al., 2022; Hamilton et al., 2021; Lui et al., 2023; Mulders et al., 2020; Slater et al., 2010; Slater & Sanchez-Vives, 2016). Research has highlighted the potential benefits of IVR for learning (e.g., Ahn et al., 2013; Cheung et al., 2013; Jacobson & Holden, 2005; Salzman et al., 1999), including its positive impact on cognitive development (Ahn et al., 2013; Salzman et al., 1999), intrinsic motivation and interest (Cheung et al., 2013; Jacobson & Holden, 2005; Winn & Jackson, 1999), emotional intelligence (Bailenson et al., 2008; Flavián et al., 2021; Riva et al., 2007), and prosocial behavior (Bailenson et al., 2008; Yee et al., 2007; Yee & Bailenson, 2007). Despite these promising findings, research has yet to fully explore how IVR can specifically enhance TEs and promote deep learning outcomes that extend to real-life engagement. While certain studies have used alternative technologies, like mobile phones, to facilitate TE experiences (Cropp et al., 2022; Heddy et al., 2023), further empirical research is needed to understand how technology can foster both in-class, low-level TEs and high-level TEs outside the classroom.

Two critical elements of the IVR environment, presence and agency, hold particular potential for fostering TEs in classroom settings. Presence refers to the feeling of being physically situated within the virtual environment, even though the user is elsewhere (Cummings & Bailenson, 2016; Lee, 2004; Slater & Wilbur, 1997). This sense of immersion and realism can encourage deeper engagement with the content and activities presented in IVR (Lombard & Ditton, 1997; Witmer & Singer, 1998). In contrast, agency refers to the level of control users feel over their actions and interactions within the virtual environment (Bowman & McMahan, 2007), enabling them to make choices, explore the environment, and influence outcomes (Freina & Ott, 2015). When users experience a high degree of agency, they are empowered to engage actively and explore within the virtual space, fostering participatory and dynamic learning experiences. However, the effectiveness of presence and agency in IVR is significantly enhanced when combined with instructional methods that align with the educational content (Makransky & Petersen, 2021). Higher levels of presence and agency have been shown to improve learning outcomes when used in concert with relevant instructional strategies (Makransky & Petersen, 2021).

IVR aligns closely with TE theory and the TTES method because TEs can occur both within and beyond the classroom. More specifically, lower-level TE experiences within the classroom are generally considered less impactful than higher-quality TEs that occur outside of school (Pugh et al., 2010). High-quality TEs that occur outside the school setting involve strong presence and autonomy, allowing students to apply academic content to real-world contexts. Integrating IVR+TTES activities—such as immersive modeling and scaffolding re-seeing—can elevate the quality of lower-level TEs within the classroom. This integration enhances the potential for immersion, engagement, and agency, thereby transforming classroom experiences into deeply meaningful, transformative learning opportunities.

Figure 1

Proposed Effect of IVR-enhanced Activities on the TE Continuum



For instance, Modeling TE serves as an instructional strategy within the Experiential Apprenticeship category of the TTES method. In this approach, instructors share their own Transformative Experience (TE) episodes to illustrate the nature of transformative learning in real-life scenarios, helping students to better understand the concept. Similarly, Scaffolding Re-seeing involves encouraging students to reflect on their own past TE episodes. Integrating IVR-enhanced versions of these activities has the potential to elevate the quality of TE experiences by enhancing feelings of presence and agency. This integration can bring in-class TE activities closer to the complexity of real-world experiences, over which instructors typically have limited control.

From a theoretical perspective, IVR shows promise for uncovering the underlying mechanisms that drive more frequent and higher-quality TEs, as well as the development of interest. Previous research on IVR in learning contexts has shown that immersion in virtual environments and the autonomy to interact with these worlds can significantly heighten levels of presence and agency (Makransky & Petersen, 2021). This enhanced state, shaped by cognitive and affective factors such as interest and motivation, has been associated with improved learning and knowledge transfer (Makransky & Petersen, 2021). In TE research, studies have also demonstrated a direct link between successful TE engagement and the development of interest (Heddy et al., 2017; Heddy & Sinatra, 2017; Kennedy et al., 2021; Pugh et al., 2017).

Building on prior research showing that immersive environments are most effective when paired with instructional methods that leverage the unique affordances of the virtual environment (Makransky & Petersen, 2021), this study proposed that integrating TTES strategies with IVR could enhance the facilitation of Transformative Experiences (TE). The IVR+TTES approach was expected to yield higher-quality TE episodes, increasing opportunities for out-of-class engagement and enriching in-class TE experiences by fostering greater presence and agency. These core affordances of immersive learning empower students to actively apply concepts in their daily lives, assigning greater value to the learning content. By elevating the quality of TE episodes within the classroom, this integration has the potential to catalyze deeper engagement, heightened interest, and more impactful learning across disciplines, especially those requiring advanced visualization and three-dimensional thinking in both educational and real-world contexts.

Problem Statement

The exploration of transformative experiences (TE) has been the subject of numerous studies, with Pugh (2004, 2011) defining TE as learning encounters where curricular concepts are applied in everyday contexts, expanding learners' worldviews with emotional resonance. Such experiences are seen as essential for fostering deeper understanding and supporting knowledge transfer (Pugh, 2011). While TE has shown promise in promoting positive learning outcomes, such as enhanced conceptual understanding and increased interest in subjects like science, challenges remain in effectively fostering TE within classroom settings (Pugh, 2011). Efforts to enhance the quality of low-level TE through in-class activities and to facilitate high-level TE through out-of-class experiences are areas that still need more empirical exploration. Additionally, there is limited research on leveraging technology, particularly IVR, to promote TE, with the TTES method remaining largely unexplored in this context.

A major issue in fostering TE within classrooms is the tendency for shallow implementation or a disconnect from other teaching activities (Pugh, 2011; Pugh et al., 2017). From a Deweyan perspective, and following the design principles of TTES (Pugh, et al., 2017), TE requires not only transforming classroom activities to engage students but also framing the content in a way that makes it compelling, prompting students to think critically, act on their learning, and apply it outside the class. However, this process can be challenging for instructors who may lack experience in creating content that extends beyond the classroom—a difficulty highlighted in teacher development research, which often points out the challenges teachers face in modifying their practice (Cochran-Smith & Lytle, 2009; Lieberman & Pointer Mace, 2008). For example, in design-based research on TE facilitation through tailored classroom activities, Pugh and colleagues (2017) found minimal impact on TE despite enthusiastic teacher involvement, underscoring the difficulty of creating meaningful change in classroom practice, especially in the early stages of an intervention. Although adjustments to strategies in the second year of the study led to notable improvements in students' TE experiences, findings suggest that the TTES model can be challenging for teachers to apply in a deep and integrated way (Pugh et al., 2017). It's also worth noting that not all difficulties are teacher-related; student engagement patterns and individual characteristics can also play a role in the variability of TE (Pugh et al., 2017).

Students are expected to engage with TTES activities and techniques at different levels, influenced by their readiness and prior knowledge (Pugh et al., 2010; Pugh et al., 2017). While interventions show promise in enhancing engagement with TTES, individual differences in readiness and engagement can present barriers to experiencing TE episodes. Research suggests that students with prior knowledge tend to report higher levels of engagement after participating in transformative teaching and learning activities (Pugh et al., 2017; Pugh, 2020; Pugh et al., 2023). Additionally, recent studies suggest that identity differences can play a role in the frequency and quality of transformative learning, as some students are simply more open to engaging with the material (Pugh et al., 2017; Pugh et al., 2023). For instance, students who have sufficient prior knowledge and a natural inclination toward transformative experiences are often the ones who benefit most from these interventions (Pugh et al., 2017). This indicates that while strategies designed to foster transformative experiences are effective, they face challenges in achieving consistent success across different student groups, highlighting the need for further research to broaden their effectiveness. Additional studies could help us better understand the factors affecting students' readiness and engagement and lead to strategies that support a wider range of students in transformative teaching and learning.

Another significant issue in the literature around TE is its assessment (Pugh et al., 2017). Assessing natural TE episodes requires students to reflect on their experiences with content in everyday life (i.e., through self-report measures), which may not always be entirely accurate and could be prone to positive response bias. Additionally, relying solely on self-reports may miss some of the nuances of transformative experiences, as students may struggle to fully articulate their thoughts and emotions. The subjective nature of self-reports can also lead to inconsistencies in interpretation, which can introduce biases when assessing the real impact of TEs on student learning and development (Pugh, 2011; Pugh et al., 2010; Pugh et al., 2017). Integrating immersive virtual reality (IVR) into TE teaching presents a promising solution to this assessment challenge. IVR offers a simulated environment that closely mirrors real-life scenarios, allowing students to engage in authentic experiences within a controlled setting (Mystakidis & Lympouridis, 2023; Radianti et al., 2020). By immersing students in virtual environments, IVR enables them to explore complex concepts and actively participate, giving educators the chance to observe and assess transformative experiences directly. Through IVR+TTES, educators can gather rich qualitative data on student interactions, behaviors, and responses, supplementing self-reports with more objective observations. Furthermore, IVR enhances the authenticity and ecological validity of assessment tasks, allowing students to apply their learning in realistic contexts and fostering deeper reflection on their transformative experiences. Consequently, IVR holds great promise for overcoming TE assessment challenges, ultimately strengthening TE teaching and learning.

Finally, in addition to the challenges of facilitating transformative experiences, the literature on IVR itself reveals areas that need further exploration. Despite recent efforts to understand immersive learning, there is limited research specifically examining the instructional benefits and design strategies of immersive environments. Models commonly used for educational technology integration, such as the Technology Acceptance Model (TAM) (Davis et al., 1989), were not designed with immersive environments in mind (King & He, 2006), leaving the interaction between IVR learning and instructional strategies largely unexamined (Mikropoulos & Natsis, 2011; Radianti et al., 2020). Efforts to define the essential components of immersive learning, such as the Cognitive and Affective Model of Immersive Learning (CAMIL), are still in need of empirical support (Makransky & Petersen, 2021). Additionally, there is a lack of evidence showing how motivational and learning theories apply in immersive learning settings (Radianti et al., 2020). As a result, the body of knowledge on IVR as both a psychological construct and a learning technology is still evolving. Much of the research focuses on the outcomes of these technologies, often at the expense of understanding the instructional strategies, goals, and classroom contexts that create meaningful learning experiences (Beck et al., 2023). This outcome-focused approach, often influenced by the novelty of the technology, can overlook IVR's true potential to transform educational practices (Beck et al., 2023).

IVR+TTES has the potential to address the challenges of creating transformative experiences (TE) in the classroom. It considers individual differences in readiness, lack of prior knowledge, and identity factors that often predict higher engagement in TE. Additionally, it aids in understanding immersive learning when supported by solid learning principles and activities. Although IVR technology may increase cognitive load for students (Moreno & Mayer, 2007; Sweller, 1994), studies have shown that well-designed interventions that allow learners to become familiar with the technology can mitigate the cognitive load associated with it (Mayer & Moreno, 2010). Moreover, students with little prior knowledge can still benefit from IVR+TTES activities by receiving guidance from instructors within the environment. Instructors play a crucial role in guiding and supporting students' cognitive processes during technology-integrated learning experiences, acting as a form of cognitive scaffolding (Hmelo-Silver & Barrows, 2006; Jonassen, 2005, 2009). Thus, the increased presence and agency facilitated by IVR, combined with instructor support during TTES activities, could help both students with no prior knowledge and those with higher readiness levels. This approach has the potential to boost motivation and interest in virtual learning activities.

The present study aimed to explore the facilitation of the TTES method with IVR support and its effect on Transformative Experiences by integrating immersive learning into instructional design and activities. This study holds scholarly significance by contributing to both Transformative Experience Theory and the immersive learning literature through a carefully designed intervention aimed at fostering meaningful engagement in everyday life experiences.

Purpose of the study

This study explored how immersion and presence in immersive virtual reality (IVR) can boost transformative experiences by strengthening the impact of instructional strategies within the Teaching for Transformative Experiences (TTES) framework. Gaining a clear understanding of the potential benefits of immersive learning technologies, alongside methods designed to foster transformative experiences, is essential. Such insights are critical for creating learning experiences that fit well with immersive or blended instructional settings, where IVR can complement lecture-based classroom activities. By leveraging IVR's key features—especially its ability to provide a sense of presence and agency—this study aimed to investigate how IVR can deepen transformative learning experiences. The ultimate goal was to foster significant and lasting changes in learners' beliefs, perspectives, and identities, with meaningful effects on their everyday lives.

Additionally, this study aimed to contribute to the growing conversation around learning in IVR environments and to explore whether well-established learning theories and instructional approaches, such as TTES, hold up effectively in immersive settings. Previous research in Transformative Experience and Immersive Learning literature has already noted connections among some key variables. For instance, engaging with transformative experiences has been linked to the development of interest (Renninger & Su, 2012), with transformative experiences acting as both triggers and reflections of specific interests (Pugh et al., 2015). On the other hand, research in immersive learning suggests that interest may mediate the connection between presence and agency in IVR and the resulting learning outcomes. However, these relationships lack sufficient empirical support, especially within TTES-based interventions conducted in immersive environments. This study aimed to fill this gap by examining how IVR's key features—presence and agency— shape transformative experiences, with these experiences framed as types of learning outcomes. Through detailed investigation and analysis, this research sought to enhance scholarly understanding and provide valuable insights for designing instructional practices that leverage IVR to create transformative learning experiences.

Research Questions

Despite the potential benefits of transformative experiences and teaching for transformative experiences, there are ongoing challenges in developing and implementing effective instructional methods to foster these experiences (Pugh et al., 2017). This difficulty stems from the unpredictable nature of transformative experiences, which require teaching approaches that are both flexible and adaptable (Pugh et al., 2017). Efforts to improve the quality of low-level transformative experiences through in-class activities and to encourage high-level transformative experiences outside the classroom still need more empirical exploration. This study aimed to explore how transformative experiences can be supported through IVR-enhanced TTES activities, focusing on the interactions between presence, agency, interest, and transformative experiences. To address this, the study sought to answer the following research questions:

RQ1. Does the IVR+TTES intervention facilitate Transformative Experiences?

RQ2. How do the affordances of IVR (presence and agency) help explain quantitative differences in the variance of TEs among students?

Significance of the study

Integrating immersive technologies into learning holds great promise for fostering transformative experiences that enable meaningful engagement with content in real-world contexts. Immersive virtual reality (IVR) has the potential to bridge the gap between classroom experiences and real-life engagement along the transformative experience (TE) continuum. By simulating or closely emulating real-world scenarios, IVR addresses several challenges associated with facilitating TE, such as superficial implementation, disconnection from other pedagogical activities, individual differences in experiencing TE. Therefore, to gain a deeper understanding on as to how IVR learning intersects with TE and leverages the unique affordances of the medium, this study aimed to explore the TTES process by incorporating IVR into TTES instructional activities. Insights from this study inform future learning design practices, enabling more effective and meaningful engagement with learning content.

This intervention study also makes a significant contribution to the literature on TE theory by examining how IVR can facilitate TE and enhance the quality and effectiveness of immersive learning. Previous research has not operationalized TE as an outcome of IVR learning, and TE interventions that integrate immersive technologies within TTES activities are scarce or non-existent. As such, this study represents one of the first attempts to explore how the TTES method, supported by IVR, can impact TE through immersive instructional activities.

Furthermore, this study will enrich theoretical understanding in immersive learning research by providing valuable data that sheds light on the IVR learning process. While prior research supports the potential benefits of IVR for learning, and theoretical models like the Cognitive and Affective Model of Immersive Learning (CAMIL) (Makransky & Petersen, 2021) offer frameworks for the immersive learning process, empirical evidence from authentic learning environments remains limited. Given IVR's unique ability to create a fully immersive experience separate from the physical world, understanding how media and methods interact is crucial for advancing research in learning technologies.

A comprehensive understanding of how immersive learning affordances, such as presence and agency, influence learning and transfer can inform evidence-based decisions in instructional design, including course structure and the development of activities. Additionally, this study's findings help identify potential weaknesses in immersive learning design, leading to improvements that enhance students' immersive experiences while also addressing issues of diversity, inclusiveness, and accessibility within learning environments. In sum, this study holds scholarly significance by examining TE as an outcome of an IVR-supported learning process and contributing to the refinement of the Teaching for Transformative Experience framework.

Chapter 2: Literature Review

The following chapter reviews the literature exploring the connection between transformative experiences, immersive virtual reality, interest, learning, and real-world engagement. It focuses on defining these concepts and sub constructs for the purpose of the current study. It also examines the theoretical and practical aspects of transformative experiences and immersive learning, highlighting their background and identifying gaps to justify the purpose and design of the current study.

Transformative Experience (TE): An Overview

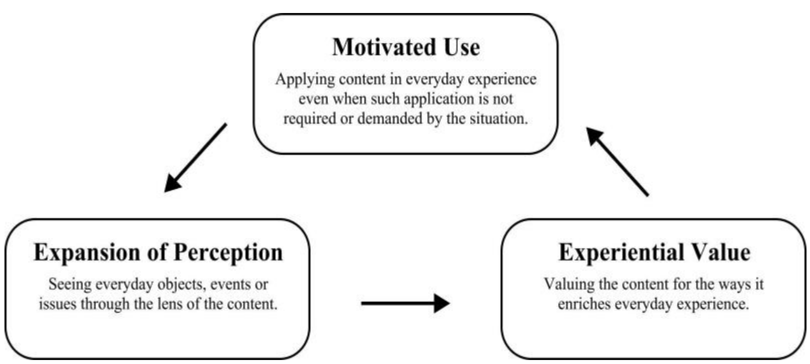
The concept of Transformative Experience (TE) has garnered significant attention in educational research, particularly due to its potential to bridge classroom learning with students' everyday lives. Scholars such as Pugh (2004, 2011) define TEs as learning experiences that extend beyond mere knowledge acquisition, involving the application of classroom concepts in real-world contexts. This active engagement enriches students' understanding of the world and fosters deeper learning outcomes. Research indicates that TEs can lead to profound educational benefits, including deep learning (Pugh et al., 2017), sustained interest (Heddy & Sinatra, 2017), positive affect (Heddy et al., 2017), and conceptual change (Heddy & Sinatra, 2013). The theoretical foundations of TE are deeply rooted in John Dewey’s educational philosophy. Dewey (1938) emphasized that education should practically enhance students' everyday experiences by applying theoretical knowledge. Building on Dewey's ideas, Pugh (2004, 2010, 2011) proposed TEs as a way to integrate classroom learning with real-life experiences. Dewey's concepts of experience, particularly the aesthetic aspect and the theory of experience, underpin the TE framework. This framework shifts the focus from learning as an end in itself to learning as a means of enriching experience (Pugh, 2004).

Pugh (2004) explains the difference between learning theory and the theory of experience. He emphasizes that while the theory of experience values the learning experience, it gives more importance to the application of learning in real-world situations. Learning approaches such as lecture-based classrooms often do not go beyond the classroom, resulting in knowledge that has little impact on students' lives (Pugh, 2004, 2011). Pugh also argues for a shift in perspective to see experience as the outcome of learning, which would transform educational practices to create more meaningful and impactful experiences (2011).

TEs consist of three interrelated components: motivated use, expansion of perception, and experiential value (Pugh, 2011). These components, derived from Dewey's theory of experience, form a unified construct essential for understanding and facilitating TEs. Motivated use involves applying learned concepts in real-life scenarios, driven by a genuine interest rather than external requirements. For instance, a student learning about architectural principles might notice and appreciate the structural designs of buildings outside of school, demonstrating a motivated use of their classroom knowledge.

Figure 2

Three characteristics of transformative experience. (Adapted from Pugh, 2011)



Expansion of perception is a cognitive shift resulting from the motivated use of knowledge, leading to a broader understanding of the world. Pugh (2002) provides an example of students studying biology began to perceive animals not just as creatures but in terms of their evolutionary adaptations, illustrating a deeper, more nuanced view of their environment. This cognitive expansion is supported by foundational theories of schema development (e.g., Anderson, 1977; Piaget, 1952) and conceptual change (e.g., Posner et al. 1982), adding a transformative dimension to earlier cognitive learning theories. Experiential value, the affective component of TE, arises when students develop a deep appreciation for the subject matter as a result of their broadened perception. This appreciation goes beyond intrinsic and utility values, focusing on real-world applications and their impact on the students' view of the world. For example, a student who applies architectural concepts outside the classroom might develop a lasting interest and value in engineering or physics, illustrating the profound personal and educational impact of TEs.

Practical applications of fostering TEs include enhancing student engagement with science concepts, increasing interest in science careers, and promoting deep, enduring learning (Pugh, 2011). The Teaching for Transformative Experiences in Science (TTES) model aims to cultivate this type of engagement, helping students to see the world through a TE perspective (Pugh et al., 2017). This approach aligns with culturally relevant pedagogy, supporting underrepresented groups in pursuing science careers and achieving deep learning goals (Pugh et al., 2017; Pugh, 2020). By encouraging students to apply knowledge in meaningful ways, TEs help build flexible knowledge structures essential for real-world application.

Practical Benefits of Cultivating Transformative Experiences in Education

Transformative experiences facilitate deep and enduring learning by promoting a type of transfer that integrates new knowledge with students' everyday experiences and conceptions of the world (Pugh 2004, 2011). By encouraging students to apply theoretical concepts in diverse contexts, educators can scaffold the development of flexible knowledge structures that facilitate deep understanding and critical thinking (Bransford et al., 2000; Hmelo-Silver et al., 2007). For instance, adding transformative experience to project-based learning or inquiry-based investigations can challenge students to make connections between abstract principles and real-world phenomena, leading to deeper insights and long-lasting conceptual change (Linn et al., 2013). By fostering a culture of inquiry and exploration, transformative experiences empower students to become active agents of their own learning, thus promoting deep learning goals and academic excellence (Alongi, 2014; Crowford, 2018).

Transformative experiences in science education have been shown to significantly enhance students' engagement with scientific concepts (e.g., Heddy & Sinatra, 2013). By providing opportunities for students to apply theoretical knowledge in real-world contexts, educators can foster a deeper understanding and appreciation for scientific principles (G Beier et al., 2008). For example, immersive learning experiences, such as hands-on experiments and field trips, have been found to promote active engagement and curiosity among students (Makransky & Lilleholt, 2018). Such engagement is essential for cultivating a lifelong interest in science and fostering the next generation of scientific innovators (Ibáñez & Delgado-Kloos, 2018).

In addition, research indicates that students who undergo transformative experiences in science education exhibit heightened interest in science content and are more inclined to pursue careers in science-related fields (Heddy et al., 2023; Pugh, 2010; Parong & Mayer, 2018). By connecting classroom learning to real-world applications, educators can inspire students to explore diverse scientific disciplines and envision themselves as future scientists or researchers (Edelson, 2001). For instance, Sadler et al., (2011) found that transformative experiences can foster a sense of identity and belonging among students within the scientific community. Their findings show that exposure to hands-on research projects or mentorship opportunities with professionals in the field can spark students' curiosity and motivate them to pursue advanced studies in science. By providing authentic learning experiences that emphasize the relevance and impact of scientific knowledge, educators can empower students to see themselves as active participants in the scientific enterprise (Beier et al., 2008). Collaborative research projects or participation in science competitions can cultivate a sense of connection and shared purpose among students, leading to greater identification with science as a discipline.

Transformative experiences also offer a culturally responsive approach to education that honors students' diverse backgrounds and experiences (Ladson-Billings, 1995). By incorporating culturally relevant content and practices into the curriculum, educators can create inclusive learning environments where all students feel valued and respected (Gay, 2010). For instance, integrating indigenous knowledge systems or local ecological practices into science lessons can enhance students' sense of cultural identity and connection to the subject matter (Bang et al., 2018). This alignment with culturally relevant pedagogy not only promotes academic achievement but also fosters social justice and equity in education.

Similarly, transformative experiences may also play a crucial role in breaking down barriers and promoting diversity in science-related fields. By providing equitable access to transformative learning opportunities, educators can empower underrepresented groups, such as women and minority students, to pursue careers in science (Cheryan et al., 2017; Heddy &

Sinatra, 2017). For example, Heddy and Sinatra (2017) demonstrated that facilitating TE with the help of parent involvement had the potential to increase middle and high school girls' engagement with technology education and maintain their interest in science. This shows that by fostering a more inclusive and diverse environment, transformative experiences may contribute to innovation and excellence in scientific research and practice.

These practical benefits highlight the importance of cultivating transformative experiences to enhance student engagement, learning outcomes, and future success. Overall, while expecting every learning experience to result in a TE is unrealistic, facilitating such experiences can profoundly impact students' educational journeys. By adopting Dewey's perspective and the TTES model, educators can enhance students' awareness and engagement, leading to transformative educational outcomes that extend far beyond the classroom.

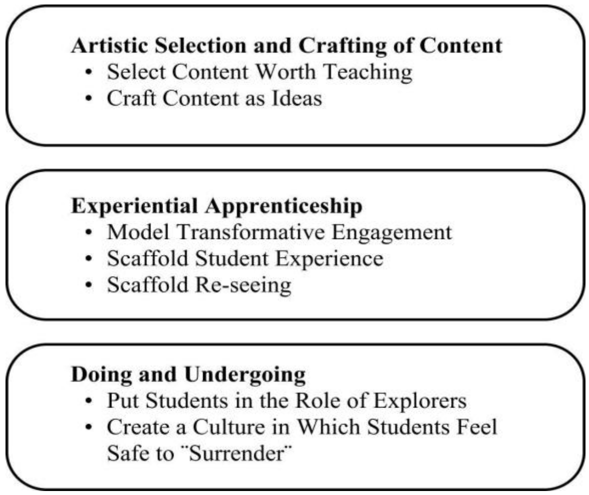
Teaching for Transformative Experiences

The concept of Teaching for Transformative Experiences (TTE) aims to bridge the gap between classroom learning and real-world application, aligning with John Dewey's philosophy that educational curricula should provide authentic experiences rather than just theoretical knowledge (Pugh et al., 2017). Dewey's analogy of reading a map versus experiencing the terrain emphasizes the importance of engaging students with real-world contexts to enhance learning outcomes (Pugh, 2020). Pugh highlights the modern challenge that classroom learning often remains confined within the classroom walls, with students seldom engaging with the content beyond the academic setting (Pugh, 2020). This disconnect suggests the need for innovative strategies that encourage students to apply classroom knowledge in their everyday lives, promoting deeper and more enduring learning (Pugh et al 2017; Pugh 2020). The TTES model, specifically developed to address this issue, focuses on fostering meaningful engagement outside the classroom to support sustained learning (Pugh et al., 2010; Pugh et al., 2017). Originally applied in scientific contexts, studies have demonstrated its efficacy across various fields, including biology, psychology, social studies, and engineering (Heddy & Sinatra, 2013; Heddy et al., 2023; Pugh, 2002, 2004; Pugh et al., 2010). The model's versatility indicates its potential as a valuable tool in diverse educational settings. Unlike traditional methods such as inquiry-based learning, TTES is designed to complement and enhance existing pedagogical approaches, offering a collaborative framework rather than a replacement (Pugh, 2020).

The TTES model comprises three design principles: artistic selection and crafting of content, experiential apprenticeship, and the process of doing and undergoing (Pugh, 2020). The initial step involves the artistic selection and crafting of content, where educators intentionally choose and present ideas to resonate with students' experiences. This approach, which can be seen as both literal and metaphorical, aims to filter and highlight core ideas that are immediately relevant to students' lives. Dewey's perspective on artistic selection aligns with this approach, emphasizing the need to create transformative experiences by thoughtfully curating educational content (Pugh, 2020). However, merely selecting engaging content is insufficient to foster transformative experiences. The content must be crafted to inspire students to act and explore further outside the classroom (Pugh, 2020). Pugh illustrates that even a compelling idea can become dull if not presented effectively, whereas a trivial knowledge can be transformed into a significant concept with the right approach (Pugh, et al., 2017; Pugh, 2020). Therefore, the crafting process involves making content not only informative but also action-inducing, encouraging students to seek deeper understanding and application in their daily lives.

Figure 3

Teaching for Transformative Experience in Science (TTES) Model (Adapted from Pugh, 2020)



The next principle, experiential apprenticeship, draws on the concept of apprenticeship and modeling (Dennen & Burner, 2008). This approach supports novice learners by providing them with experiences that closely mimic real-world scenarios (Pugh et al., 2017). In the context of TTES, this involves modeling transformative engagement with content through personal stories and expressions of passion. By exposing students to various models of transformative engagement, such as anchored instruction (Cognition and Technology Group at Vanderbilt., 1990), educators can scaffold students' understanding and increase the likelihood of them applying their learning in meaningful ways (Pugh, 2020).

The final principle, doing and undergoing, emphasizes providing students with opportunities to take meaningful action in a supportive environment. Dewey (1938) posits that transformative experiences require both action and a willingness to be immersed in the experience. This immersion, or "surrender," allows students to fully engage with and be transformed by the learning process (Pugh, 2020). Creating a supportive environment that fosters mindfulness, mastery goals, and autonomous motivation is crucial for students to feel safe and willing to undergo transformative experiences (Pugh, 2020).

The TTES model offers a robust framework for enhancing student engagement and fostering transformative experiences both inside and outside the classroom. By artistically crafting content, modeling transformative engagement, and providing opportunities for meaningful action, educators can create learning environments that encourage students to connect academic content with real-world experiences. Empirical studies have shown that the TTES model can significantly enhance engagement and interest in various educational contexts (e.g., Heddy et al., 2023; Pugh et al., 2015). However, challenges remain in the implementation of TTES. Studies indicate mixed findings regarding the depth of implementation and learning outcomes, often due to the complexities of effectively integrating TTES strategies into existing curricula (Cropp, 2019; Heddy & Sinatra, 2017; Pugh, 2011, 2020). These challenges point to the need for further refinement of the TTES model and a better understanding of the factors affecting its implementation and effectiveness.

Practical applications of TTES in educational settings

The Teaching for Transformative Experiences in Science (TTES) model, originally conceptualized to enhance science education, has demonstrated its efficacy in engaging students across various disciplines, such as biology, psychology, social studies, and engineering. Studies conducted by Pugh (2002, 2004, 2020) and Heddy and Sinatra (2013) have shown increased student interest and engagement through TTES, yet significant challenges in implementation remain. For example, difficulties in fostering transformative experiences (TEs) stem from variations in students' prior knowledge, engagement levels, and the reliability of self-reported data on real-life TEs (Heddy et al., 2023; Pugh, 2011; Pugh et al., 2023). These factors highlight the necessity for further research to address these challenges and refine instructional methods.

Initial studies revealed mixed outcomes regarding the depth of implementation and its effects on learning outcomes. For instance, Pugh (2002) conducted a small-scale study in a high school zoology class, finding that students who engaged in TEs performed better on follow-up assessments compared to those in a control group. Similarly, Girod and Wong (2002) explored "aesthetic understanding" in a fourth-grade geology class, noting that even students who were not academically excelling showed interest when learning was approached aesthetically. These early findings underscored the potential of TTES to foster meaningful engagement but also pointed to limitations in generalizability due to small sample sizes and short intervention durations.

Subsequent research sought to address these limitations through more extended and comprehensive studies. Pugh et al. (2010) and Pugh et al. (2017) conducted two-year design-based interventions in K-12 settings, revealing that while teachers could implement TTES strategies enthusiastically, the impact on fostering TEs was minimal in the first year of the intervention. These mixed findings indicated that the TTES model requires further refinement and highlighted the complexities of implementing it deeply and consistently across different educational contexts. A more recent study by Heddy et al. (2023) investigated the use of video software as a supplementary tool to enhance TEs among middle school students learning about engineering. The study utilized Notice, Change, Value (NCV) journals supported by mobile technology, finding that initial emotional responses predicted later interest and TEs. However, the results were mixed regarding the prediction of post-intervention interest scores, highlighting the nuanced and variable nature of TEs in educational settings.

The research on TTES in higher education, although promising, is relatively sparse compared to K-12 studies. Heddy and Sinatra (2013) examined TEs and conceptual change in biological evolution among undergraduates, finding that TTES instruction led to higher levels of TEs and greater conceptual change. This study suggested that TTES can effectively engage young adults and foster long-term interest in content, potentially influencing their career decisions and life satisfaction. However, the limited generalizability and external validity of these studies call for more extensive research to confirm these findings across diverse higher education contexts.

In summary, existing studies affirm that TTES can significantly enhance student engagement and learning outcomes across various educational levels. The potential of TEs to yield profound and lasting educational benefits is evident, but further empirical research is necessary to refine TTES strategies and address implementation challenges. This includes developing reliable and valid intervention designs, conducting long-term observations, and incorporating diverse instructional approaches. Addressing these challenges will ensure that TTES can be more widely and effectively applied, fostering transformative engagement and learning in both K-12 and higher education environments.

Interest Development

Interest development plays a crucial role in the learning process, influencing engagement, motivation, and, ultimately, academic achievement (Hidi & Renninger, 2006). It describes the progressive deepening of a learner's engagement with a particular topic or domain (Hidi & Renninger, 2006). This process unfolds in stages, with two key types playing a crucial role: situational interest and individual interest (Ainley et al., 2002). Situational interest refers to the immediate engagement evoked by specific tasks or contexts, while individual interest pertains to enduring, personally meaningful topics or domains (Hidi & Renninger, 2006). Understanding how these interests develop and interact is vital for educators seeking to optimize learning experiences.

Situational interest is a transient state of curiosity or fascination triggered by specific learning environment features. It often arises from external stimuli or contextual factors (Mitchell, 1993). Hidi and Renninger (2006) propose that situational interest is evoked when a task or topic is perceived as novel, challenging, or personally relevant. The novelty and visual appeal might spark curiosity in a student who is captivated by a science experiment that involves colorful chemicals bubbling in a test tube. For example, in a study by Ainley and colleagues (2002), situational interest in mathematics increased when students were presented with problem-solving tasks that aligned with their individual abilities and preferences. This shows that facilitating the initial spark is important. However, it may fade quickly without further engagement, exploration, or connection to the underlying concepts (Hidi & Renninger, 2006).

In contrast, individual interest represents a more enduring form of engagement that reflects a deeper personal connection with the topic. It arises from repeated interaction and a growing sense of value and relevance (Renninger & Hidi, 2017). Students with strong individual interests actively seek new information, persist through challenges, and readily transfer their knowledge to new situations (Hidi & Renninger, 2006). For example, the interest of a student fascinated by the history of ancient Egypt goes beyond the initial spark of a captivating documentary. The student might delve into library resources, visit museums, and even attempt to learn hieroglyphics. Renninger and Hidi (2017) suggest that individual interest develops over time through repeated exposure and positive experiences within a specific domain. Supporting this, in a longitudinal study by Harackiewicz et al. (2008), students who demonstrated initial individual interest in science were more likely to persist in related academic pursuits over time—the personal connection and sense of value fuel their sustained engagement.

The positive impact of interest on learning outcomes is well-supported by empirical evidence. For instance, Schiefele et al. (1992) found that students' situational interest positively correlated with their comprehension and retention of text material. Hidi and Renninger (2006) conducted a study demonstrating that students with higher levels of situational interest exhibited greater focus and more active participation and ultimately achieved better results (Hidi & Renninger, 2006). Similarly, Ainley and Ainley (2011) discovered that individual interest in a topic significantly predicted students' motivation and achievement in related academic tasks. Silvia (2006) explored the role of individual interest, finding that students with strong personal connections to the subject matter were more likely to engage in critical thinking and self-directed learning (Silvia, 2006). These findings point out the importance of fostering situational and individual interest in the classroom.

In conclusion, interest development plays a critical role in fostering a love of learning (Hidi & Renninger, 2006). By understanding the nuances of situational and individual interest, educators can create engaging learning environments that ignite curiosity and empower students to become self-motivated learners who are intrinsically driven to explore and understand the world around them. Furthermore, nurturing interest empowers students to become self-motivated learners. By understanding student interests and building upon them, educators can create learning experiences that hold personal value and relevance (Renninger & Hidi, 2017).

Interest and Transformative Experiences

Previous research suggests that there is a reciprocal relationship between TE and interest (Pugh et al., 2015; Pugh et al., 2021). That is, interest promotes TE, and engaging with TE can maintain situational interest and lead to the development of individual interest (Heddy et al., 2023). Renninger and Su (2012) theorized that Transformative Experiences (TE) could effectively cultivate interest by promoting re-engagement, perceived value, and achievement. Indeed, research indicates that TE can bolster interest levels (Heddy & Sinatra, 2017; Heddy et al., 2017; Heddy et al., 2021; Heddy et al. 2023). For example, Heddy et al. (2021) found that graduate engineering students exhibited heightened interest in engineering concepts after engaging in TE activities. In a similar domain but with middle school students learning about engineering, Heddy et al. (2023) found that engaging with TE predicted post levels of interest. However, the reciprocal relationship between interest and TE needs to be explored empirically in greater depth. In the meantime, the applicability of such findings to other domains and immersive virtual environments necessitates further investigation.

Leveraging IVR Technology for Transformative Learning

Defining Virtual Reality: A Multifaceted Construct

Immersive Virtual Reality (IVR) refers to a simulated experience that can range from being similar to the real world to completely fantastical. This versatility in IVR experiences is largely attributed to the advanced computer technology that allows for the creation of both realistic and imaginative environments (Hamilton et al. 2021). IVR uses head-mounted displays (HMDs), motion tracking, and other technologies to create an interactive, three-dimensional environment that users can explore and interact with. These components work together to track the user's movements and adjust the virtual environment, accordingly, providing a seamless and immersive experience (Poux et al., 2020). IVR has seen increasing integration into various fields, including education, healthcare, and entertainment, due to its ability to provide unique, immersive experiences that can enhance learning and engagement. For example, in education, IVR can create interactive learning environments that can enhance student engagement and retention of information. In healthcare, it is used for surgical simulations and patient education, offering a safe and controlled environment for learning complex procedures (Mystakidis et al., 2021; Wang & Degol, 2014).

Defining virtual reality is a multifaceted endeavor, as it encompasses a variety of technologies and experiences that go beyond traditional digital interactions. Unlike conventional digital interfaces, IVR creates a fully immersive experience by blocking out the physical world and replacing it with a virtual one, which can be explored and interacted with in real time (Sanchez-Vives & Slater, 2005). While early IVR systems primarily focused on visual immersion, contemporary IVR environments increasingly incorporate multisensory elements to enhance the sense of presence and immersion. These multisensory systems can simulate not only visual and auditory stimuli but also haptic (touch), smell, and taste sensations, contributing to a more holistic and convincing virtual experience. For instance, haptic feedback devices, such as gloves and suits, allow users to feel physical sensations corresponding to virtual objects, enhancing the sense of touch. Smell and taste technologies, although less common, are being developed to simulate smells and tastes, further enriching the immersive experience (Hartson & Pyla, 2018; Spence et al., 2017).

Just like the development of technology, early attempts to define IVR also focused on the technological components that enable VR, such as HMDs and motion tracking, emphasizing the creation of a convincing sense of presence in a computer-generated environment. Over time, the definition has expanded to include the psychological and experiential aspects of VR, such as immersion, interactivity, and the user's sense of presence. Presence, a core concept in VR, refers to the feeling of being in a place despite not physically being there. Researchers like Steuer (1995) and Slater (2009) have emphasized presence as a critical factor that distinguishes VR from other media (Steuer, 1995; Slater, 2009).

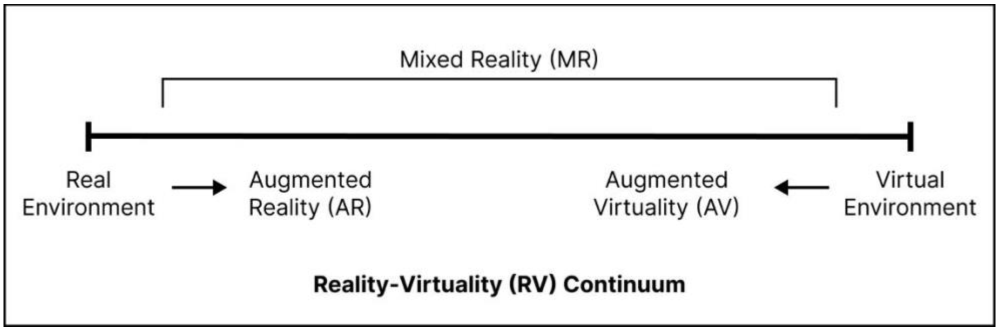
Various models have also attempted to define virtual reality and the affordances that make this medium unique compared to other forms of digital technologies. Some models questioned the distinction between reality and virtuality, while others focused on specific components. However, defining and determining the appropriate use of virtual reality has been a topic of concern in multiple fields, such as human-computer interaction, communications, and instructional design, for a while. Despite these efforts, a recent review by Speicher et al. (2019) revealed the lack of consensus among IVR professionals regarding a single, universally accepted definition. To address this, the concept of Extended Realities (XR) has been suggested as an umbrella term encompassing various realities (augmented reality and virtual reality) that are transforming the way we interact with the world (Akçayır & Akçayır, 2019).

The Reality-Virtuality Continuum (RVC): A Framework for Understanding VR

The Reality-Virtuality Continuum (RVC) is a foundational framework for understanding the spectrum of experiences ranging from the real world to completely virtual environments (Milgram et al., 1991; Milgram & Kishino, 1994; Milgram et al., 1995). The continuum places the real world on one end and a fully immersive virtual environment on the other, with various mixed reality (MR) experiences in between, such as augmented reality (AR) and augmented virtuality (AV).

Figure 4

Reality Virtuality Continuum (Adapted from Milgram et al., 1995)



In this framework, MR environments blend real and virtual elements to varying degrees. AR overlays digital information onto the real world, while AV integrates real-world elements into a predominantly virtual environment. This continuum helps in categorizing different types of virtual experiences and understanding their distinct characteristics and potential applications. A later work of Milgram et al. (1995) expands the framework as a three-dimensional model, in which each component corresponds to one dimension of the three-dimensional reality (i.e., the extent of world knowledge, reproduction fidelity, and extent of presence metaphor) (Milgram et al., 1995). However, a key limitation of the RVC model is its primary focus on visual displays since physical reality encompasses more than just visual perception (e.g., haptics) (Speicher et al., 2019). IVR technology has the potential to simulate various senses beyond sight, including audio, motion, haptics (touch), taste/flavor, and smell (Jones et al., 2021). Integrating these additional sensory modalities can significantly enhance the immersive experience and improve user engagement (Lin et al., 2019).

Alternative Models of VR: Exploring Additional Dimensions

The Reality-Virtuality Continuum (RVC) established a foundational framework for understanding immersive virtual reality (IVR) along a spectrum from entirely real to fully computer-generated environments (Milgram & Kishino, 1994). However, this initial model did not capture the full complexity of the IVR experiences. As a result, numerous other models have been proposed, each offering a unique lens through which the interplay between user perception, interaction, and technology in creating a sense of immersion could be examined.

Several models delve into the user's experience within the virtual world. The Cube Model by Zelter (1992) and the model by Salzman et al. (1999) both emphasize the user's ability to interact and engage with the virtual environment. Zelter (1992) highlights properties like autonomy (the environment's ability to respond to user actions) and interaction (two-way communication), while Salzman et al. (1999) focus on the user's ability to switch perspectives within the VR space (frames of reference) for a richer experience. Both models acknowledge the importance of user agency and a dynamic virtual world that responds to user input, contributing to a sense of presence.

In contrast, Wickens' (1992) model focuses more on the technological aspects that contribute to a cohesive VR experience. It emphasizes five key features: 3D perspective, dynamic rendering, closed-loop interaction, inside-out perspective, and enhanced sensory feedback. While Wickens' model and those focusing on user experience (Salzman et al., 1999; Zelter, 1992) share the concept of a 3D perspective and closed-loop interaction (immediate response to user actions), Wickens goes further by highlighting the importance of technical aspects like dynamic rendering (smoothly updating visuals) and inside-out perspective (seeing the virtual world from the user's viewpoint) for a seamless experience. However, Wickens' model does not explicitly address the user's subjective sense of presence within the VR space.

Recent models, on the other hand, have led to new concepts that refine our understanding of the psychology of virtual experiences. Slater's (2009) "place illusion" (PI) and "plausibility illusion" (Psi) delve deeper into the psychological aspects of presence. PI refers to the user's feeling of being physically present in the virtual location, while Psi reflects the perceived believability of events happening within VR. These illusions highlight the importance of not only visual fidelity but also the believability of the entire VR experience for a strong sense of presence. Similarly, Jerald's (2015) "Continuum of Virtuality" and the concept of "embodiment" explored by Kilteni et al. (2012) emphasize the user's ability to interact with and feel embodied within the VR environment. Jerald (2015) suggests a high degree of interactivity and rich sensory feedback are crucial for a strong sense of presence, while Kilteni et al. (2012) highlight the importance of users feeling a sense of ownership and agency over their virtual bodies. These models point to the potential limitations of models that solely focus on visual aspects, suggesting that a user's sense of self and interaction within the VR space are also crucial elements for a truly immersive experience.

Building upon these insights, Cummings and Bailenson's (2016) "Framework for Immersive Virtual Environments" (FIVE) takes a more holistic approach. FIVE goes beyond user perception to evaluate VR systems based on various factors, including sensory fidelity, user control, content quality, and user characteristics. This comprehensive framework acknowledges that a successful VR experience is not just about the technology itself but also the content, user comfort, and individual differences in user experience. Similarly, the Bowman and McMahan (2007) framework offers a valuable summary, incorporating key features of successful VR experiences: high-fidelity sensory experience, real-time interaction, a computer-generated world, and a sense of presence. This framework captures the essence of VR by acknowledging both technological capabilities and the user's subjective experience of "being there."

In conclusion, despite the progress in defining and understanding IVR, inconsistencies remain in the literature, often stemming from differing terminologies and focus areas. For this reason, understanding VR requires looking beyond a single model. By examining the strengths and limitations of various models, we gain a richer understanding of the complex interplay between user experience, technological advancements, and the design of VR environments. Moving forward, it is crucial to integrate insights from various models and frameworks to build a unified understanding of IVR. This includes considering the psychological aspects of presence, the technical components of interactivity and sensory feedback, and the user experience. Continued interdisciplinary research and collaboration will be essential in advancing the field and unlocking the full potential of immersive virtual reality.

Presence and agency as affordances of IVR environments

In immersive virtual reality (IVR) environments, digital landscapes blur the lines between the physical and the simulated worlds. The appeal and effectiveness of these environments stem not only from their technological capabilities but also from the profound psychological experiences they create. Central to understanding these experiences, two fundamental constructs shape the very essence of user experiences: presence and agency.

Imagine stepping into a virtual world where the boundaries between reality and imagination dissolve, and you find yourself fully immersed in an alternate reality. This sensation, known as presence, transcends mere visual or auditory stimuli. Presence in the context of virtual reality (VR) refers to the sensation of "being there" in the virtual environment, often described as a feeling of immersion or the perception of actually being physically present in the simulated world (Held & Durlach, 1992; Slater & Wilbur, 1997). It encompasses a sense of spatial presence, where users feel as if they are occupying the virtual space, as well as social presence, which involves the perception of other entities within that space (Biocca, 1997). As researchers Held and Durlach (1992) put it, presence is not just about seeing and hearing; it's about experiencing the virtual environment as if it were tangible, as if you could reach out and touch it. As users inhabit the virtual environment, they often exhibit physiological responses mirroring those evoked in physical reality (Sanchez-Vives & Slater, 2005).

However, presence alone is not enough to fully immerse oneself in the virtual experience. A contributing factor, agency, refers to the sense of control or influence that users feel they have over their actions and the environment within the IVR space (Slater et al., 2009). It encompasses the freedom to navigate the virtual environment, interact meaningfully with virtual elements, and perceive cause-and-effect relationships within the virtual world (Slater & Wilbur, 1997). With agency, users become active participants in their virtual adventures, free to explore, interact, and shape the world around them. In the words of Slater and Wilbur (1997), the agency is the key to unlocking the full potential of immersive virtual environments, empowering users to navigate through digital landscapes with a sense of purpose and autonomy.

Presence and agency are closely intertwined in immersive virtual reality experiences. The level of presence experienced by users can significantly impact their sense of agency within the virtual environment (Ahn et al., 2014). For instance, when users feel a strong sense of presence, they are more likely to perceive their actions within the virtual world as having real consequences, thus enhancing their sense of agency (Slater et al., 2009). Conversely, a lack of presence may diminish users' feeling of agency, as they may perceive their interactions with the virtual environment as disconnected or inconsequential (Kizony et al., 2017). Together, presence and agency form the bedrock of IVR experiences, shaping the way users interact with and perceive virtual environments. Research has shown that enhancing presence and agency can lead to more engaging and effective VR experiences across various domains, including education, training, and therapy (Dede, 2005; Powers & Holmes, 2020).

Consider, for instance, the use of IVR in educational settings. With a heightened sense of presence, students can dive deep into virtual worlds, exploring complex concepts with unparalleled clarity and engagement (Dede, 2005). And with agency at their fingertips, they can actively participate in their learning journey, experimenting, problem-solving, and discovering at their own pace. In a study by Ahn et al. (2014), participants who experienced a virtual simulation of deforestation with a high degree of presence reported greater concern for environmental issues compared to those who experienced a low-presence version of the simulation. This suggests that increasing presence can lead to more impactful emotional and cognitive responses.

In the context of virtual training environments, higher levels of agency have been associated with improved learning outcomes and skill acquisition. For instance, in a study by Kizony et al. (2017), stroke patients who had a greater sense of agency in a VR-based rehabilitation program demonstrated greater improvements in upper limb motor function compared to those with lower agency. Meanwhile, in therapeutic contexts, the fusion of these two constructs also holds immense potential for healing and transformation. This suggests that through carefully crafted IVR simulations, therapists can create immersive experiences that evoke a strong sense of presence and agency, allowing individuals to confront and overcome their fears in a safe and controlled environment (Powers & Holmes, 2020).

In summary, presence and agency are fundamental aspects of immersive virtual reality experiences, influencing users' perceptions, behaviors, and outcomes within virtual environments. Indeed, the possibilities afforded by presence and agency in IVR environments are as vast as the digital landscapes they inhabit. From education to therapy, entertainment to training, these two constructs serve as guiding beacons, illuminating the path toward more immersive, engaging, and impactful virtual experiences.

The Potential of Immersive Virtual Reality for Learning and Development

Immersive Virtual Reality (IVR) technology has gained substantial interest in the educational sector over recent years, offering a unique and engaging approach to learning. Unlike traditional methods confined to textbooks and lectures, IVR creates simulated environments that immerse students in the subject matter, fostering deeper understanding and knowledge retention (Merchant et al., 2014; Radianti et al., 2020). The field is rapidly growing with significant potential to enhance learning experiences, as research highlights IVR's ability to improve engagement, motivation, knowledge retention, and skill acquisition (Chang & Hwang, 2019; Makransky & Lilleholt, 2018).

Current studies indicate that IVR can enhance various aspects of learning. For instance, it can significantly impact education by enhancing engagement and motivation (Hamilton et al., 2021) and improving knowledge retention and skill acquisition (Lee & Wong, 2014). The immersive nature of VR creates a sense of presence, making students feel like they are actively participating in the learning experience, leading to improved learning outcomes (Makransky & Lilleholt, 2018). This is particularly valuable in complex subjects that benefit from spatial representation and interactive experiences (Marougkas et al., 2023; Pellas et al., 2021). Beyond individual learning, IVR also holds promise for fostering collaboration. By simulating real-life scenarios, IVR can encourage teamwork and communication skills, supporting collaborative learning (Scavarelli et al., 2021; Zheng et al., 2019). This multifaceted approach highlights IVR's potential to transform various educational contexts, from traditional classrooms to specialized training environments.

However, the research on IVR in education also highlights several challenges and limitations. Some researchers caution against overhyping IVR's benefits, noting that IVR experiences can be passive and non-interactive if not designed thoughtfully (Fowler, 2015). For IVR to be truly effective, learning experiences must be interactive and allow active student participation (Fowler, 2015). In addition to that, significant challenges in design, implementation, cost, and accessibility remain. Also, the technology required for IVR can be expensive, and some students may experience motion sickness or other physical discomfort, limiting widespread adoption in schools (Radianti et al., 2020). Furthermore, the potential for cognitive overload is a concern, as VR experiences can be complex and require careful design to avoid overwhelming learners (Parmaxi, 2023).

Despite these challenges, the current state of research underscores VR's potential as a powerful tool for education. As IVR technology continues to develop and become more affordable, we can expect more innovative and effective VR learning experiences to emerge. Extensive reviews of the literature highlight IVR's ability to enhance engagement, cognition and metacognition, knowledge retention, transfer, experiential learning, and soft skills and collaboration. However, more extensive studies across diverse educational settings are needed to solidify the evidence base (van der Meer et al., 2023). The following section discusses a detailed analysis of IVR, and the learning related to each specific field.

Engagement and Motivation

One of IVR’s most compelling advantages lies in its ability to boost student engagement and motivation. IVR environments create a powerful sense of presence, transporting students from passive observers to active participants in the learning experience. Studies by Parong and Mayer (2018) and Huang et al. (2010) consistently demonstrated that students in IVR environments exhibit higher levels of engagement compared to traditional classroom settings. This heightened engagement translates into a more positive attitude towards learning. Emphasized by Makransky and Lilleholt's (2018) findings that IVR simulations can boost intrinsic motivation and improve learning outcomes.

Early studies on VR’s role in motivation emphasized VR's potential to increase learning motivation (Wickens, 1992). However, these initial investigations often viewed motivation as a single, undifferentiated concept. This perspective neglected the multifaceted nature of motivation, which includes factors like regulatory styles, interests, and attributions. More recent research has shifted its focus toward the intrinsic and extrinsic aspects of motivation (Ewert et al., 2013; Huang et al., 2010; Limniou et al., 2008; Zavalani & Spahiu, 2012). For instance, Limniou et al. (2008) compared traditional video animations with VR environments to explore their impact on student interest and motivation. Their findings revealed that students in the VR group reported higher enthusiasm and intrinsic motivation toward the learning content. Despite these promising results, the current understanding of motivation in VR education is limited. Future studies should delve deeper into these sub-components and explore how motivation interacts with factors like engagement to optimize learning experiences.

Cognition and Metacognition

While research suggests IVR can significantly enhance cognitive engagement, spatial awareness, and emotional involvement, leading to improved learning (Bellgardt et al., 2023), there are also concerns about potential drawbacks like cognitive overload and negative psychological effects. Studies by Rieger and Risch (2023) and Yang et al. (2024) highlight VR's potential to create near-realistic experiences, particularly beneficial for subjects requiring practical engagement and situational understanding. Bellgardt et al. (2023) further strengthen this notion by demonstrating VR's effectiveness in conveying complex scientific concepts through interactive simulations.

VR's ability to foster cognitive learning can be attributed to its role in building mental models. As Salzman et al. (1999) proposed, immersion can increase user engagement, and this increase strengthens the association of new information with existing knowledge structures (schemas). Ahn et al. (2016) reinforces this notion, suggesting that VR's rich sensory information replicates real-life scenarios more effectively than traditional media, leading to more efficient schema building. On the other hand, Wickens (1992) offers an alternative perspective on VR's role in cognitive learning, suggesting that VR environments can enhance spatial and perceptual abilities by creating tailored realities specifically designed for learning objectives. This approach acknowledges that VR experiences do not need to mirror the physical world perfectly but rather offer a unique platform optimized for knowledge acquisition. However, Roettl and Terlutter's (2018) findings raise caution that IVR's immersive nature, while captivating, can also increase cognitive load, potentially hindering learning if not managed effectively. This highlights the need for a nuanced approach that optimizes the learning experience by balancing immersion with appropriate instructional design.

In the context of metacognition, or "thinking about thinking.", studies by Kniffin et al. (2014), Sakdavong et al. (2019), and Chen and Hsu (2020) explore how VR can support self-regulation, a key aspect of metacognition. While some research, like Mitsea's (2022) work in therapy, focuses on areas distinct from traditional education, others, like Chen and Hsu's (2020) language learning study, demonstrate VR's potential to enhance self-efficacy and self-regulation in educational contexts.

Knowledge Retention and Transfer

IVR can enhance knowledge retention by allowing students to actively engage with the learning material rather than passively receiving information (Makransky et al., 2019). Studies show that IVR's interactive and immersive capabilities contribute to improved knowledge retention and a deeper understanding of complex concepts (Mikropoulos & Natsis, 2011; Sitzmann et al., 2018). For instance, Makransky and colleagues (2019) conducted a study on science lab simulations and found that students using IVR had a better grasp of complex scientific concepts. The IVR simulations allowed students to visualize and interact with abstract content in three dimensions, facilitating a deeper understanding. In retention, Sitzmann et al. (2018) and Mikropoulos and Natsis (2011) found that IVR learning experiences led to improved student performance on knowledge retention tests compared to lecture-based learning methods or in a lab environment (Mikropoulos & Natsis, 2011; Sitzmann et al., 2018). In another study, Krokos, and colleagues (2019) demonstrated that participants learning through IVR exhibited better knowledge retention due to the spatial memory benefits of immersive environments. IVR's ability to create realistic scenarios can also facilitate the transfer of learned knowledge to real-world applications. For example, a VR simulation for surgical procedures can allow medical students to practice their skills in a safe and controlled environment before operating on real patients.

Experiential and Active Learning

One of the most significant advantages of IVR is its ability to create experiential learning opportunities. Unlike passive learning methods, IVR allows students to actively engage with the learning material. By transporting them to virtual worlds and enabling interaction with objects and scenarios, IVR facilitates a deeper understanding of complex concepts. Dede et al. (2009) conducted a comprehensive review of IVR applications in education, highlighting its potential to create simulations for various subjects, from dissections in biology classrooms to virtual tours of historical landmarks (Dede et al., 2009). This immersive quality allows students to learn by doing, fostering a more meaningful connection with the subject matter. VR's potential for experiential and active learning by simulating real-world environments and scenarios allows students to practice skills and apply knowledge in safe, controlled settings. For example, medical students can perform virtual surgeries, and engineering students can explore complex machinery without the risks and costs associated with physical prototypes (Freina & Ott, 2015). This hands-on approach not only enhances understanding but also prepares students for real-world applications.

Soft Skills, Collaboration, and Social Interaction

Immersive Virtual Reality (IVR) simulations provide controlled environments for practicing essential soft skills, such as communication, collaboration, and social interaction—skills critical across diverse professional fields (Radianti et al., 2020). Through realistic scenarios, IVR enables users to develop these skills while receiving feedback on their performance in a low-risk setting. For example, healthcare training programs often use VR simulations to help practitioners refine patient communication, fostering empathy and improving interpersonal skills in settings that mimic real-life interactions (Riches et al., 2020).

Social VR platforms, like Engage and AltspaceVR, further enhance collaborative learning by enabling students to work together in virtual classrooms, regardless of physical location (Dalgarno & Lee, 2010). Research indicates that shared VR experiences can deepen cognitive engagement, enhance problem-solving abilities, and strengthen teamwork. For instance, VR-based training in business education has shown improvements in students' negotiation and team collaboration skills by replicating real-world project management scenarios (Jensen & Konradsen, 2018). These immersive interactions offer a level of engagement and presence often unmatched by traditional online platforms.

However, while VR shows substantial promise for soft skills development, there are also limitations and potential challenges to consider. VR environments demand high-performance hardware and reliable internet connections, which can create accessibility barriers for students from under-resourced backgrounds (Radianti et al., 2020). Additionally, extended VR sessions may contribute to "social fatigue," where users feel overly dependent on digital interactions, potentially diminishing the benefits of face-to-face engagement (Makransky et al., 2019). Moreover, the initial novelty of VR can enhance engagement, but overuse or poorly integrated sessions might lead to reduced enthusiasm and effectiveness over time (Freina & Ott, 2015).

Beyond skill development, IVR also offers unique insights into social behavior and interaction. Yee and Bailenson (2007) explored how virtual avatars affect user behavior, finding that users exhibited more confident or intimate behaviors when assigned attractive or tall avatars. This phenomenon suggests that virtual self-representations can shape social interactions within the VR environment. Further, Yee et al. (2007) observed that social norms like personal space and eye gaze were consistently maintained in VR, indicating that traditional social rules often translate into virtual spaces. This insight underscores VR’s potential as a platform for studying and improving real-world social interactions.

Integrating cognitive and social perspectives in VR research offers additional benefits. Bailenson et al. (2008) examined how visual attention, and spatial proximity could improve teacher-student interactions in VR environments, suggesting that VR may provide tools for enhancing classroom dynamics through customized visual cues and proximity adjustments. The inclusion of virtual co-learners also showed promise for improved learning outcomes. Another study by Bailenson and Yee (2005) investigated mimicry, where users unconsciously imitated virtual characters who mimicked them, aligning with the "chameleon effect" observed in real-world social interactions. VR’s potential as an "empathy machine" is particularly promising for fostering prosocial behavior. Herrera et al. (2018) compared traditional empathy interventions with VR-based experiences, finding that while both approaches increased self-reported empathy, participants in the VR group were more likely to take prosocial actions afterward. This suggests that VR could enhance empathy training beyond traditional methods by immersing users in others’ perspectives.

In summary, while IVR holds significant potential for developing soft skills and improving social interaction, it requires balanced implementation and a critical understanding of its limitations. Acknowledging VR’s benefits alongside its challenges will allow for more effective integration of these technologies in educational and professional contexts.

Beyond the Hype: Challenges and Considerations

The adoption of Immersive Virtual Reality (IVR) in educational settings promises transformative potential but is accompanied by significant challenges and limitations. These barriers range from high costs and technical complexities to pedagogical and health concerns, each impacting the feasibility and effectiveness of VR integration in classrooms (Beck et al., 2023; Radianti et al., 2020). One of the most significant barriers to VR implementation in education is the high cost associated with acquiring and maintaining VR equipment. VR headsets, powerful computers, and specialized software represent a significant financial investment that many educational institutions find unaffordable, particularly those located in less financially supported areas (DigitalDefynd, 2024). This financial strain limits widespread adoption and creates disparities in access to advanced learning tools (DigitalDefynd, 2024; Radianti et al., 2020). The rapid evolution of VR technology further compounds these financial constraints, necessitating continuous updates and maintenance, adding to the complexity and cost.

Moreover, the high costs of VR technology can exacerbate existing educational inequalities, as only well-resourced schools are likely to afford and maintain the necessary infrastructure. This digital divide means that students in underfunded schools miss out on the benefits of VR-enhanced learning, widening the gap in educational opportunities (BMC Medical Education, 2024). Ensuring accessibility and inclusivity in VR is crucial for promoting an equitable educational environment where all students, regardless of their background, can benefit from immersive learning experiences (Radianti et al., 2020).

Another critical issue is the lack of high-quality educational content tailored to VR platforms. Developing engaging, effective VR educational materials requires significant resources and expertise, often only accessible to well-funded institutions or through partnerships with tech companies. This is crucial because not all VR experiences are created equal. Effective VR design must incorporate elements that encourage interaction, exploration, and critical thinking tailored to specific learning objectives (Dede et al., 2017). The fast-paced evolution of

VR technology deepens these challenges. Continuous updates and maintenance are needed to keep up with advancements, placing additional strain on institutional budgets and technical capabilities (DigitalDefynd, 2024). On the other hand, effective use of VR in teaching requires not only technical proficiency but also a shift in pedagogical strategies. Professional development and support are essential for teachers to become proficient with VR tools and design VR-enhanced curricula (Dede et al., 2017; Radianti et al., 2020). This transition from lecture-based teaching methods to VR-enhanced learning can be daunting, requiring significant time and resource investments. Moreover, the empirical evidence is not yet conclusive regarding the long-term benefits of VR in education, emphasizing the need for rigorous, long-term studies to fully understand its potential (Radianti et al., 2020).

Health concerns associated with prolonged use of VR, such as eye strain, headaches, and motion sickness, also pose significant challenges. These issues, commonly called cybersickness, can deter the use of VR in educational settings, particularly for younger students who may be more susceptible to such side effects. Addressing these health concerns is crucial to ensure safe and comfortable VR experiences for students (DigitalDefynd, 2024).

Empirical studies, such as systematic reviews and meta-analyses, highlight these challenges. For instance, a systematic review of VR in nursing education noted significant improvements in theoretical knowledge and practical skills among students using VR compared to traditional methods. However, it also highlighted the technological and financial barriers that limit the broader application of VR in education (BMC Medical Education, 2024). These results demonstrate the importance of addressing these challenges to realize VR's full potential in educational settings. While VR offers exciting possibilities for transforming education, significant challenges must be addressed to ensure its effective and equitable implementation.

Financial, technological, pedagogical, health, and equity issues present substantial barriers that require collaborative efforts from educators, policymakers, and technology developers. Ongoing research and development are crucial to overcoming these limitations, as is the need for more rigorous, long-term studies to fully understand VR's educational potential. Only through such concerted efforts can the full potential of VR in education be realized.

Diversity, Equity, and Inclusion in Immersive Virtual Reality (IVR) Environments

The integration of Immersive Virtual Reality (IVR) technologies into educational settings offers promising avenues for advancing Diversity, Equity, and Inclusion (DEI). However, these opportunities are paired with significant challenges that educators and developers must carefully navigate. IVR can simultaneously serve as a powerful tool to promote DEI and as a medium that inadvertently perpetuates existing biases and inequalities if not critically examined and structured.

IVR as a Tool for Addressing DEI Issues

IVR has the potential to create inclusive and accessible environments, particularly for DEI training and education on sensitive topics like unconscious bias and cultural empathy. For instance, Bursztein and colleagues (2024) describe how Google employed VR in its DEI training to offer employees an immersive experience that raised awareness of unconscious biases and fostered empathy across diverse cultural backgrounds. This approach allowed participants to virtually experience different perspectives, aiding in their understanding of complex social dynamics and biases, which other DEI training methods might not effectively capture.

In educational contexts, IVR environments can also offer students from underrepresented groups an immersive experience that fosters engagement and inclusion. According to Witchel and Lee (2022), these immersive experiences help bridge the gap between abstract theoretical concepts and real-life applications, potentially increasing accessibility for students from diverse backgrounds who may not have had prior exposure to advanced educational tools. Zallio and Clarkson (2022) also note that immersive environments, such as the metaverse, are being designed with inclusivity in mind, aiming to ensure that these digital spaces provide equitable access to all users. Their research stresses the importance of creating immersive learning spaces that are safe, diverse, and inclusive by design, which can help address issues of accessibility and equal representation in virtual learning.

Challenges in IVR: Replicating and Reinforcing Inequity

Despite its potential benefits, IVR can also inadvertently replicate and amplify existing inequities if not designed with DEI principles at the forefront. Franks (2017) underscores the risk that, because VR environments are crafted by developers who operate within certain cultural and social biases, these biases can become embedded in the technology itself. This phenomenon, referred to as "the desert of the unreal," highlights how virtual worlds, often created with little regard for diverse user experiences, can unintentionally reinforce societal inequalities. For example, VR developers might not account for racial, gender, or ability-based differences in designing avatars or in creating scenarios, which could lead to alienation or misrepresentation of certain groups.

Bradshaw (2017) stresses the importance of critical pedagogy in educational technology, urging developers to consciously integrate cultural and social awareness into their design processes. In her view, the ethical responsibility in educational technology goes beyond simply providing access; it involves examining and addressing any underlying assumptions or biases embedded in the technology itself. Bradshaw argues that failing to consider these factors risks perpetuating systemic inequalities, as technologies can inadvertently reflect the cultural and ideological norms of their creators.

Moreover, Bradshaw's (2018) perspective on implicit narratives within educational technologies highlights how unexamined design elements can propagate dominant cultural norms that may alienate or disadvantage certain user groups. In IVR, for instance, the creation of standardized learning environments without critical consideration of diverse cultural narratives can inadvertently reinforce hegemonic worldviews. By neglecting these "hidden curricula," IVR technology risks becoming an exclusionary space, rather than an inclusive one, particularly if culturally specific narratives are embedded unconsciously by the designers.

Ensuring Inclusive Design and Cultural Sensitivity

Addressing these challenges necessitates that IVR development be approached with a commitment to inclusivity and equity. Slot and colleagues (2019) advocate for a professional development model that includes training for educators on how to use virtual environments in a way that fosters intercultural competence and awareness. By equipping educators with the skills to navigate and utilize VR in culturally sensitive ways, IVR can become a tool that empowers rather than excludes.

Bradshaw (2018) also emphasizes the need for educational technology designers to engage in reflective practices to ensure their tools promote equity and inclusivity. She calls for the integration of a critical pedagogical approach that not only acknowledges but actively addresses power dynamics, striving to avoid replicating social biases. This means engaging with diverse groups during the development process to create environments that reflect a variety of perspectives and avoid reinforcing existing biases. By embedding social justice within the instructional design process, educators and developers can use VR not just as a learning tool, but as a vehicle for meaningful DEI engagement.

Future Directions and Potential Developments for Immersive Learning

Several trends and advancements are expected to shape the future of VR in education. First, it is crucial to remember that VR does not replace any teaching method but rather serves as a powerful tool to complement and enrich existing educational frameworks (Radianti et al., 2020). To be successful, VR implementations need to be seamlessly integrated with existing lesson plans, textbooks, and learning materials, creating a holistic and engaging learning experience that leverages the strengths of learning approaches. Looking ahead, continued research and development efforts are paramount to the future of VR in education. More research delving deeper into the most effective ways to design and implement VR learning experiences is needed, maximizing their impact on student learning outcomes (Beck et al., 2023). It is projected that the advancements in VR technology itself, particularly in resolution, comfort, and affordability, will play a critical role in widespread adoption (DigitalDefynd, 2024).

The integration of immersive virtual reality (IVR) with technologies like artificial intelligence (AI) and machine learning (ML) represents a significant potential for advancing personalized and adaptive learning experiences (Makransky & Petersen, 2021; Radianti et al., 2020). AI has potential to support individualized learning by analyzing students' interactions within VR environments, identifying specific learning needs, and adjusting the content, accordingly, creating tailored experiences based on student progress and performance (Fisher et al., 2022). However, realizing this potential also requires acknowledging the practical and ethical challenges associated with implementing AI, such as privacy concerns, data accuracy, and the need for continuous monitoring to avoid bias in personalized learning pathways (Dede & Richards, 2017; Radianti et al., 2020). The combination of VR with AI also has applications in fields that benefit from high-fidelity simulations. For instance, engineering and medical training programs could use VR to create simulations that adjust in real time to a trainee's actions, improving skill acquisition through context-specific feedback (Fisher et al., 2022; Radianti et al., 2020). In medical training, for example, AI-driven VR scenarios could replicate complex surgeries with a high degree of realism, enabling students to practice in a risk-free environment that would otherwise be unavailable in a traditional classroom setting (Makransky & Petersen, 2021).

Pedagogically, the potential for VR to support active learning requires further innovation from educators to fully leverage VR's interactive and experiential capabilities. New teaching strategies are needed that go beyond conventional methods, incorporating VR in ways that deepen student engagement and enhance learning outcomes. For instance, VR-based experiential learning can allow students to practice complex skills and apply theoretical knowledge within immersive environments that simulate real-world scenarios, which may foster greater retention and understanding (Hupont Torres et. al., 2023).

Expanding social VR platforms that allow students to collaborate across physical distances represents another promising direction for immersive learning. Unlike standard online collaborative tools, social VR offers the potential for a shared presence, where students interact within the same virtual environment, facilitating teamwork and communication skills in ways that are challenging to replicate in non-immersive settings. Research on social VR, such as virtual lab simulations in STEM education, suggests that these environments can enable students to work through problems collaboratively in real-time, offering insights and feedback as they navigate shared challenges (Hupont Torres et. al., 2023).

Finally, ensuring accessibility and equity is essential for the meaningful integration of VR in education, especially given the challenges highlighted in Diversity, Equity, and Inclusion

(DEI) research. While IVR holds potential for inclusive and accessible learning—such as through DEI training that fosters empathy and cultural awareness—these opportunities are only realized if the technology is developed with critical awareness. For example, initiatives like Microsoft's SeeingVR adapt VR content for visually impaired users, a step toward ensuring accessibility. However, as Bradshaw (2017, 2018) emphasizes, creating genuinely inclusive IVR experiences requires more than accessibility features; it involves embedding cultural sensitivity into the design itself to prevent reinforcing biases inherent in unexamined narratives and default perspectives. Developers and educators must be mindful of diverse cultural and social contexts, actively engaging with diverse perspectives during the design process to avoid alienation or misrepresentation of underrepresented groups. As VR technology becomes increasingly affordable, bridging the digital divide remains a priority. Ensuring that all students, regardless of background or ability, can access and benefit from VR will allow IVR to reach its transformative potential as a tool not only for educational advancement but for fostering inclusivity and social justice in learning environments.

Investigating the Interplay of IVR and TEs

The integration of Immersive Virtual Reality (IVR) with Teaching for Transformative Experiences (TTE) holds significant promise for enhancing educational practices. This section delves into the potential benefits of integrating VR with TTES, the role of presence and agency in transformative experiences (TEs), and the rationale for exploring this synergy. It also highlights the research gap in the existing literature and discusses the potential contributions of VR-enhanced TTES to the field of education.

Potential Benefits of Integrating IVR with TTES

Integrating IVR with TTES offers a range of potential benefits that could revolutionize educational experiences. IVR provides a highly immersive environment that allows learners to engage deeply with content, offering an interactive and engaging way to learn compared to lecture-based methods. Research indicates that VR can significantly enhance the quality of educational activities by creating an immersive and interactive learning environment that fosters deeper understanding and retention of knowledge (Hamilton et al., 2021; Radianti et al., 2020). By simulating real-world scenarios, IVR can help students apply theoretical knowledge in practical contexts, thus bridging the gap between classroom learning and real-life application (Mystakidis & Lympouridis, 2023).

Presence and agency are critical components in the effectiveness of TEs facilitated by IVR. Presence refers to the sense of "being there" in a virtual environment, which can significantly enhance learners' engagement and immersion (Witmer & Singer, 1998). A strong sense of presence may lead to more profound and meaningful learning experiences as students feel more connected to the content and activities within the IVR environment (Lombard & Ditton, 1997). Agency, on the other hand, involves the learners' ability to control and influence their actions and interactions within the virtual space. High levels of agency empower learners to explore and experiment within the virtual environment, leading to more active and participatory learning experiences (Bowman & McMahan, 2007; Freina & Ott, 2015).

Exploring the potential synergy between IVR and TTES is crucial for advancing educational practices. The affordances of IVR, such as enhanced presence and agency, align well with the goals of TTES to promote deep and meaningful learning experiences (Makransky & Petersen, 2021). By integrating IVR with TTES, educators can create more immersive and engaging learning environments that facilitate higher levels of student engagement and motivation (Chen et al., 2021). This integration can help address the challenges of fostering high-quality, transformative experiences within traditional classroom settings, where the complexity and authenticity of real-life experiences are often lacking (Pugh, 2011).

Additionally, IVR can offer safe and realistic opportunities for students to apply scientific concepts and other curricular content in virtual environments, thus promoting deeper understanding and retention of knowledge (Salzman et al., 1999). This approach can also allow educators to tailor learning experiences to individual student needs and interests, providing more personalized and effective instruction (Makransky & Petersen, 2021). Moreover, IVR-enhanced TTES can contribute to the development of evidence-based practices for transformative education. By leveraging the unique capabilities of IVR, educators can design instructional activities that foster higher levels of presence and agency, leading to more meaningful and impactful learning experiences (Pugh et al., 2010). This integration can also help overcome the challenges of assessing transformative experiences, as VR provides opportunities for authentic and observable interactions within controlled educational settings (Radianti et al., 2020).

Despite these potential benefits, the current state of TE research is not even close to understanding the synergy between TTES and immersive experiences. Today, there is a notable lack of research on the integration of IVR with TTES. While there have been limited attempts at the use of various technologies to facilitate transformative experiences (Heddy et al., 2023), the specific impact of IVR on TTES has not yet been explored. When it comes to immersive learning methodologies, current literature often focuses on the outcomes of immersive learning technologies without thoroughly examining the instructional strategies and practices that underpin these technologies (Beck et al., 2023). This gap highlights the need for empirical studies to investigate how IVR can be effectively integrated with TTES to enhance educational outcomes and foster deeper learning experiences.

Conclusion

The exploration of the integration of Immersive Virtual Reality (IVR) with the Teaching for Transformative Experience (TTES) model has unveiled a significant research gap and presented a compelling rationale for the proposed intervention study. While the potential of IVR in enhancing educational experiences has been acknowledged, its specific impact on fostering Transformative Experiences (TEs) through the TTES model remains underexplored. This gap highlights the necessity of investigating how IVR can be leveraged to facilitate deeper and more meaningful learning outcomes, thereby enriching the existing body of educational research and practice.

The potential contributions of IVR-enhanced TTES to educational practice and research are substantial. By integrating IVR with TTES, this study aims to harness the key affordances of IVR, such as presence and agency, to create more immersive and interactive learning environments. These environments are expected to significantly increase student engagement and motivation, providing learners with safe and realistic opportunities to apply scientific concepts in virtual settings. Furthermore, the ability of IVR to tailor learning experiences to individual student needs and interests promises to enhance the personalization and effectiveness of educational interventions.

The implications for future research and educational practice are far-reaching. This study is poised to offer valuable insights into the design and implementation of IVR-enhanced learning activities that promote TEs. Such insights will be crucial for developing evidence-based practices that can be adopted across various educational contexts. Moreover, understanding the interplay between presence, agency, and transformative experiences within IVR environments will inform the creation of more effective instructional strategies, thus advancing the theoretical and practical understanding of immersive learning technologies.

In summary, the literature review has highlighted the promising yet underexplored potential of integrating IVR with the TTES model to foster TEs. This intervention study seeks to address this gap, contributing to both the theory and practice of transformative education. By doing so, it aims to pave the way for future research that will continue to explore and expand the transformative potential of immersive educational technologies.

Chapter 3: Methods

Overview

This study aimed to investigate Transformative Experiences (TE) that are implemented and facilitated through immersive virtual reality (IVR). The intervention was developed based on the Teaching for Transformative Experiences for Science (TTES) model. More specifically, the effectiveness of the IVR+TTES intervention and the impact of presence and agency was explored, leading to a more nuanced understanding of how students experience TE and how IVR technology can facilitate this experience. A significant gap was identified in the relevant literature regarding the shallow implementation or disconnection from other pedagogical activities in class, as well as issues related to individual differences in being ready for TE and assessment. To address these gaps, an IVR+TTES intervention was designed and implemented. This chapter presents the research design of this study by referring to the rationale behind data collection and analysis procedures as well as participant selection, the chosen sampling method, research context, data collection, and data analysis tools.

Research Design

This study employed a quasi-experimental, one-group pretest-posttest design with a mixed-methods approach (Reichardt, 2019). This design involved measuring a dependent variable before and after an intervention to assess the intervention's impact. One-group designs are often utilized in contexts where including a control group is challenging or impractical, such as in educational or health interventions conducted at a single site (Reichardt, 2019). However, as it lacks a control group, this design is susceptible to threats to internal validity, such as history, maturation, testing effects, and regression to the mean. To address these validity concerns, a mixed-methods approach was integrated into the study design.

A convergent parallel mixed-methods design was specifically selected (Creswell, 2017; Plano Clark, 2017; Tashakkori et al., 2020), as it allowed both quantitative and qualitative data to contribute equally to the findings. This methodology was instrumental in drawing upon the strengths of both data types, fostering a deeper understanding of the learning experience (Creswell, 2017). In this approach, quantitative and qualitative data were collected and analyzed separately and later interpreted together.

Quantitative data were gathered from pretest and posttest student surveys to assess the extent to which the IVR+TTES pedagogy and technology influenced student learning and transformative experiences. In tandem, qualitative data were obtained from semi-structured student interviews, which provided a rich understanding of students' lived experiences during the IVR+TTES learning sessions and how these experiences affected their real-life engagement with the content.

Participants

Participants in this study were undergraduate students enrolled at Southern University in the United States, selected through a combination of convenience and criterion sampling. To ensure a learning environment with minimal prior exposure to architecture, the primary selection criterion excluded students enrolled in the College of Architecture or those who had completed any advanced-level architecture courses. This criterion was essential for creating a purposeful learning setting where students lacked extensive background and experience in the content area.

Students were recruited from the Educational Psychology Department due to the convenient proximity of the technology lab, which facilitated both the recruitment process and attendance for intervention sessions. Following approval from the Institutional Review Board (IRB), the researcher coordinated with instructors teaching undergraduate educational psychology courses to invite interested students to participate voluntarily. These courses, which included two distinct subjects across four sections offered in the Fall 2024 semester, were core requirements in the "professional studies for teacher education" program, designed for students in teaching majors.

In collaboration with course instructors, all intervention protocols, data collection procedures, and other study components were finalized before the start of data collection. The study design was guided by established protocols from previous research (Alongi et al., 2016; Heddy et al., 2016, 2023; Pugh, 2004, 2020; Pugh & Girod, 2007; Pugh et al., 2010), incorporating pretest-posttest surveys and semi-structured interviews to capture a comprehensive view of students' transformative experiences and the effects of immersive virtual reality (IVR) on their learning.

Participation in the study was entirely voluntary. Students who opted out of either the intervention or data collection continued their coursework without disruption, as intervention sessions were held in the college computer lab on separate days scheduled around the availability of both students and the researcher.

At the time of data collection, 132 students were enrolled in the targeted courses. However, due to a potential conflict of interest—since the researcher instructed one section—25 students were removed from the recruitment pool, resulting in 107 eligible students. Of these, 20 students initially signed up for intervention sessions; however, three did not attend, and another three did not complete all sessions. Thus, the final sample comprised 14 university students who met the inclusion criteria of limited architectural knowledge.

Participant ages ranged from 20 to 40, with a balanced gender distribution (7 male, 7 female). Racially, most participants identified as White/Caucasian, with one participant identifying as Asian. Participants rated their confidence with technology on a 10-point scale, averaging 6.8, indicating a generally high level of comfort with technological tools. Additionally, prior experience with virtual reality was assessed: 78.57% of participants had used a VR headset at least once, primarily through school or family exposure, while 21.43% had no prior experience beyond observing others. Although none owned a VR headset, two expressed interests in future purchase. This familiarity with VR technology was desirable, as it minimized the novelty effect that could otherwise bias responses.

Finally, none of the participants had received formal training in architecture or completed architecture coursework, though two students mentioned having a family member who worked as an architect.

Data Collection

Quantitative Measures

The quantitative data was collected to evaluate the efficacy and variance differences of the IVR+TTES intervention through pre- and post-surveys. These surveys were the Transformative Experience Survey (Pugh et al., 2010), the Situational Interest and Individual Interest Scales (Linnenbrink-Garcia et al., 2010), the Igroup Presence Questionnaire (IPQ) (Schubert et al., 2001), the Scale of Agency Rating System (SOARS) (Polito et al., 2013), and a Knowledge Assessment, which was collaboratively developed by an SME faculty member from the College of Architecture and the researcher.

The Transformative Experience Survey (TE) comprised 28 Likert scale items designed to assess three components of TE: active use, expansion of perception, and experiential value. Students rated the extent to which they applied learned concepts to everyday life experiences, responding to statements such as "I find myself contemplating architecture in everyday situations" on a 5-point Likert scale (ranging from 1 = strongly disagree to 5 = strongly agree). This survey, validated in prior studies, has consistently demonstrated high-reliability scores (Koskey et al., 2018; Pugh, 2011; Pugh et al., 2017). Recent research by Heddy et al. (2023) further confirmed its reliability (pretest: $\alpha = .97$; posttest: $\alpha = .98$).

The Igroup Presence Questionnaire (IPQ), developed by Schubert and colleagues (2001), evaluated spatial presence, involvement, and experienced realism through 14 items. Spatial presence gauges the participant's feeling of physical presence in the virtual environment, while involvement measures attention devoted to virtual reality. Experienced realism assesses subjective perceptions of realism within the virtual environment. This widely used psychometric instrument incorporates normal and reversed items to mitigate response bias and has demonstrated acceptable to high reliability in previous validations (e.g., Vasconcelos-Raposo et al., 2016).

The Scale of Agency Rating System (SOARS) consisted of ten items assessing subjective alterations in a person's sense of agency due to specific experiences. Participants reflected on intervention tasks and rated their agreement with statements on a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree." The SOARS encompasses two factors: involuntariness, reflecting a decrease in perceived control over actions, and effortlessness, indicating increased ease and automaticity of actions. Initially designed for hypnosis, the SOARS has shown strong internal consistency and validity across various contexts, including virtual reality settings. (e.g., Polito et al., 2013).

The Situational Interest Survey and Individual Interest Scale, adapted from Linnenbrink-Garcia et al. (2010), consisted of 12 and 8 items, respectively, rated on a 5-point Likert scale. These surveys gauge situational and individual interest in architecture-related topics, with statements like "I am excited about what I am learning in my architecture class" and "The topics in my architecture class are useful in my life outside of school." Both instruments have been extensively validated and demonstrate high reliability in the literature. (e.g., Chen & Darst, 2002).

Qualitative Data

Informed by the Transformative Experience theory, an interview protocol was meticulously crafted to delve into the interplay among presence, agency, transformative experience. This protocol encompassed a series of interview questions, probes, and follow-up inquiries. Each session interview spanned approximately 30-45 minutes. Conducted via Zoom software, each interview was audio and video-recorded with explicit permission from the interviewees. Subsequently, the interviews were transcribed verbatim, with meticulous attention to accuracy and consistency. Data obtained from interviews went through thorough analysis, employing both deductive and inductive approaches. Deductive analysis was conducted, employing the theoretical framework of the Transformative Experience Theory (Pugh, 2004) and its subcomponents motivated use, expansion of perception and experiential value. In addition, the virtual reality experience was coded under presence and agency. For the questions spontaneously emerging from the flow of interviews, thematic analysis, following the guidelines outlined by Braun and Clarke (2006), was also used to identify emergent patterns in the data. Researcher's notes during and after the interviews supported the analysis of the qualitative data. Memoing and triangulation techniques further bolstered the validation of qualitative data. In addition, the researcher kept a research journal to capture the details of the research process from the beginning to the end. As a result, the combination of all sources was used to triangulate the data collected in addition to the quantitative data.

IVR+TTES Intervention

The Teaching for Transformative Experience in Science (TTES) model is built on three fundamental design principles: the artistic selection and crafting of content, experiential apprenticeship, and the process of doing and undergoing (Pugh, 2020). The first principle, artistic selection and crafting of content, involves educators intentionally curating and presenting ideas in ways that resonate deeply with students' experiences. The second principle, experiential apprenticeship, draws on the foundational concept of apprenticeship and modeling (Dennen & Burner, 2008). The third principle, doing and undergoing, underscores the importance of providing students with opportunities to take meaningful action within a supportive environment. Together, these principles guide educators in crafting interventions that prioritize transformative learning experiences.

TTES interventions focus on facilitating Transformative Experiences (TE) as the product of educational interventions while simultaneously valuing the learning outcomes necessary for sustained TE, interest, and long-term value. This dual focus represents a critical distinction of TTES interventions compared to other learning frameworks, which often prioritize learning outcomes alone. A growing body of research has demonstrated the effectiveness of the TTES design principles in promoting transformative experiences (Pugh et al., 2017), sustained interest (Heddy & Sinatra, 2017), positive affect (Heddy et al., 2017), and conceptual change (Heddy & Sinatra, 2013). Building on this foundation, this study applied these three principles in designing and developing the intervention and learning environment. However, while TTES design principles emphasize the facilitation of TE, they do not explicitly address the design of the learning environment or the specific methodologies for developing and implementing educational interventions.

To address these aspects, this research integrated the TTES framework with design-based research (DBR) guidelines (McKenney & Reeves, 2019), which are tailored specifically for educational research interventions. DBR outlines four core processes essential for designing interventions: analysis and exploration, design and construction, evaluation and reflection, and implementation and spread (McKenney & Reeves, 2019). These processes served as a systematic and iterative framework for the study, enabling the development and refinement of the intervention to align with the educational goals. This combination of DBR processes with TTES principles ensured the intervention was both theoretically grounded and practical, effectively supporting transformative learning experiences.

Analysis and Exploration

The exploration stage began with a comprehensive problem identification process, a thorough investigation of the literature, and the formulation of research questions to guide the effective design and implementation of the learning environment. This phase aimed to identify key study constructs, clarify the theoretical framework, and provide a robust foundation for the intervention design. Initial analyses highlighted the growing body of evidence supporting the benefits of facilitating Transformative Experiences (TE) in learning environments, as well as the challenges associated with implementing the TTES model to achieve these outcomes. Concurrently, learning technologies emerged as a potentially beneficial yet underexplored area for supporting TE facilitation.

Grounded in the theoretical frameworks of TE theory and immersive learning theories, the exploration revealed that the affordances of the TTES model and immersive virtual reality (IVR)—particularly presence and agency—have the potential to complement one another and enhance the effectiveness of TTES interventions. This intersection of theories provided a compelling rationale to investigate how the affordances of IVR could extend the TTES framework’s impact.

A significant focus during this stage was on understanding why exploring the potential of learning technologies, specifically immersive virtual reality, is essential. The investigation revealed that the immersive qualities of virtual environments could address the lack of presence when revisiting lived experiences in the classroom. These qualities facilitate cognitive shifts in students' understanding and contribute to the development of sustained value. As Makransky & Petersen (2021) highlighted, the true benefits of immersive virtual reality environments emerge when instructional methods are carefully designed to leverage their unique affordances. In this study, IVR complements TTES strategies by using presence and agency to restore the authenticity of lived experiences and enhance the effectiveness of TTES activities.

Subsequent exploration centered on the selection and framing of content deemed significant for teaching. According to Pugh (2020), this process involves identifying "big ideas" within a discipline—core concepts with broad explanatory power. For example, evolution is a big idea in biological sciences. Each discipline has its own set of big ideas, and selecting those particularly relevant to students' everyday lives and cultural experiences is a critical consideration. In the context of this study, architecture was chosen as the focal discipline for several reasons. First, the content chosen for the IVR+TTES intervention needed to align with the affordances of the environment and instructional methods to ensure effective outcomes. Second, most previous TE and TTES intervention studies focused on science concepts, leaving a gap in research related to other disciplines. Finally, architecture offered unique opportunities to investigate how instructional methods can connect theoretical learning to real-world applications.

Architectural design involves creating functional spaces that improve the quality of life in both indoor and outdoor environments (Ummihusna & Zairul, 2022). Thus, architectural education should extend beyond classroom learning to foster interest and meaningful learning experiences (Ummihusna & Zairul, 2022). Although traditional architectural education has incorporated site visits and field trips, scholarly studies have yet to investigate these experiences' capacity to intentionally transform students' everyday perspectives. Additionally, architecture students often struggle with three-dimensional thinking and model visualization, which makes connecting real-life experiences to classroom learning challenging (Herrera, 2022). Addressing these challenges, there is increasing interest in leveraging immersive virtual reality environments to support architectural education (Ummihusna & Zairul, 2022; Crosbie, 2020). However, most IVR applications focus on replicating design studios or responding to emergency remote learning needs, such as during the COVID-19 pandemic (Ummihusna & Zairul, 2022). This perspective overlooks the potential of IVR environments to enhance learning when paired with instructional methods that leverage key affordances like presence and agency (Makransky & Petersen, 2021).

The exploration stage also provided critical insights into the integration of diversity, equity, and inclusion (DEI) considerations into the design process. A review of existing literature highlighted several DEI issues associated with IVR in learning environments and strategies to mitigate these concerns. Specifically, IVR technologies were identified as amplifying existing DEI challenges, such as implicit biases or the imposition of dominant cultural perspectives on marginalized groups. Additionally, IVR could introduce new accessibility barriers, including common challenges posed by head-mounted displays (HMDs), such as motion sickness, eye strain (especially for students who wear prescription glasses), and, in rare cases, photosensitive epilepsy (PSE) triggered by visual stimuli. These findings informed the design and implementation stages of the intervention, ensuring that potential DEI issues were addressed to prevent adverse impacts on students' learning experiences.

Design and Development

This phase outlines the design and construction process of the IVR+TTES intervention, encompassing idea generation, content selection, and the design of intervention sessions. As emphasized in the Analysis and Exploration section, the literature review highlighted that the architecture discipline could benefit from integrating virtual spaces with TTES strategies. This integration was deemed valuable for facilitating real-world, out-of-class engagement with core disciplinary ideas at the introductory level, where students often lack extensive subject-matter knowledge. To achieve this, collaboration with a subject matter expert (SME) and a course instructor was essential.

Addressing localized challenges in design-based research (DBR) projects requires both theoretical insights and practical strategies. The DBR process is inherently dynamic, requiring iterative adjustments and collaboration to ensure practical applicability. McKenney and Reeves (2019) state that while there is no universal guideline for navigating design challenges, the process should remain systematic and intentional. The design stage begins with generating draft ideas, which are then iteratively refined by researchers and stakeholders. This collaborative effort aims to establish a robust framework tailored to the local context. The process involves moving from broad, preliminary concepts to selecting the most appropriate and practical ideas for addressing identified challenges (McKenney and Reeves, 2019). This systematic narrowing and refinement ensure alignment with both the theoretical underpinnings of TTES and the practical needs of the educational context.

In alignment with this process, in the Spring of 2024, the researcher reached out to faculty members in the College of Architecture to collaborate on designing the intervention. Two faculty members initially expressed interest, but collaboration continued with only one after communication did not progress with the other. An introductory meeting was scheduled, during which the researcher outlined the intervention concept, the underlying theoretical framework, and the instructional approach planned for the intervention. During this in-person session, the researcher demonstrated various software options to provide an overview of the expected virtual experience. This demonstration aimed to showcase the possibilities to the subject matter expert (SME) and facilitate idea generation. The final decision on software selection was postponed until the learning outcomes and content structure were finalized. The primary goal of this collaboration was to gain expert insights from the SME and to support the integration of architectural content into the IVR+TTES intervention lesson plans. Following this initial meeting, the SME agreed to collaborate with the researcher on designing the intervention, sharing materials from an introductory architecture course tailored for non-major students interested in foundational architectural concepts.

This intervention represented an early attempt to facilitate Transformative Experiences (TE) using IVR and collaborative software, with an awareness of potential technical and procedural challenges. Recognizing the complexities of introducing new technologies in an educational setting, developing materials such as technical and procedural protocols for data collection was critical. Upon receiving the class materials, the researcher created an IVR+TTES intervention manual, detailing the contextual, theoretical, and methodological background, intervention procedures, timeline, learning objectives, and lesson plans. Additionally, a ten-question multiple-choice knowledge assessment was developed to be administered pre- and post-intervention, designed to measure changes in student learning.

In late Summer 2024, the researcher and the faculty SME reconvened to review and discuss the materials developed. During this meeting, the class materials and knowledge assessment were reviewed, and adjustments were made as necessary. The initial list of learning outcomes suggested by the SME for an introductory architecture course designed for non-majors is presented in Table 1 below:

Table 1

Introductory Architecture Course Objectives Provided by SME

Objective List
1. Students will develop the ability to read and critique the built environment. 2. Students will train their sensitivity to design and explore the effect design has on them directly. 3. Students should grow their understanding of architecture and its impact on society. 4. Students will become familiar with the tools and methods used by architectural professionals as well as the criteria by which theorists, historians, and critics regard it. 5. Students will take part in the discourse surrounding contemporary issues in the built environment and be expected to offer their insights.

After reviewing the initial plans, the team decided to simplify the scope of the intervention and its learning objectives. This decision was made due to the potential complexities of using the IVR+TTES approach for the first time, as well as the limited time available. Consequently, the learning objective for the IVR+TTES intervention was refined to: “Students will develop the ability to read and critique the built environment.” Based on this objective, the learning content was organized into distinct categories, outlined in Table 2. This table provides the content structure for the IVR+TTES intervention.

Table 2

IVR+TTES Content Structure

Content
Differentiating Between a Building and Architecture
Observing and Critiquing a Building
Understanding How Buildings Stand Up: Simple Structures
Contextual Influence on Architectural Significance
The Role of Sustainability in Architecture
Analyzing Aesthetic Qualities

*Learning Objective: Students will develop the ability to read and critique the built environment.

In the next phase, software possibilities were explored before finalizing the intervention design, lesson plans, and specific TTES activities. The selection of the IVR software involved evaluating whether to design purpose-built software or use existing commercial products. The software needed to effectively support presence and agency, enable collaboration among multiple students, and avoid amplifying or creating new DEI concerns for students during the intervention process.

The possibility of designing purpose-built software was quickly eliminated due to a lack of resources such as funding, labor, and time. This led the team to focus solely on off-the-shelf commercial products. However, such software can present challenges: it might only partially align with the educational goals, as it is typically designed for commercial purposes with profit in mind. Additionally, commercial software may inadvertently target dominant cultural groups or reflect implicit biases of developers, potentially disadvantaging marginalized groups.

To mitigate these issues, the instructor and SME narrowed down software options to open-world platforms that do not follow pre-determined narratives or series of tasks. This approach allowed the SME and the researcher to design intervention activities that aligned with the educational goals and teaching methodology. Ultimately, an application named "Wooorld VR" was selected for its unique features. Unlike other VR apps and games, Wooorld VR focuses on the real world, transforming Google Earth's 3D catalog into an immersive playground of over 2,500 cities. This made it an ideal platform for the IVR+TTES intervention to explore architectural spaces and facilitate TE experiences.

After selecting the VR software, a three-session intervention was planned based on Pugh’s (2004) Transformative Experience Theory and the Teaching for Transformative Experiences in Science (TTES) model (Pugh et al., 2017; Pugh, 2020). Originally designed for science learning, the TTES model has demonstrated its effectiveness across various domains, including biology, psychology, and engineering (Heddy & Sinatra, 2013; Heddy et al., 2023; Pugh, 2002, 2004; Pugh et al., 2010). To our knowledge, this intervention marks the first application of the TTES model in a virtual space and within the architecture domain.

Table 3

TTES Design Model (Adapted from Pugh et al., 2017)

Transformative Experience	**TTES Design Principles**		**Specific Classroom Strategies**
Motivated Use	Frame Content as Ideas	● Present the content as compelling possibilities. ● Emphasize the value of the content in everyday experience.	¨Artistically¨ crafted topic introductions.
Expansion of Perception	Scaffold Re-seeing	● Provide guidance and supports that helps students see aspects of everyday world through the lens of the content.	Identifying and sharing everyday experiences related to the content.
Experiential Value	Model Transformative Experiences	● Share personal transformative experiences and express a passion for the content.	Checking-in on real-world phenomena related to the content

Teaching for Transformative Experience in Science (TTES) Design Model, adapted from Pugh et al. (2017) outlines specific design principles and classroom strategies to foster transformative experiences in students. For "Motivated Use," the principle of "Framing Content as Ideas" encourages presenting content in an engaging manner that highlights its relevance to everyday life. Classroom strategies include using artistically crafted introductions to make the topic intriguing and relatable. "Expansion of Perception" is supported by "Scaffold Re-seeing," where instructors provide guidance to help students view everyday phenomena through the lens of the content. A practical strategy for this is to encourage students to share their personal, everyday experiences related to the subject matter, thus reinforcing the content’s applicability in their lives. Finally, "Experiential Value" is enhanced by "Modeling Transformative Experiences," wherein instructors share their personal transformative experiences, showcasing a genuine passion for the subject. This approach can be reinforced by classroom strategies such as checking in with students about real-world applications of the content, emphasizing its broader significance.

Table 4

IVR+TTES Intervention Structure and Design Principles

Intervention Session	Course Content	TTES Design Principle
Session 1	Introduction and VR Tutorial + Pre-test survey	
Session 2	Immersive TTES Learning ¨Understanding and Critiquing the Built Environment¨	● Frame content as ideas ● Modeling transformative experiences ● Scaffold re-seeing
Session 3	Review and application of ¨Understanding and Critiquing the Built Environment¨	● Scaffold re-seeing ● Modeling transformative experiences ● Frame content as ideas
Session 4	Reflection + Post surveys	

This table outlines the structure and design principles of the IVR+TTES intervention sessions used in the study, with each session aimed at fostering transformative experiences through immersive virtual reality. In Session 1, participants were introduced to the course content and received a VR tutorial. This introductory session set the foundation for future immersive learning but did not apply specific TTES design principles. Session 2 involved immersive TTES learning centered on "Understanding and Critiquing the Built Environment." This session applied several TTES design principles: Framing Content as Ideas presented the subject matter as engaging and relevant, Modeling Transformative Experiences demonstrated the instructor's enthusiasm and personal connection to the content, and Scaffolding Re-seeing encouraged participants to view the built environment from new perspectives. Session 3 built upon Session 2 by reviewing and applying the concepts covered, reinforcing participants' understanding and encouraging deeper critique of the built environment. The design principles remained consistent, again incorporating Framing Content as Ideas, Modeling Transformative Experiences, and Scaffolding Re-seeing to support the transformative goals of the intervention.

Overall, these sessions were structured to progressively deepen participants' engagement with the content, using immersive VR to facilitate a more meaningful and transformative educational experience. Specific details of the intervention sessions are explained below.

Implementation

At the start of the semester, the researcher introduced the IVR+TTES intervention in each course and invited students to participate. Due to the limited availability of VR headsets, space constraints, and technical limitations—such as the software's capacity to support only a few simultaneous users—students received intervention in groups of three. All groups completed the intervention over a 3- to 4-week period, from the initial tutorial session to the final learning session and follow-up interviews.

In Session 1, students were briefed again on the study's purpose, and pretest surveys were administered following the completion of consent forms. All participants consented to proceed with the study. After the pretest, students participated in a VR tutorial session. Before using the headsets, the researcher explained how to wear them comfortably and introduced the VR controllers, detailing the functions and actions they would use during the sessions. Throughout the tutorial, the researcher monitored students' actions on a mirrored TV screen to help guide them as they navigated the virtual environment. Each student completed the tutorial using the

"First Steps Quest" application and practiced the controls for the architecture app "Wooorld VR" which would be used in later sessions.

Figure 5

Students completing the IVR+TTES Session 1 tutorials

*Students consented to have their photos taken and used in the research.

Session 2 began with the researcher sharing a personal story from childhood about playing with building toys, specifically Kinex, and drawing structures, an activity he enjoyed. He recalled telling others that he wanted to be an architect, though his career path ultimately took a different direction. However, he explained that his fascination with architecture endured and that he continued to hold a deep appreciation for the discipline. This introduction was designed to model a personal connection to the content, making the learning experience more relatable and relevant for students. By sharing his enthusiasm, the researcher aimed to model a transformative experience for students and emphasize architecture not simply as a study topic but as a meaningful and dynamic field.

Preparing students for the virtual reality (VR) experience, the researcher described growing up in a southern coastal Mediterranean town where significant architectural examples were scarce due to a limited building culture. His perspective shifted during a turning point in his life when he moved to the United Kingdom as an exchange teaching assistant and took the opportunity to backpack across England, exploring diverse architectural sites. This narrative served as a bridge to the virtual environment, guiding students seamlessly into the next phase of the session.

Once students and the researcher wore their VR headsets, they entered the virtual space, where the researcher invited them to explore places he had visited during his time in England. Together, they embarked on virtual tours of Liverpool, London, and other historic locations, taking selfies in front of landmarks like Big Ben and Westminster Palace while the researcher shared his experiences. Throughout these visits, the researcher highlighted the cognitive shift in his understanding of architecture, describing how seeing these landmarks firsthand deepened his appreciation for the discipline and allowed him to recognize the historical and cultural significance embedded in these structures.

Figure 6

A moment from the IVR+TTES intervention

*Students consented to have their photos taken and used in the research.

This experience provided a seamless transition into teaching students the introductory architecture concepts central to the IVR+TTES intervention's learning objectives. Building on the experience, the researcher explained how this exposure sparked his curiosity to further explore the history and architectural significance of these places. He shared insights gained from his research, such as the distinction between "a building" and "architecture": the latter is constructed with attention to form, function, and aesthetics, whereas the former primarily fulfills a functional purpose. To illustrate, he pointed to a standard office building next to Westminster Palace, explaining, “This building, for example, serves the function of hosting a business or perhaps a residential space. However, its architectural value is questionable. When we look at Westminster Palace, its purpose is to host the Parliament of England. Yet, you can also see it was designed with aesthetic intention, showcasing the characteristic features of Gothic architectural style.”

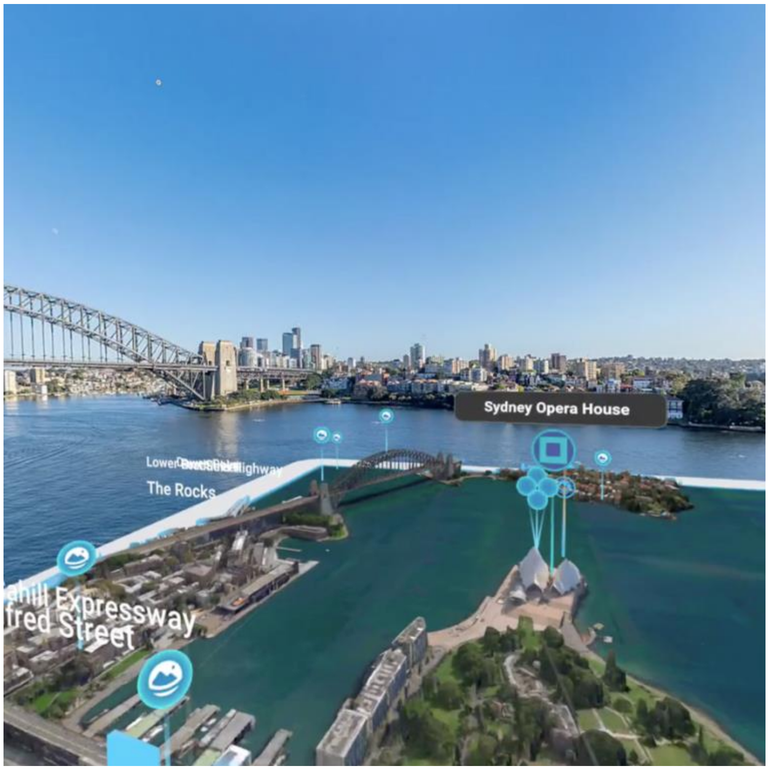
This approach aimed to heighten students’ sense of presence in the virtual environment by encouraging active engagement with elements in the virtual space. The researcher continued shaping the lesson based on his transformative experience, while inviting students to actively participate by posing questions, prompting them to identify architectural details they noticed on various buildings, or to make comparisons with structures in the virtual surroundings. As they visited additional locations, students delved further into architectural concepts, guided by the instructor’s modeling of transformative experiences and a focus on architecture as an actionable field rather than mere lecture content.

At the session's close, the researcher tasked students with selecting a random city on the world map and embarking on a virtual exploration of that location as a group. The students were allotted 10 minutes to navigate the 3D virtual map collaboratively, observe various buildings, and evaluate their architectural significance. This activity's objective was to identify an architecturally valuable structure and present its characteristics to the researcher. While the researcher remained silent throughout this activity, he was present within the virtual environment, allowing students to independently explore and discuss their findings. At the end of the exercise, each group presented and discussed their selected architecture, justifying their choices by connecting them to the architectural concepts they had recently learned.

After removing the headsets, the researcher checked in to ensure that the virtual experience had not posed any significant issues for students. Before dismissing them for the day, he encouraged students to observe architectural environments around them before the next session, and to capture moments where they noticed architecture or found themselves reflecting on concepts introduced in the session—though this was presented as a suggestion, not a formal assignment.

Figure 7

A look at the blend in between virtual space and the 3D map



Session 3 began with a discussion centered on students' reflections, or "captures," of Transformative Experience (TE) episodes. The researcher asked students about their week, specifically if they had noticed any architectural features or found themselves reflecting on concepts from the first session. He clarified that sharing was optional but invited students to share if they had noted any such experiences. Many students described one or two TE episodes where they became aware of architectural elements in their environment. Some students mentioned picturing these places in their minds while relaxing or watching television, while others discussed how a building in a show, they were viewing had triggered thoughts related to the concepts they had learned. A few went further, searching through old photos to examine architectural details in their backgrounds or conducting online research to learn more about the historical sites visited in the initial VR sessions. While these TE episodes were common, some students reported not experiencing such moments.

The researcher shared his own experiences, noting that, even as he taught the concepts, he had begun noticing new architectural features in his surroundings as a result of these sessions. He then transitioned the session back into the virtual environment by saying he would like to show them some of these places. This phase of the session followed a similar structure to the previous one, as the researcher used Transformative Experience teaching strategies to guide the conversation. However, unlike in the first session, the researcher invited each student to individually control the map and guide the group to physical locations where they had personally experienced TE episodes. These places often included spots on campus or in the nearby college town where the students lived. Some students chose locations they had visited previously to share memories and relate them to the architectural concepts discussed in class. This exercise served as an exemplary "re-seeing" experience, where students revisited memories through the lens of a Transformative Experience, often reporting a shift in their perception—referred to as an “expansion of perception”—as a result.

The session concluded with a group activity similar to the one in the first session, where the researcher remained silent while students explored various virtual cities in search of architectural examples. Before wrapping up, the researcher reminded students to look for TE episodes in the days ahead, suggesting they notice any new insights compared to their initial observations.

Figure 8

Students learning about Sydney Opera House from different angles

The final sessions did not involve VR activities. Instead, students were asked to discuss their overall experiences with the IVR+TTES intervention. The researcher posed questions that encouraged reflection on both the TE and VR experiences. To avoid novelty bias from the VR technology, post-test surveys were administered with a delay. Each session was spaced approximately 7 to 10 days apart, depending on the availability of both students and the instructor. This final discussion marked the conclusion of the IVR+TTES intervention, after which students were reimbursed for their participation.

From the first session, the researcher made deliberate efforts to minimize potential DEI (Diversity, Equity, and Inclusion) issues that could negatively impact students' learning experiences. In addition to addressing equity concerns related to the selected software and IVR (Immersive Virtual Reality) technology, the researcher implemented specific measures to reduce accessibility challenges. For example, students who wore prescription glasses received individualized guidance on how to wear the headset comfortably with their glasses. They were also given extra preparation time before sessions began to ensure their comfort.

Furthermore, these students were allowed to exit any virtual locations at any time and remove their headsets if they desired. When feasible, students were offered the option to select alternative locations if they felt uncomfortable with specific virtual sites.

Despite these precautions, some students reported experiencing temporary discomfort during the sessions. The researcher regularly checked in with these students to monitor their well-being and determine if their discomfort persisted. Notably, all students reported that their discomfort resolved shortly after removing the headset.

Data Analysis

This study utilized a convergent parallel mixed-methods approach to evaluate the effectiveness of immersive virtual reality (IVR) in fostering Transformative Experiences (TE) among participants. Data analysis was conducted in both quantitative and qualitative phases, followed by an integration of findings to address the research questions comprehensively.

For the quantitative analysis, data screening was initially performed to ensure completeness and accuracy, resulting in the removal of three participants due to incomplete engagement with the intervention. This left a final sample size of n=14. Descriptive statistics, including means and standard deviations, were calculated for key variables—specifically, TE subscales (motivated use, expansion of perception, and extended value), presence, agency, and interest—offering a foundational view of data distribution. Normality checks were conducted on the dataset, and analyses proceeded with pre-post comparisons to assess the impact of the IVR intervention. Given that data normality was not met, the Wilcoxon signed-rank test, a nonparametric alternative, was employed to evaluate these pre-post differences. Additionally, correlation analyses were performed to examine associations between TE, presence, and agency, shedding light on possible relationships between participants' VR experiences and their engagement levels in transformative learning.

The qualitative analysis primarily utilized a deductive coding framework, organized around TE subscales, presence, and agency components, directly aligning with the interview protocol’s guiding questions. To capture insights beyond the established framework, an inductive coding approach was also applied for open-ended responses, allowing unanticipated themes to emerge. Transcripts were systematically analyzed for recurring themes, with consistent coding applied across participants’ responses to ensure rigor in theme identification. Key themes were illustrated with representative participant quotes, offering a nuanced understanding of how participants engaged with the content both within and outside the VR environment.

To strengthen the reliability and trustworthiness of the qualitative analysis, member checking was employed. Participants reviewed their transcripts and initial interpretations, confirming the accuracy of data representation. Themes were further validated through triangulation with quantitative findings, allowing for a complementary analysis across qualitative and quantitative data. This integrative approach enriched the understanding of how immersive VR experiences contribute to transformative learning, providing valuable insights into the affordances of IVR for fostering educational engagement.

Chapter 4 Findings

This chapter presents the results of the study, integrating both quantitative and qualitative data to provide a comprehensive view of how the IVR+TTES intervention influenced participants' engagement, learning, and transformative experiences. The findings are organized to address the study's two primary research questions: (1) *How does the IVR+TTES intervention facilitate transformative experiences?* (2) *How do the affordances of immersive VR—presence and agency—contribute to facilitation and engagement with transformative experiences?* The chapter begins by reporting the quantitative data analysis, which provides insights into how participants' engagement, presence, and transformative experiences changed from pre-test to post-test. Then presents statistical analyses, including Spearman's rank correlations to explore relationships among the key constructs and the Wilcoxon Signed-Rank Test to assess significant pre-post changes. These quantitative analyses highlight the impact of the intervention across multiple dimensions, including the three TE subscales—motivated use, expanded perception, and experiential value, levels of situational and individual interest —as well as participants' sense of presence and agency.

Following the presentation of quantitative results, the chapter delves into the qualitative findings derived from participant interviews and TE episodes students reported. The qualitative analysis offers a richer understanding of the students' personal experiences during and after the intervention, providing illustrative examples that align with the numerical trends. Key constructs such as presence, agency, and transformative experience are explored through participants' narratives, which reveal how they applied their learning beyond the classroom and developed new ways of seeing and valuing architecture. The integration of quantitative and qualitative data further enhances the analysis by connecting statistical trends with personal insights.

Data Screening and Descriptive Statistics

Descriptive statistics were calculated for each key variable to provide a comprehensive overview of the distribution and characteristics of the data collected from participants. Specifically, the mean, standard deviation, skewness, and kurtosis for the Transformative Experience (TE) scale including its subscales (Motivated Use, Expanded Perception, Experiential Value), Interest, Presence, Agency and Knowledge Test were assessed. These measures allowed us to understand both the central tendency and the variability within the dataset, as well as the overall shape and distributional properties of each construct.

The mean and standard deviation provide an indication of the average score and the degree of variation around this average for each of the key variables. Additionally, skewness and kurtosis statistics were calculated to assess the normality of the data distribution. The descriptive statistics for each variable are presented in Table 5 below.

Table 5

Descriptive Statistics for Key Variables (Pre- and Post-Test Measures)

Descriptive Statistics for the Transformative Experience Scale (Pre to Post), Presence Scale (Pre to Post), Agency Scale (Pre to Post), Situational Interest Survey (Pre to Post), Individual Interest Scale (Pre to Post), Knowledge Test (Pre-Post) (N = 14)

	Pre-test			Post-test		
Statistic	M (SD)	Skewness	Kurtosis	M (SD)	Skewness	Kurtosis
TE	3.16 (0.27)	-.228	-.937	3.51 (0.50)	-.128	1.174
Motivated Use	3.03 (0.33)	1.068	1.167	3.20 (0.34)	-1.671	3.336
Expansion of Perception	2.99 (0.51)	.463	-.345	3.58 (0.63)	1.140	1.222
Experiential Value	3.45 (0.37)	-.072	-.543	3.79 (0.68)	-.223	.376
Presence	3.10 (0.18)	1.021	.577	3.32 (0.20)	-.168	-.133
Agency	3.22 (0.24)	.301	-1.539	3.30 (0.22)	.047	-1.761
Situational Interest	3.27 (0.36)	1.161	.672	3.81 (0.62)	.115	-1.523
Individual Interest	3.27 (0.36)	1.175	.446	3.79 (0.62)	.509	-.034
Knowledge Test	6.35 (2.79)	-.529	-1.192	7.78 (1.52)	.268	-1.243

Note. M = Mean, SD = Standard Deviation.

Descriptive statistics for each of the key variables are presented in Table 5, providing insights into the distribution characteristics for both pre- and post-test measures. As indicated, there was an increase in the mean scores for all variables from pre-test to post-test, suggesting that the IVR+TTES intervention had a positive impact on participants' transformative experiences and engagement. For instance, the mean score for Transformative Experience increased from M = 3.16, SD = 0.27 at pre-test to M = 3.51, SD = 0.28 at post-test, indicating an improvement. An increase in the mean scores for TE based on a TTES intervention is in line with expectations based on similar interventions reported in previous studies (e.g., Alongi, 2014, Heddy & Sinatra, 2013). However, further statistical tests are needed to confirm whether these changes are significant.

Skewness and kurtosis values were also assessed to determine the normality of the distribution for each variable. The skewness values for most variables were within the range of -2 to +2, which indicates acceptable normality (Tabachnick & Fidell, 2013). However, for the Motivated Use (post-test) variable, the skewness value (-1.671) and kurtosis value (3.336) suggest some deviation from a normal distribution, implying a potential leptokurtic pattern (Tabachnick & Fidell, 2013).

To determine the appropriate statistical tests for analyzing the effects of the intervention, a normality assessment was conducted on both pre- and post-intervention data for key variables. The normality of the distribution for each variable was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Given the sample size ($n = 14$), the Shapiro-Wilk test was primarily relied upon for interpretations, as it is more sensitive to deviations from normality in smaller samples (Razali & Wah, 2011). Both tests assessed the normality of variables related to Transformative Experience (TE) subscales (Motivated Use, Expansion of Perception, and Extended Value), along with measures of Presence, Agency, Situational Interest, and Knowledge. A significance level of $p < 0.05$ was used to indicate a statistically significant deviation from normality, suggesting that the variable does not follow a normal distribution.

The Shapiro-Wilk test results revealed that several post-intervention variables did not meet the assumption of normality ($p \leq 0.05$). Although some variables did not significantly deviate from normality due to the small sample size, further analysis was completed using non-parametric tests. This is because normality tests, such as Shapiro-Wilk and Kolmogorov-Smirnov, may not always detect deviations from normality in small samples because they lack power (Tabachnick & Fidell, 2013, p.79-81). In other words, with small sample sizes, normality tests can sometimes yield non-significant results even when the data is not perfectly normal, which can lead to misleading interpretations (Ghasemi & Zahediasl, 2012). Non-parametric tests are often recommended for small sample sizes, as they do not assume a specific distribution and are less affected by outliers or deviations from normality (Conover, 1999). Since some variables significantly deviated from normality, opting for non-parametric tests across all variables-maintained consistency in the analysis method (Tabachnick & Fidell, 2013, p.87) This approach helps avoid the need to switch between parametric and non-parametric tests, which can introduce complexity and reduce comparability across results. Non-parametric methods provide a safer alternative that upholds the reliability of findings when the distribution of variables is uncertain (Field, 2013). Consequently, a final visual inspection of the distribution has supported the decision to use non-parametric tests for the analysis of these variables to ensure robustness in the statistical analyses (Lomax & Hahs-Vaughn, 2012). Specifically, Spearman's rank correlations were employed to explore relationships among key constructs and the Wilcoxon Signed-Rank Test was used to assess pre-post differences.

Furthermore, z-scores were calculated to identify potential outliers in the dataset. No data points were found with z-scores greater than 3 in magnitude, indicating that no outliers were present (i.e., $zs \leq 3$). Data from 3 participants were removed because they did not complete the intervention sessions leaving 14 total participants in data analysis. All reported tests are two-tailed. All statistical analyses, including data screening, descriptive statistics, and advanced statistical tests, were conducted using SPSS version 29 software.

Quantitative Findings

As the first step of the quantitative analysis, Spearman's Rank Correlation Coefficients were calculated for the post-intervention scores of various constructs, including Transformative Experience (TE) and its subcomponents (Motivated Use, Expansion of Perception, and

Experiential Value), as well as Presence, Agency, Situational Interest, Individual Interest, and Knowledge Test scores. Correlations are used to understand the relationships between these variables after the IVR+TTES intervention. Correlation coefficients (ρ) are displayed, with significance levels marked by asterisks to indicate the strength and direction of associations between constructs. Although correlations do not measure changes over time, it gave us an idea about relationships between key study constructs. Several statistically significant correlations emerged, reflecting meaningful associations among the constructs. Table 6 displays the Spearman's rank correlation coefficients among the variables assessed at post-test.

Table 6

Spearman's Rank Correlation Coefficients

Spearman's Rank Correlation Coefficients for the Transformative Experience (Post), Presence (Post), Agency (Post), Situational Interest Survey (Post), Individual Interest (Post), Knowledge Test (Post) (N = 14)

Variable (Post)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. TE	1.00								
2. Motivated Use	.793***	1.00							
3. Expansion of Perception	.945***	.661*	1.00						
4. Experiential Value	.967***	.694*	.921	1.00					
5. Presence	.456	.611*	.397	.238	1.00				
6. Agency	-.146	-.143	.052	-.253	-.285	1.00			
7. Situational Interest	.802***	.576	.838***	.806***	.661**	-.144	1.00		
8. Individual Interest	.697**	.468	.766**	.698**	-.110	.158	.661***	1.00	
9. Knowledge Test	-018	.007	.043	.005	-.042	.010	.143	.189	1.00

Notes:
- Correlation coefficients (ρ) are displayed in the table.
- Significance levels are indicated by:
  (*) $p < 0.05$, (**) $p < 0.01$, (***) $p < 0.001$
- The diagonal values (1.00) represent self-correlations, which are always equal to 1.

The results in Table 6 indicate several significant correlations among the constructs measured in the study. TE Overall demonstrates strong positive correlations with its subcomponents, including Motivated Use ($\rho = .793$, $p < .001$), Expansion of Perception ($\rho = .945$, $p < .001$), and Experiential Value ($\rho = .967$, $p < .001$), underscoring the cohesion among these elements within transformative experiences. This suggests that participants who had a higher overall transformative experience also tended to perceive the learning environment more expansively, were motivated to apply what they learned, and found experiential value in the experience. Considering that Motivated Use, Expansion of Perception and Experiential Value are the three sub-components of a Transformative Experience, strong correlations were expected.

Situational Interest (Post) also shows notable correlations with several constructs. It is strongly correlated with Expansion of Perception ($\rho = .838$, $p < .001$), Experiential Value ($\rho = .806$, $p < .001$), and Individual Interest ($\rho = .661$, $p = .010$), indicating that an engaging learning environment on a situational level may contribute to participants' broader perception, perceived value, and sustained interest in the material. This link between situational and individual interest suggests that immediate engagement may foster longer-term interest in the subject.

Presence (Post) has a moderate positive correlation with Motivated Use ($\rho = .611$, $p < 0.05$), suggesting that greater immersion during VR sessions could be associated with increased motivation to use or apply the knowledge gained. This indicates that feeling present within the virtual environment might support the motivational aspects of the learning experience. Agency (Post) does not exhibit strong or significant correlations with other measured constructs, which may imply that the sense of control in the VR environment did not have a direct relationship with other transformative experience elements or interest measures in this context. Finally, Knowledge Test (Post) scores do not show significant correlations with other variables, suggesting that knowledge acquisition, as measured here, might operate independently of the transformative and immersive experience constructs assessed in the study.

These findings provide a snapshot of the relationships between transformative experience subcomponents, interest, and VR-related constructs, offering a foundation for understanding how these elements interact within the context of immersive learning experiences. Further analyses would be needed to determine any significant changes over time related to these constructs.

In the next step, for the analysis of pre-post intervention effects on each variable, the Wilcoxon Signed-Rank Test was employed as a non-parametric alternative to the paired samples t-test. This choice was made to accommodate deviations from normality in some variables, ensuring a robust analysis of the intervention's impact on participants (Ghasemi & Zahediasl, 2012). The Wilcoxon Signed-Rank Test is appropriate for comparing two related conditions (pre and post) without requiring the assumption of normally distributed data, making it ideal for small samples or datasets with non-normal distributions (Conover, 1999; Gibbons, & Chakraborti, 2020). Given that this study involves only two time points, more complex non-parametric methods such as the Friedman Test, which is used for comparing three or more conditions, were not applicable (Field, 2013; Sheskin, 2020).

The results of the Wilcoxon Signed-Rank Test for pre- and post-intervention measures across multiple constructs are presented in Table 7. The constructs evaluated include Transformative Experience (TE), along with its subcomponents (Motivated Use, Expansion of Perception, and Experiential Value), as well as Presence, Agency, Situational Interest, Individual Interest, and Knowledge Test scores. The table highlights median values for pre- and post-test scores, as well as statistical results including the Wilcoxon Z values, significance levels, and effect sizes for each variable. These tests were conducted to determine whether significant differences existed between pre- and post-intervention scores.

Table 7

Wilcoxon Signed-Rank Test (Pretest-Post-test)

Wilcoxon Signed-Rank Test for the Transformative Experience (Pre-Post), Presence (Pre-Post), Agency (Pre-Post), Situational Interest Survey (Pre-Post), Individual Interest (Pre-Post), Knowledge Test (Pre-Post) (N = 14)

Variable	Median (Pre-test)	Median (Post-test)	N	Z	p	Effect Size (r)
Transformative Experience	3.18	3.51	14	-2.387	.017*	0.638
Motivated Use	3.04	3.27	14	-1.374	.169	0.367
Expansion of Perception	3.00	3.43	14	-3.046	.002**	0.814
Experiential Value	3.50	3.80	14	-2.065	.039*	0.552
Presence	3.07	3.35	14	-2.727	.006**	0.729
Agency	3.15	3.25	14	-.806	.420	0.216
Situational Interest	3.25	3.87	14	-2.004	.045*	0.536
Individual Interest	3.06	3.81	14	-1.995	.046*	0.533
Knowledge Test	7.00	8.00	14	-1.527	.127	0.408

Note: *p < .05, **p < .01. Effect sizes are calculated as r = Z / sqrt(N).

Table 7 demonstrates statistically significant increases in several of the key constructs following the IVR+TTES intervention. Variables such as Transformative Experience, Expansion of Perception, Experiential Value, Presence, Situational Interest, and Individual Interest all showed significant positive changes, as indicated by p-values below the .05 threshold and moderate to large effect sizes. In contrast, Motivated Use, Agency, and Knowledge Test scores did not show statistically significant improvements, suggesting variability in how different aspects of transformative learning and engagement were impacted by the intervention. These findings provide important insights into the areas where the intervention was most effective and highlight opportunities for enhancing certain aspects of the learning experience in future implementations. Next, the detailed analysis of key constructs is described.

Transformative Experience (TE) Findings

To observe the change over time between data points of Transformative Experience, a two-related samples Wilcoxon Signed-Rank Test was conducted using time (pre to posttest on the TE scale) as the paired test variables. The results from the Wilcoxon Signed-Rank Test indicated a significant increase in participants' overall Transformative Experience (TE) scores from pre-test to post-test, suggesting that the IVR+TTES intervention was effective in promoting perceived out of school engagement. Specifically, the TE construct, which encompasses students' integration of learning into their everyday life, demonstrated a statistically significant positive change after the intervention (Mdn = 3.51, n = 14) (z = -2.387, p = .017) compared to before (Mdn = 3.18, n = 14), with a large effect size (r = 0.638). This result indicates that participants experienced an overall enhancement in transformative learning following the intervention, suggesting that the intervention effectively fostered deep engagement with the subject matter.

In terms of the Motivated Use subscale, the Wilcoxon Signed-Rank Test results did not indicate a significant increase from pretest to post-test (z = -1.374, p = .169). However, the effect size (r = 0.367) was moderate, suggesting that the intervention may still have led to improvements in motivated use, although this was not statistically confirmed. The descriptive data also showed a trend toward improvement in motivated use from initial scores (Mdn = 3.04, n = 14), to final scores (Mdn = 3.27, n = 14) with participants expressing a growing interest in applying the knowledge they acquired during the IVR+TTES sessions to real-world contexts.

This non-significant result suggests that while participants found some value in utilizing their knowledge beyond the immersive setting, the change was not as pronounced as it was for other components of TE. It is also possible that the small sample size may have influenced the ability to detect significance.

The expansion of perception sub-scale, which reflects participants' ability to view the world through new perspectives fostered by the intervention, showed a statistically significant increase from pre-test (*Mdn* = 3.00, $n = 14$) to post-test (*Mdn* = 3.43, $n = 14$) ($z = -3.046$, $p = .002$), with a large effect size ($r = 0.814$). This result might indicate that the IVR+TTES intervention was highly effective in helping participants broaden their perception of architecture and related concepts. Participants reported experiencing new ways of seeing structures and designs that were previously unexamined or unnoticed. This kind of perceptual shift is a crucial aspect of sustained effects of transformative experiences, emphasizing the ability of the intervention to deepen participants' understanding and awareness.

Finally, the experiential value sub-scale also showed a significant positive change from pre-test (*Mdn* = 3.50, $n = 14$) to post-test (*Mdn* = 3.80, $n = 14$) ($z = -2.065$, $p = .039$), with a large effect size ($r = 0.552$). Experiential value refers to the extent to which participants found personal meaning and relevance in what they learned during the IVR+TTES intervention. The results suggest that the intervention succeeded in making the learning experience more personally valuable for participants. Participants reported feeling the architectural content felt more connected to their own lives and interests, which contributed to an overall increase in the perceived value of the learning experience.

Interest Findings

To observe the change over time between data points of Interest Development, a two-related samples Wilcoxon Signed-Rank Test was conducted using time (pre to posttest on the Situational and Individual Interest scales) as the paired test variables. The results from the Wilcoxon Signed-Rank Test indicated a significant increase in participants' engagement and interest in the learning content during the VR intervention and revealed a statistically significant increase from pretest to post-test. Specifically, the median score for situational interest increased from 3.25 at pre-test to 3.87 at post-test. The Wilcoxon Signed-Rank Test indicated a significant positive change (z = -2.004, p = .045), with a large effect size (r = 0.536). This suggests that the IVR+TTES intervention was successful in capturing and maintaining participants' situational interest throughout the learning activities.

Individual interest, which reflects the participants' enduring interest and personal connection to the subject matter over time, also showed a significant increase from pretest to post-test. The median score for individual interest rose from 3.27 at pre-test to 3.79 at post-test. The Wilcoxon Signed-Rank Test indicated a significant increase (Z = -1.995, p = .046). The effect size was large (r = 0.533). These findings suggest that the IVR-supported intervention helped foster a lasting interest in architectural topics presented in an immersive environment. The experiential qualities of the immersive activities might have allowed participants to relate to the material on a deeper, personal level.

VR Experience Findings: Presence and Agency

To observe the change over time between data points of key constructs related to the immersive virtual reality experience: presence and agency, a two-related samples Wilcoxon Signed-Rank Test was conducted using time (pre to posttest on the Presence and Agency scales) as the paired test variables. The results from the Wilcoxon Signed-Rank Test indicated a significant increase in participants' presence, however the agency did not yield significant changes.

The analysis of Presence, which reflects participants' sense of immersion during the IVR+TTES intervention, indicated a significant positive change from pretest to post-test. The median score for Presence increased from 3.07 at pre-test to 3.35 at post-test. The Wilcoxon Signed-Rank Test showed that this change was statistically significant ($z = -2.727$, $p = .006$), with a large effect size ($r = 0.729$). This suggests that the immersive environment substantially enhanced participants' feeling of being immersed in the architectural content. The increased sense of presence likely played a crucial role in engaging with transformative experiences.

In contrast to the results for Presence, Agency, which refers to the participants' perceived control over their actions and decisions during the IVR intervention, did not show a statistically significant increase from pretest to post-test, even though the median score increased from pre-test ($Mdn = 3.15$, $n = 14$) to post-test ($Mdn = 3.25$, $n = 14$). The Wilcoxon Signed-Rank Test results for Agency ($z = -0.806$, $p = .420$) indicate no significant change, with a small effect size ($r = 0.216$). These results suggest that while the VR environment was immersive, it may not have provided enough opportunities for participants to experience a significant increase in their sense of control or decision-making throughout the intervention. This could imply that the structure of the VR activities, which was more guided than exploratory, limited the potential for increased agency.

Knowledge Test Findings

To observe the change over time between data points of knowledge tests, a two-related samples Wilcoxon Signed-Rank Test was conducted using time (pre to posttest on the Knowledge Tests) as the paired test variables. The analysis of the Knowledge Test, which assessed participants' understanding of key architectural concepts before and after the VR-supported intervention, did not reveal a statistically significant change. The median score for the Knowledge Test increased from 7.00 at pre-test to 8.00 at post-test. However, the Wilcoxon Signed-Rank Test indicated that this change was not statistically significant ($z = -1.527$, $p = .127$), with a medium effect size ($r = 0.408$).

Although the increase in median scores suggests some improvement in participants' knowledge, the lack of statistical significance implies that this improvement may not be substantial enough to be conclusively attributed to the intervention. Nonetheless, the medium effect size suggests that the intervention might still have had a meaningful impact on participants' understanding of architectural concepts, indicating potential learning gains that were not large enough to reach statistical significance. It is possible that factors such as the relatively small sample size or the specific design of the knowledge test affected the ability to detect statistically significant changes.

Integrating Quantitative to Qualitative Findings

The results from the quantitative analysis suggest that students receiving IVR+TTES intervention self-reported significant changes for meaningful use of content outside the class in addition to increased engagement with the content during learning sessions. This finding is in line with the literature supporting that TTES intervention is an effective method to promote TE (e.g., Heddy & Sinatra, 2013; Heddy et al. 2023; Pugh, 2011; Pugh et al. 2017). Further, when the TE scale was disaggregated into its three components (motivated use, expansion of perception, experiential value) and analyzed, the results of the significant changes based on student self-reports were confirmed for expansion of perception and experiential value sub-components. Different from these two components there was no significant difference between the pretest and post-test time points of the motivated use sub-component of transformative experience. This means that students perceived a cognitive shift for looking at the content from a different perspective than before the intervention. Similarly, the perceived value they attached to the discipline changed significantly. This result is supported by the significant perceived changes of student situational and individual interest results based on students' self-reports, which two constructs were identified to be significantly correlated with experiential value, suggesting that the intervention was effective in creating meaningful perceived interest and value in for the content.

The results discussed above also highlighted interesting findings regarding students' experiences with the immersive learning environment enabled by the integration of virtual reality technology. When presence and agency, two main constructs that are associated with the immersive virtual experience, were analyzed, the results suggested that students' self-reported significant changes in presence in the virtual environments, while agency did not yield any significant self-reported changes. This finding demonstrates that the immersive capabilities of virtual reality experience were actually able to create a sense of perceived presence. This is an interesting finding because the student's perceived sense of presence was significantly correlated with the motivated use components of transformative experience, suggesting a possible positive contribution of presence increased by the virtual facilitation of transformative experience throughout the intervention. However, motivated use did not yield a significant change after the intervention, even though mean scores showed an increase in scores between pretest to post test scores and the effect size was moderate.

Despite observed relationships, the single group design of the intervention makes it difficult to attribute these results through quantitative findings to the addition of virtual experience to the TTES intervention. Therefore, these findings should be approached with caution, and further qualitative analysis is needed to understand the potential positive contribution of presence on the TTES methods in order to promote transformative experiences.

Qualitative Findings

The focus of the qualitative findings was to provide a deeper understanding of students' experiences with the IVR+TTES intervention and its effects on their engagement with the content both in and out of the classroom. Specifically, the purpose was to add context to the students' perceived significant changes of the transformative experience, and its subcomponents motivated use, expansion of perception and experiential value, as well as significant increase in presence enabled by the immersive virtual environment and its contribution to the effectiveness of the TTES teaching method.

To achieve this, the qualitative interviews of the thirteen students were analyzed thematically using a combination of the deductive coding method (Saldana, 2013) and inductive coding methods (Fleiss, 1981). The three components of the Transformative Experience (TE) construct and its subcomponents were used to frame the deductive coding process. In addition, to understand the impact of immersive experiences of students, specifically the presence and agency constructs, were added to understand their effect in promoting students' transformative experiences. Therefore, the deductive codes were Transformative Experience (with sub-themes Motivated Use, Expansion of Perception, and Experiential Value), VR Experience (Presence, Agency). Meanwhile following the inductive coding of open-ended questions of the semi-structured interviews three additional themes: Overall Experience, IVR Preference and Challenges and Barriers also emerged and added to the themes for comprehensive analysis.

Table 8

Qualitative Codes and Sample Student Excerpt

Theme	**Sample Excerpt**
Overall Experience	*"I gained more from this than I thought—this was more than just being a test subject."*
TE - Motivated Use	*"I see the steam-spewing building and wonder, is this eco-friendly? ¨*
TE - Expansion of Perceptions	*"It makes you think differently about why some things are built that way."*
TE - Extended Value	*"I've thought about taking a class on acoustics and concert hall design."*
VR - Presence	*"When you're looking at something through VR, you almost feel like you're there. I can still vividly remember the street view of Big Ben and Westminster Palace."*
VR - Agency	*"I liked that I could look around and explore as I wanted—just like in real life."*
VR - Preference	*"If given the option, I'd prefer learning architecture in VR—it's a completely different experience."*
Challenges and Barriers	*"The headset got heavy, and not wearing my glasses made it worse."*

As a result, the final list of themes used for qualitative analysis were Transformative Experience (with sub-themes Motivated Use, Expansion of Perception, and Experiential Value), VR Experience (Presence, Agency, and IVR Preference). Every student interview conducted was coded at the sentence level and categorized under one or more components of transformative experience or immersive virtual reality. For instance, if students talked about noticing an architecture in their environment (e.g., ¨I was driving to work and noticed the library¨), this experience was coded under motivated use. Two independent researchers applied the codes to the semi-structured interviews and the interrater reliability was established with 85% agreement, which is considered excellent (Fleiss, 1981). In order to resolve the disagreements, the coder scheduled an online meeting. During this meeting, a data triangulation table was created, listing all the disagreed codes side by side and the disagreements were resolved through discussion. Each of these categories are explained and student responses are provided below.

Overall Experience

Participants consistently described their experiences as engaging, eye-opening, and impactful, offering new ways to explore and understand architecture. Many expressed that the virtual environments provided immersive experiences that traditional learning methods could not achieve. One student noted, "It felt like I was physically in the location, even though I wasn't." Similarly, another emphasized that the sessions were more than just visual encounters, describing them as "much more immersive than looking at a phone screen."

Several participants reflected on how the VR sessions changed their perceptions of architecture by simulating real-world visits. For example, a student remarked, "It felt to me like I actually went there, and I got to see it from the outside." Participants expressed excitement about the possibility of visiting these places in real life after having experienced them virtually. Another peer echoed this sentiment, stating, "It felt like being in two places at once." This ability to mentally "travel" through architecture was often described as key benefits of the VR sessions compared to lecture-based learning environments.

For many students, the IVR intervention expanded their awareness of the built environment, leading them to observe buildings and architectural elements in their daily lives with newfound curiosity. One student shared, "I just look at stuff differently now—it's a whole new experience." Another elaborated, "I never used to think about architecture, but now I see there's more to it than just drawing and building." These reflections show that even those without prior architectural interests are connected to the content on a personal level.

Initially, some students had reservations or limited familiarity with VR but grew comfortable over time. One student reflected, "At first, I was anxious, but the tutorial made it easier, and it turned out to be really fun." This process of adaptation highlights how the engaging nature of the sessions helped mitigate initial concerns about the technology.

Transformative Experience Findings

Motivated Use. Many participants described how the IVR-supported sessions motivated them to apply architectural concepts beyond the classroom. For some participants, the sessions encouraged them to initiate discussions with family or friends about what they learned. A student shared, "I talked to my parents about what I saw, and they shared what they knew about those places." One student reflected, "I noticed the fraternity and sorority houses and thought about whether they were architecture or just buildings." Another shared that they began paying attention to buildings on campus in a new way: "After the sessions, I noticed buildings on campus in a new way." These insights suggest that the intervention prompted students to apply their learning to real-world settings.

A few participants described engaging more deeply with the content after the VR sessions. For instance, one student mentioned conducting additional research on specific architectural styles they had seen in VR. Another noted, "A couple of days after the VR session, I found myself noticing and actively comparing campus buildings while walking past them." These comments demonstrate IVR+TTES intervention might have created lasting cognitive impressions that prompt ongoing engagement with learned concepts.

The participants' engagement often went beyond passive observation. Several participants sought opportunities to explore architecture actively. One student noted, "I'd see long skinny windows and think, 'Oh, that's Gothic.'" Another student even described biking around campus during breaks, observing architectural styles: "I like, ride my bike around, and I noticed different houses and how they're built." These experiences highlight how participants integrated architectural knowledge into their daily routines, demonstrating the motivational impact of the intervention.

However, the extent of engagement varied among participants. While many participants described being motivated to apply architectural knowledge in their daily lives, some expressed limited engagement. For example, a participant noted that although he enjoyed the sessions, his opportunities to apply the concepts were minimal: "I haven't really had the chance to apply what I learned yet." Similarly, a student explained that although the sessions influenced their awareness, they did not actively seek new architectural content: "I didn't watch anything specifically or read more about architecture after the sessions." Another student also demonstrated mixed engagement. While she acknowledged noticing architecture more in familiar places, her interest seemed situational: "I noticed things more at Catlett [music building], but it's not something I'd say I think about all the time." These examples highlight that although some participants gained awareness, their motivation to engage with architecture beyond the sessions varied.

Expansion of Perception. A common theme across participants was the expansion of their perception of architecture, moving beyond superficial observations to deeper awareness. One student described this shift as "just seeing things differently, realizing there's more to it than I had thought." Another emphasized how the sessions helped them analyze design details: "Instead of just saying it looks cool; I could ask deeper questions and compare styles." Similarly, another student shared that he now considers the intent behind buildings: "I realized not all buildings are purely functional—some are designed to stand out, others to blend in."

Some students noted experiencing re-seeing moments during or after the VR sessions. One student reported, "I started noticing differences in the houses around me on my way to work after the first VR session," indicating a heightened attention to architectural elements previously overlooked. Another participant discussed how VR made them think about why certain architectural features, such as the use of brick, were chosen, emphasizing a shift in their analytical perspective.

Participants also reported a heightened ability to identify architectural elements they had previously ignored. A student mentioned, "Now I have new vocabulary to go along with what I knew was very surface level." The sessions expanded participants' understanding of how architecture serves both functional and aesthetic purposes. Another student reflected on this, saying, "The physics building seemed more functional, while Bizzell [library] was designed with the intention to look beautiful." These shifts in perception illustrate how the intervention provided participants with tools to interpret architecture in new ways, deepening their understanding of the built environment.

However, not all participants found this expanded perception to be transformative. Some found it difficult to articulate the significance of these new insights, with one student commenting, "I put more thought into it now, where I didn’t before, but it’s hard to explain exactly how." This highlights the variability in how students experienced changes in perception. These comments illustrate that although participants recognized new dimensions of architecture, not all found the experience transformative in a meaningful or lasting way. For some, the new awareness sparked curiosity but did not necessarily translate into deeper intellectual engagement.

Experiential Value. Some participants expressed a new appreciation for architecture, recognizing both the practical and symbolic value of architectural design. Several participants noted that the IVR-supported TTES sessions not only made them more aware of architectural processes but also cultivated their interest in the discipline. One student reflected on potential connections with his interests, saying, "I’ve thought about taking a class on acoustics and concert hall design." Similarly, another student, who plans to become a history teacher, stated, "I think having this knowledge will bring a cool aspect to the lessons I’ll teach." This appreciation e beyond the classroom, with participants considering how architectural knowledge might be useful in their personal or professional lives.

The experiential value also extended to recognizing cultural symbolism in architecture. A student noted that the design of the university library, with its distinct style, represented local heritage. They reflected, "The admissions building and Bizzell share a Gothic Cherokee design, and it’s tied to OU’s theme." Such reflections indicate that the IVR-supported intervention helped participants see architecture as both an art form and a cultural symbol, enriching their understanding beyond a purely functional perspective. Participants also expressed admiration for the effort involved in architectural projects. A surprised student marveled at the time and precision required to build the Sydney Opera House, saying, "It’s crazy how long it took to make, and they had to calculate everything just right."

In contrast to participants like this one, who expressed excitement about connecting architectural knowledge to his interests in acoustics, some participants indicated that the experience, while enjoyable, was unlikely to shape future interests or pursuits. One of these students mentioned, "I think it will be useful for teaching history, but I don’t see myself using it beyond that." Another one, echoed this sentiment, noting that while the sessions were interesting, the content did not inspire further exploration: "I didn’t look anything up or Google more about the places—we talked about it in class, and that was enough."

VR Experience Findings

Presence. Participants frequently emphasized how the VR sessions provided a sense of immersion, with many describing the environments as vividly memorable. For instance, one student remarked, "I can vividly remember the street view of Big Ben and Westminster Palace, down to how the sunlight hit the buildings." Another one echoed this sentiment, stating, "It felt very realistic, like being in two places at once." These comments highlight how VR enabled participants to feel immersed in places they had never physically visited, offering them a unique perspective.

Another interesting insight was how VR contributed to emotional engagement. One student described feeling "small" when viewing a large building from the ground up, explaining, "I felt small when we were in Barcelona—it made me feel part of something bigger." This emotional connection contributed to the participants’ sense of presence, helping them engage more deeply with the content. Students also mentioned how the instructor's modeling of TE experiences enhanced their sense of presence. One student explained that hearing the instructor share their personal transformative experiences while in VR helped them feel more connected and engaged. "It was like I was walking in your shoes," they said, emphasizing the emotional connection fostered by the shared immersive experience.

Interestingly, not all participants reported a consistent sense of presence in similar experiences. One student shared that his sense of presence was occasionally interrupted by the physical environment: "It looked sunny in Australia, but I could still feel the air conditioning on me." These experiences demonstrate that while VR provided many participants with a sense of presence, the level of immersion varied depending on both the technology and the participants' physical surroundings.

Additionally, a student explained that even when they found their focus wavering during the instructor's explanations, the immersive quality of VR kept them engaged with the architecture displayed. They shared, "Even whenever I was zoning out a little bit, I was still thinking about the architecture." This illustrates how VR can maintain engagement even in moments where attention might otherwise lapse, showcasing the benefit of an immersive environment.

Meanwhile, some students discussed how external factors affected their sense of presence. For example, one student mentioned, "I could feel the air conditioning on my body, which reminded me I was still physically in the classroom." These reflections suggest that while VR can be highly immersive, physical surroundings can sometimes disrupt the experience.

Agency. The ability to navigate and interact with the VR environments was another key element of participants' experiences. Most participants felt that they had meaningful control over their exploration. One student shared, "I was able to take control of the map and move around the different cities—if I wanted to go somewhere, we went there." This ability to explore at their own pace fostered a sense of agency. Similarly, another peer emphasized the ease of exploration, saying, "Moving the map and zooming in and out was fun and easy." These experiences highlight how VR enabled participants to explore the content at their own pace, fostering a sense of agency.

The participants' sense of agency was enhanced by the freedom to explore environments according to their interests. One student appreciated this freedom, stating, "Once I got a better grasp of the controls, I could move around easily and find where I wanted to go." This ability to explore independently was a highlight for many participants, contrasting with lecture-based classroom settings where content delivery is more structured. Another student expressed this difference, saying, "With VR, you can explore what you want, unlike in a lecture where you just follow what the teacher tells you."

For some participants, however, the sense of agency was not as significant. One of these students reflected, "The controls were fine, but I think the map could've been more straightforward—it got a bit confusing at times." These comments suggest that while most participants enjoyed the freedom offered by VR, the experience could have been enhanced with smoother controls and more intuitive navigation tools. A few students noted that they initially struggled with the controls, which affected their sense of autonomy. One participant commented, "At first, I felt in control, but I forgot how to use the map and struggled with it later." Despite these challenges, most participants adapted quickly and found the controls intuitive once they became familiar with them.

IVR Preference. The majority of participants expressed a strong preference for VR-based learning over lecture-based formats. They appreciated how VR allowed them to explore architectural sites in a way that felt more engaging and personal. One student reflected on this by saying, "If given the option, I'd prefer learning architecture in VR—it's a completely different experience." Similarly, another student emphasized that VR's hands-on nature made the sessions more effective: "I learn more when it's hands-on, so I would prefer using VR in smaller classes." Participants also highlighted that VR provided opportunities to explore places that would otherwise be inaccessible. one noted, "VR was great—it stuck with me better than a lecture ever would." Several participants echoed these sentiments, emphasizing that the immersive nature of VR made it more memorable than their previous learning experiences.

The social aspect of VR was also highlighted, with students noting that being in VR together as a group was beneficial. One student commented, "Someone in the group would point out something, and I'd turn to look at it, even if I hadn't noticed it before." Similarly, one student appreciated having peers alongside her in the virtual space, saying, "It was helpful to have someone there to bounce ideas off." This illustrates how collaborative VR sessions can enhance the learning experience by allowing students to share discoveries and insights in real-time.

A few participants expressed mixed feelings about the long-term use of VR. They expressed that a mix of VR and in-person classes would be better due to the headset getting heavy after a while. One student suggested that VR works well for introductory topics but might not be ideal for more advanced study: "It's good for an introduction, but advanced classes might need more than just VR." These comments suggest that while participants valued VR, they also recognized its limitations, particularly for extended or advanced learning scenarios.

Challenges and Barriers. While most participants found VR engaging, several reported challenges that affected their experience. Technical difficulties, such as issues with VR controls, were commonly mentioned. One student explained, "I struggled a few times with accessing different features, and it sometimes made me feel like I wasn't in control of the map." Another student reported experiencing motion sickness, noting, "I had to close my eyes for a few seconds when I felt dizzy." These challenges indicate that while VR has great potential as an educational tool, careful consideration must be given to usability and accessibility to ensure all students can benefit.

Physical discomfort also emerged as a barrier for some participants. A student mentioned, "The headset got heavy, and not wearing my glasses made it worse." These comments suggest that while VR offers unique advantages, its physical demands and the need for technical proficiency can impact the overall learning experience.

Finally, a few participants expressed concerns about the practicality of VR for large classrooms or extended use. One student raised the issue of scalability, "It’s hard to implement VR in big classrooms—everyone is at different levels.", referring to the different technology skills of students in a class. These comments suggest that while VR offers unique advantages, its integration into formal education requires thoughtful planning to address logistical and technical challenges.

Summary of Qualitative Findings

The findings indicate that the IVR+TTES intervention successfully facilitated moments of transformative experience for many participants, but the extent of engagement varied. While some participants were motivated to explore architecture further, others found the experience interesting but not compelling enough to pursue outside of class. Additionally, while most participants experienced some expansion of perception, a few struggled to articulate these shifts or expressed ambivalence toward their significance. Similarly, although the intervention sessions provided experiential value, not all participants felt that the knowledge gained would significantly impact their personal or professional lives.

The findings also pointed out that the virtual reality experience provided participants with a meaningful sense of presence and agency, although the depth of these experiences varied. For many, the sense of immersion was vivid, creating lasting mental images and emotional connections with the places they explored. Participants valued the sense of control and freedom VR provided, although some encountered challenges with navigation and collaboration. The physical strain from extended VR uses and the difficulty of scaling the experience to larger classrooms were also noted as barriers.

Chapter 5: Discussion and Conclusion

Overview

The aim of this chapter is to interpret the findings presented in Chapter 4 in light of existing literature and the theoretical frameworks guiding this study. The discussion is centered on linking the results back to the Transformative Experience (TE) Theory (Pugh, 2004) and the Teaching for Transformative Experience in Science (TTES) model (Pugh et al., 2011) to explore how the IVR+TTES intervention may influence learning experiences by fostering transformative experiences (TE). Additionally, this chapter addresses the implications, limitations, and future directions of the research as well as addressing considerations for equity, justice, and inclusiveness.

The findings from Chapter 4 suggested that the IVR+TTES intervention was effective in promoting transformative experiences for this sample, with statistically significant increases in participants' engagement, interest, and perceived value of architectural content. The quantitative data showed improvements across several key dimensions of TE, including expansion of perception, and experiential value. Although motivated use did not yield significant differences in the quantitative analysis, qualitative experiences of students revealed that students engaged with content inside and out of class experiences. Interestingly, the immersive virtual space itself served as an authentic experience to provide opportunities to students for motivated use of architecture concepts during the immersive learning sessions heightened by modeling TE and re-seeing activities.

Notably, presence as an affordance of VR was linked to enhanced TE, while agency exhibited more nuanced effects, highlighting areas for potential refinement in future applications. The qualitative data supported these findings by providing deeper insights into how participants experienced learning through VR, highlighting both the immersive qualities and the challenges faced.

Research Question 1: How Does the IVR+TTES Intervention Facilitate Transformative Experiences?

The findings of this study suggested that the IVR+TTES intervention may have enhanced transformative experiences among participants, specifically in the domains of motivated use, expansion of perception, and experiential value. These results align with previous research on transformative experiences, which suggests that effective TE interventions can extend learning beyond the classroom and into participants' everyday lives (Heddy & Sinatra, 2013, 2017; Pugh, 2004, 2011). However, these findings should be viewed as exploratory due to context-specific nature of this intervention study.

The concept of Teaching for Transformative Experience (TE) is deeply rooted in John Dewey's educational philosophy, which posits that education should not only enhance classroom learning but also extend and enrich everyday experiences (Dewey, 1938). Both the patterns in TE survey results and qualitative student experiences illustrate that the IVR+TTES intervention appeared to foster such connections by enhancing motivated use, expansion of perception, and experiential value. Pugh's (2004) development of the TE theory emphasizes the importance of bridging this gap between formal education and real-world application, which may have been reflected in this study. By enabling students to virtually explore architectural environments, the intervention helped participants perceive learning as relevant and applicable beyond the classroom, which aligned with the goals of the TTES model (Pugh, 2011, 2020).

Previous studies, such as those by Pugh et al. (2010, 2017), and Heddy & Sinatra (2013), provide empirical support for the claim that well-designed instructional interventions can significantly enhance student engagement and interest by crafting experiences that resonate with real-world scenarios. In this study, participants demonstrated these enhanced connections, supporting the potential for immersive virtual reality (IVR) to successfully implement the principles of TE and TTES by creating engaging educational experiences. The quantitative improvements seen in expansion of perception and experiential value reflect the possible success of this approach, aligning with prior findings that underscore the effectiveness of linking learning content with students' lived experiences (e.g., Pugh & Girod, 2007).

One of the three components of the TE construct, motivated use showed a moderate effect size for improvements in quantitative findings, though the changes were not statistically significant. This nuanced finding suggests that while the intervention encouraged participants to apply architectural knowledge outside the classroom, the magnitude of change was more modest compared to other TE subcomponents. This is consistent with Pugh's (2011) assertion that fostering motivated use is often challenging due to individual differences in readiness and prior knowledge. In this study, several participants reported applying architectural concepts during everyday activities, such as noticing and discussing architectural designs with others, highlighting the potential of immersive VR to bridge classroom learning with real-world engagement. This finding is supported by the work of Heddy & Sinatra (2013), who found that designing learning experiences that encourage students to apply what they have learned outside the classroom can increase their engagement and motivation. In this study, the immersive qualities of VR provide promising evidence for creating the contextual relevance needed to foster such applications, resonating with Pugh's emphasis on meaningful use of content in real-life scenarios.

The findings gathered also highlight the effectiveness of the learning activities implemented during the intervention in supporting motivated use and transformative experience overall. This study specifically employed the Experiential Apprenticeship principle of the Transformative Teaching and Engaged Scholarship (TTES) method, which was originally designed to foster TEs through in-class activities (Pugh et al., 2017). In the context of TTES, this principle involves modeling transformative engagement through personal stories, expressing passion, and encouraging students to reflect on their past TE episodes. There were notable instances where students reported engaging with content outside of the classroom, which can be categorized as re-seeing familiar environments or concepts from the perspective of transformative experiences. For example, students recognized that the buildings they passed on their way to work, or school showcased different architectural styles and held significant meaning, illustrating moments of re-seeing.

Additionally, students appreciated the immersive modeling of transformative experiences that facilitated their engagement with the content by creating personal relevance through the instructor's own TE experiences. They expressed a deep engagement, forming emotional connections between the instructor's previous experiences and envisioning themselves in his position. These findings support Pugh's assertion that educators can scaffold students' understanding and enhance the likelihood of applying their learning in meaningful ways outside the classroom by exposing them to various models of transformative engagement (Pugh, 2011, 2020). As Pugh defines it, it seems the experience of "surrender" allowed some students to fully immerse themselves in and be transformed by the learning process (2020).

The IVR+TTES intervention also showed a significant increase in the expansion of perception, evidenced by both quantitative and qualitative findings. The statistical analysis revealed a large effect size, indicating that participants experienced meaningful cognitive shifts that broadened their understanding of architectural concepts. Qualitative findings further supported this by showcasing participants' reflections on how they now perceive architectural structures with greater depth and complexity, a key element of expanding perception (Pugh, 2011). This finding aligns with Dewey's (1938) theory of experience, which posits that meaningful learning occurs when learners integrate new knowledge into their existing frameworks, thereby re-seeing their environment through new perspectives. Similar findings were reported by Girod and Wong (2002) when exploring "aesthetic understanding" in a fourth-grade geology class, demonstrating the potential of transforming everyday views through carefully crafted educational experiences. The current study's results highlight how immersive VR, by allowing learners to virtually interact with complex architectural designs, facilitates the cognitive shift necessary for an expanded perception of these concepts.

Meanwhile, some students engaged with the content and recognized a shift in their perception but hesitated to articulate that this experience was transformative. For example, students acknowledged their engagement with the content and noted that they viewed the discipline differently yet found it challenging to explain exactly what this meant for them.

Although there is limited support for this result in the existing literature, a possible explanation could be related to individual differences in readiness and identity, which may influence the experience of transformative moments (Pugh, 2020). A growing body of research on transformative experiences suggests that students engage with such experiences at varying levels (Pugh et al., 2010; Pugh et al., 2017; Pugh, 2020). Recent studies indicate that students who have a natural inclination toward transformative experiences, stemming from prior knowledge or relevant personality traits, tend to benefit the most from transformative experience interventions (Pugh et al., 2017). Students who struggle to explain their shifts in perception as transformative may require more time to fully understand their cognitive changes or need additional opportunities to practice viewing content through the lens of transformative experience. This suggests that extending intervention durations in future studies could provide students more opportunities to internalize these shifts.

Participants also reported a statistically significant increase in experiential value, meaning that the content became personally meaningful to them. This aligns with previous research indicating that experiential value arises when learners see how classroom content is applicable to their own lives (Heddy & Sinatra, 2017; Pugh, 2011). In the current study, participants reported that exploring architectural sites in VR fostered a deeper appreciation for the complexity of architectural design, adding personal value to their learning experience. One participant expressed how the immersive aspect of VR allowed them to "feel like I was actually there," which not only made the learning experience more impactful but also contributed to a sustained interest in the content. These findings indicate that virtual reality (VR) has immersive qualities that can create emotionally resonant and personally meaningful experiences. This aligns with the results reported by Pugh et al. (2010), which highlighted that for students to gain experiential value from educational content, their experiences must be both emotionally and cognitively engaging.

Finally, the results of this study contribute to existing research on TE and TTES, particularly by exploring how immersive VR environments *can* foster transformative experiences. By creating a sense of presence and allowing students to explore and interact with content in meaningful ways, the IVR+TTES intervention appears to have enhanced some elements of motivated use, expansion of perception, and experiential value—critical components of transformative experience.

Another critical discussion point related to the IVR+TTES intervention is the interplay between learning and experience. In this study, the primary focus was on "experience" rather than "learning," as Transformative Experience (TE) is a theory of experience, not a theory of learning (Pugh, 2004, 2011). TE theory emphasizes students' motivation to apply their learning in real-life contexts, particularly in situations where such application is not explicitly required. However, findings from this study suggest that motivation to apply knowledge is unlikely to exist without foundational learning. This tension between the theoretical focus on experience and the practical necessity of learning highlights the complexity of designing and assessing TE interventions.

Quantitative analysis of pre- and post-test knowledge assessments in this study did not yield statistically significant differences, although mean scores increased from pre-test to post-test. This suggests that, for this small sample, the intervention may have been limited in its ability to demonstrate measurable learning gains. High pre-test scores can narrow the window for assessing learning gains, possibly reflecting participants' prior knowledge or the limitations of the assessment tool in differentiating levels of understanding. These findings suggest that the knowledge test used in this intervention requires refinement and testing with a larger sample. Additionally, caution should be exercised when interpreting these results, particularly given the limitations in generalizability.

While the quantitative data did not provide conclusive evidence of learning gains, qualitative interviews offered valuable insights into students' reflections on their TE episodes, hinting at varying levels of learning. For instance, when discussing the distinction between architecture and a building, students frequently referred to their TE episodes from the intervention sessions. These reflections suggest that students gained conceptual understanding through the intervention, even if this was not fully captured by the quantitative assessments.

A notable difference in students' engagement with TE and learning experiences emerged in the depth of their reflections. One student remarked, "I like to ride my bike around, and I noticed different houses and how they're built," indicating a relatively surface-level observation. Another student demonstrated a more specific understanding, stating, "I'd see long skinny windows and think, 'Oh, that's Gothic.'" A third student offered an even deeper level of engagement by saying, "The admissions building and Bizzell share a Gothic Cherokee design, and it's tied to OU's theme." These reflections indicate the potential for varying levels of conceptual understanding within the sample, with some students internalizing architectural concepts more deeply than others.

Pugh (2004) observed similar patterns in his research, noting that even high-achieving students—based on assessment scores and classroom participation—sometimes lacked engagement with content outside the classroom. For example, a student in Pugh's study demonstrated cognitive transformation within classroom contexts but did not extend their engagement with physics to real-world situations. This discrepancy between learning and application highlights the complexity of assessing TE solely through students' episodes. Pugh attributes this difference to the depth of learning, distinguishing between shallow and deeper learning processes, which are more effectively identified through process-oriented assessments such as project-based or problem-based learning.

These findings emphasize the importance of further exploring the relationship between learning and experience in future research. While some students demonstrated a strong connection between learning and real-world application, others engaged superficially or struggled to articulate how their experience was transformative. This variability may stem from individual differences in readiness, prior knowledge, or the timing of the intervention relative to students' developmental stages. Furthermore, the absence of application of learning outside the classroom based on self-reports of some students does not necessarily indicate a lack of learning. Students may have acquired knowledge but lacked opportunities to apply it, or they may not yet have been ready to experience learning in a transformative way.

Ultimately, the findings indicate that while the IVR+TTES intervention facilitated transformative experiences for some participants, further investigation is needed to understand the nuanced interplay between learning and experience. Future studies with larger samples and refined methodologies could build on this work, addressing these complexities more comprehensively.

Research Question 2: How Do the Affordances of Immersive VR: Presence and Agency Contribute to Facilitation and Engagement with Transformative Experiences?

The affordances of immersive VR, specifically presence and agency, were expected to enhance the facilitation and engagement with transformative experiences. The findings partially supported this expectation, suggesting that for this sample, presence had a significant positive impact on TE, while agency exhibited more nuanced effects.

The integration of immersive VR into the TTES model aims to capitalize on the key affordances of presence and agency. Presence, defined as the feeling of 'being there' in a virtual environment, plays a crucial role in deepening emotional and cognitive connections to learning content (e.g., Milgram et al., 1995; Slater & Wilbur, 1997). Studies by Makransky & Lilleholt (2018) and Hamilton et al. (2021) have previously highlighted the potential of immersive technologies to create realistic scenarios that lead to greater learning outcomes by enhancing a learner's sense of presence. This study provided supporting evidence for these findings in the context of the current intervention, as the sense of presence was significantly enhanced, contributing to deeper transformative experiences among participants and making the virtual exploration of architectural sites more meaningful and personal. Quantitatively, the presence scores showed a statistically significant increase from pre-test to post-test, with a large effect size. This suggests that participants felt deeply immersed in the architectural environments they explored.

The qualitative findings complemented this by illustrating how the sense of presence helped participants emotionally connect with the content, which in turn fostered transformative experiences. For instance, several participants described feeling as if they were physically visiting iconic architectural sites, which made the experience more memorable and impactful. These descriptions are consistent with literature suggesting that higher levels of presence can enhance learners' engagement and emotional connection to the content (Makransky & Petersen, 2021). Talking about their experience, students reported emotional experiences similar to those in real life. For instance, students described feeling small when viewing architecture from the ground up in the virtual space, a sensation that is commonly experienced in the physical world. This observation supports the argument by Slater and Wilbur (1997) that IVR can heighten the sense of "being there." Additionally, this supports the claims made by Sanchez-Vives and Slater (2005), who argued that as users engage with the virtual environment, they often exhibit physiological responses similar to those triggered in physical reality. Such findings suggest that presence played a key role in shaping the emotional depth of the learning experience within this study.

Another noteworthy finding that reinforced the heightened presence among students was their use of vocabulary commonly associated with physical experiences. For example, students who expressed high engagement with the content during or after the intervention sessions often referred to their virtual excursions with phrases like "when we were in Barcelona" or "when we visited Japan." As Held and Durlach (1992) argued, presence extends beyond visual and auditory perception to encompass a tangible, almost tactile connection to the virtual environment. In this study, such responses suggest that the IVR+TTES intervention elicited reactions akin to those experienced in physical environments, amplifying participants' engagement with the content.

The concept of presence is closely aligned with Pugh's (2004) Transformative Experience theory, which emphasizes the importance of a deep and engaging experience in fostering meaningful connections to learning content. In this context, learners in the current study experienced an amplified sense of presence, which appeared to support their ability to perceive architectural spaces with greater emotional and cognitive depth compared to traditional instructional methods. This finding aligns with previous studies suggesting that immersive VR's ability to foster emotional engagement (e.g., Ahn et al., 2014; Huang et al., 2010; Parong & Mayer, 2018) and realistic simulation of environments contributes significantly to learning experiences (e.g., Makransky & Lilleholt, 2018; Systems, 2023).

Research indicates that presence and agency are fundamental to immersive virtual reality (IVR) experiences, influencing how users interact with and perceive virtual environments (Ahn et al., 2014; Dede, 2005; Powers & Holmes, 2020; Slater, 2009). Enhancing both presence and agency can result in more engaging and effective VR experiences across various fields (Dede, 2005; Powers & Holmes, 2020). While the findings in this study confirmed the positive impact of presence, the results for agency were more complex. Although the intervention was successful in increasing students' presence in the virtual environment, it did not significantly enhance their sense of agency. Participants reported varying degrees of perceived control in qualitative interviews. These findings, specific to this sample, diverge from some existing literature that suggests a close link between presence and agency in virtual environments (Ahn et al., 2014; Kizony et al., 2017; Slater et al., 2009).

Agency, defined as the sense of control over one's actions within a virtual environment (Slater et al., 2009), was influenced in this study by both the design of the intervention and participants' comfort with VR technology. While many participants appreciated the opportunity to navigate and explore the virtual spaces, others found the controls cumbersome, which may have impacted their sense of autonomy. Some students struggled to navigate the 3D virtual map or interact with the software during lectures, which likely diminished their sense of agency. This finding aligns with Bowman and McMahan's (2007) argument that the usability of virtual interfaces is critical in determining users' sense of agency. These results suggest that improving user comfort and familiarity with VR controls in future interventions could enhance the sense of agency and potentially amplify the transformative potential of such learning experiences.

The role of agency in immersive learning environments has been widely discussed in recent literature (e.g., Dede, 2005; Powers & Holmes, 2020; Slater et al., 2009; Slater & Wilbur, 1997). Agency is essential to the learning process as it allows learners to interact actively with the content, thereby fostering a sense of ownership and engagement. However, in this study, limitations such as group collaboration in shared virtual spaces appeared to create cognitive load for some participants, reducing their sense of agency. Studies by Parmaxi (2023) highlight that cognitive load can significantly impede agency in immersive environments. Some participants expressed frustration at navigating shared spaces, which may have reduced their perceived control over the learning experience. The VR environment, while enriching, also introduced complexities that some participants found difficult to manage effectively, further limiting their sense of agency. These challenges point to the importance of balancing individual and collaborative activities in future IVR+TTES designs. By balancing individual exploration with group activities, students may experience enhanced agency, fostering greater motivation and deeper engagement. Providing students with opportunities to navigate autonomously could help them reevaluate their learning experiences and foster a stronger sense of ownership over their educational journey.

The findings related to the second research question underscore the nuanced role of presence and agency in shaping transformative experiences within this intervention. The presence afforded by immersive VR aligns with Dewey's notion of experiential learning, which emphasizes active engagement and emotional immersion as key to meaningful educational outcomes (Ahn, et al., 2014; Dede, 2005; Kizony et al., 2017). The effectiveness of the IVR+TTES intervention in enhancing expansion of perception and experiential value provides empirical support for the argument that immersive environments make abstract concepts more tangible, enriching students' understanding and interest in the subject matter (Pugh et al., 2017). The potential of immersive VR to enhance presence highlights its ability to make abstract concepts more tangible, contributing to students' understanding and interest in the subject matter (Pugh et al., 2017). However, the results for agency suggest that further refinements are needed to optimize its role in transformative learning experiences.

The findings related to agency provide important insights into future research. Although agency did not show significant improvement overall, participants' varied responses suggest that the structure of VR activities should be reconsidered to provide more exploratory learning opportunities. This aligns with previous assertions that agency must be carefully balanced with instructional goals to maximize the benefits of immersive learning environments (Makransky & Petersen, 2021). Furthermore, addressing cognitive load, as highlighted by Parmaxi (2023), is essential for designing VR interventions that allow students to experience autonomy without feeling overwhelmed.

The reported minor challenges voiced by students that affected their presence, agency, and overall experience during the IVR+TTES intervention highlight the need for a nuanced discussion regarding the Diversity, Equity, and Inclusion (DEI) challenges that IVR technology and virtual spaces might create for students. While previous studies have highlighted the potential of immersive environments to mitigate DEI issues through well-designed training and interventions, they also caution against the risks of perpetuating existing biases and inequalities. These risks become especially pertinent when introducing new learning technologies, as they may amplify existing accessibility barriers or, in some cases, create new forms of exclusion, such as reinforcing implicit biases or advancing dominant cultural agendas.

In this study, findings shed light on potential DEI challenges that students may encounter. While further research is needed to fully understand the direct and indirect effects of these challenges—such as their impact on presence, agency, and overall Transformative Experiences (TE)—the data revealed specific instances of concern. For example, although most participants found the VR experience engaging, some reported difficulties with VR controls or motion sickness, which could have undermined their sense of presence and agency and, consequently, the quality of their TE episodes. One student shared that the headset became heavy after prolonged use (around 60 minutes), and the inability to wear prescription glasses during the session caused temporary headaches. The researcher proactively checked in with students to ensure that these discomforts were short-lived, yet these reports underscore the influence of usability and accessibility issues on students' experiences. This aligns with Bradshaw's (2017, 2018) assertion that fostering truly inclusive environments through educational technologies requires addressing accessibility and cultural sensitivity simultaneously, rather than simply providing equal access to tools.

The design of the intervention itself may have inadvertently introduced cultural or social biases that impacted students' presence and agency. For instance, the narrative framework employed by the researcher to model TE experiences included a virtual recreation of a trip across England, featuring culturally significant locations such as Westminster Palace and Liverpool Cathedral. While no students explicitly expressed concerns, these places might convey implicit messages about dominant cultural values or hierarchies, which may have gone unrecognized or unvoiced by participants. Similarly, discussions surrounding Native American heritage through Cherokee Gothic architectural designs could have unintentionally highlighted cultural narratives that some students found difficult to relate to. Since presence and agency are heavily influenced by personal relevance and emotional responses, these implicit cultural messages may partially account for why certain students reported lower engagement or struggled to connect their experiences to real-world applications.

A related concern involves the avatars representing students in the virtual environment, which play a crucial role in shaping IVR experiences. Research by Yee and Bailenson (2007) demonstrates that avatars can significantly influence users' behaviors, such as fostering confidence or intimacy in virtual interactions. Although this study did not specifically investigate the impact of avatars on presence, agency, or TE episodes, prior findings suggest that avatars can reinforce systemic biases if not designed thoughtfully. Franks (2017) describes this as "the desert of the unreal," referring to the overlooked social implications of virtual representations that may inadvertently replicate racial, gender, or ability-based inequities. For example, assigning students avatars with differing skills or characteristics could unintentionally reinforce stereotypes, such as associating cognitive or physical abilities with specific races or genders.

In this study, avatars were randomly assigned and did not intentionally convey social status, cognitive abilities, or physical attributes. However, students might have experienced a sense of disconnect if their assigned avatar failed to align with their gender identity, physical characteristics, or skin tone. While participants were unable to view their avatars in reflective surfaces, the lack of customization options may have limited their ability to identify with their virtual presence. This issue is particularly relevant for young learners or adolescents, as the inability to personalize avatars could open the door to identity-based exclusion or even bullying. Given that presence in virtual environments is closely tied to personal relevance, these factors likely influenced students' agency and their overall engagement with the IVR+TTES intervention.

These findings reveal that while the IVR+TTES intervention was carefully designed to support motivation and learning application beyond the classroom, several DEI-related concerns might have reduced the meaningfulness of some students' experiences. Addressing these challenges in future studies is critical. Researchers should explore how DEI issues shape presence, agency, and the quality and frequency of TE episodes in IVR environments. Future interventions must prioritize inclusivity by designing experiences that integrate cultural sensitivity, enhance physical accessibility, and provide meaningful opportunities for virtual representation, ensuring equitable and transformative learning for all students.

Implications of the study

Theoretical Implications

This study makes significant contributions to the theoretical understanding of how immersive virtual reality (IVR) can facilitate transformative experiences (TE) in educational settings, particularly by enriching Pugh's (2004) Transformative Experience theory and the Teaching for Transformative Experience in Science (TTES) model (Pugh, 2011). By integrating IVR into the TTES instructional model, this study provides empirical evidence that presence—a core affordance of VR—plays a crucial role in fostering transformative engagement. The findings illustrate how immersive technologies, through their ability to simulate realistic experiences, enhance key elements of TE, such as motivated use, expansion of perception, and experiential value. These results extend Pugh's work by showing that immersive environments can effectively deepen students' engagement, making learning more relevant and personally meaningful.

Furthermore, this study contributes to immersive learning theories such as the Cognitive Affective Model of Immersive Learning (CAMIL) (Makransky & Petersen, 2021). The findings align with CAMIL's emphasis on the importance of emotional and cognitive immersion, demonstrating that presence within immersive environments significantly enhances learners' engagement and their transformative experiences. By empirically validating the role of presence and exploring the nuanced effects of agency, this research provides a more detailed understanding of how different affordances of VR contribute to transformative learning.

Additionally, the study highlights the complexity of fostering agency within immersive environments, suggesting that greater autonomy and opportunities for exploration may be required for learners to fully benefit from IVR experiences. This finding opens new avenues for refining immersive learning theories, suggesting that future iterations of the TTES model could benefit from incorporating more open-ended tasks and learner-driven exploration to optimize the sense of agency and overall learning outcomes. By integrating these elements, this study enriches both TE theory and immersive learning frameworks, demonstrating the potential of VR to not only enhance student engagement but also contribute to the broader theoretical landscape of transformative education.

Implications for Practice

The practical implications of this study extend to educators, instructional designers, and policymakers interested in leveraging immersive technologies for educational purposes, specifically for facilitating out-of-school engagement through IVR+TTES-based educational interventions aimed at fostering transformative experiences. One major insight is the importance of creating a sense of presence. For educators, this means designing VR experiences that are not only visually immersive but also contextually relevant to students' lives, thereby promoting deeper engagement. The significant increase in presence and expansion of perception suggests that IVR can effectively bridge the gap between classroom learning and real-world application, enhancing the depth of student engagement. The immersive qualities of VR helped students perceive architecture as an art form, underscoring the need to use VR to make abstract or complex subjects more tangible and engaging.

Another practical implication involves the importance of fostering agency within the VR environment. Allowing students to explore content autonomously was shown to enhance their perceived engagement in qualitative interviews, although it did not yield a significant quantitative result. For instructional designers, the findings imply that integrating VR activities that emphasize presence—through realistic simulations and opportunities for sensory immersion—can enhance the overall impact of learning interventions. Educators designing VR interventions should consider incorporating elements that give learners control over their exploration. For example, open-ended tasks that allow students to navigate freely or manipulate architectural designs can foster a sense of ownership over their learning process, which is essential for transformative engagement. Providing clear guidance while allowing students freedom to explore can maximize engagement and support meaningful inside and outside the classroom transformative experiences.

In addition to these aspects of presence and agency, this study's focus on equity, justice, and inclusiveness has important implications for educational practice. VR technology holds the potential to democratize access to experiences that may otherwise be inaccessible to many learners. For instance, students who may never have the opportunity to visit historical architectural sites can experience these environments virtually. However, it is crucial to ensure that access to such technologies is equitable. Schools and educators must be mindful of the digital divide and strive to provide equal opportunities for all students to engage with transformative VR experiences. Addressing usability issues is essential for ensuring that IVR is inclusive and accessible for diverse learner populations.

Implementing DEI principles within VR-supported learning requires a commitment to inclusive design, accessibility, and ethical reflection. VR developers and educators should approach design with an inclusive lens, consulting diverse groups during development to create environments that reflect a variety of cultural, social, and economic backgrounds. By ensuring that VR platforms accommodate different perspectives, developers can reduce the likelihood of reinforcing biases and instead support a more equitable experience for all learners. Accessibility should be prioritized to make VR's benefits widely available. This involves developing adaptable VR systems that accommodate different physical abilities and offering cost-effective solutions to reduce financial barriers. Creating features like alternative input methods, compatibility with assistive technologies, and customizable interfaces can help VR reach a broader audience. These efforts not only broaden access but also enrich the VR experience by welcoming diverse users into the virtual space.

Additionally, integrating elements of critical pedagogy within VR experiences can help learners engage more deeply with DEI issues. As Freire (1970/2005) emphasized, meaningful education involves both reflection and action to address and transform societal structures that perpetuate inequities. In VR-supported DEI education, this can mean designing experiences that invite users to question their assumptions, explore the roots of social inequalities, and consider ways they can act meaningfully to support equity. For instance, VR programs could include prompts or activities that encourage users to reflect on their role in promoting social justice within and beyond the virtual environment, fostering critical consciousness as part of the learning experience.

This study also highlighted some of the challenges involved in implementing VR for educational purposes. The literature notes potential barriers such as high costs, specialized equipment needs, and the possibility of cognitive overload. These barriers were observed during the study, as some participants reported feeling disoriented or overwhelmed at times during the VR experience. To mitigate these challenges, it is essential for educators to provide appropriate training and support, ensuring that VR activities are well-structured and accessible to all learners. Educators should also be mindful of scaffolding VR experiences to avoid overwhelming students and to enhance the effectiveness of the transformative experiences.

Finally, this study underscores the potential of IVR not only to enhance content understanding but also to foster interest and motivation, contributing to lifelong learning and the real-world application of academic concepts. In conclusion, incorporating DEI principles into IVR-supported transformative experiences holds the potential to create learning environments that are not only immersive but also equitable and socially conscious. By prioritizing inclusive design, enhancing accessibility, and fostering critical engagement, educators and developers can leverage VR's strengths while addressing its challenges, ultimately supporting a more inclusive educational landscape.

Limitations of the Study

Despite the promising findings, this study had several limitations that should be acknowledged. One of the primary limitations was the relatively small sample size, which may have impacted the generalizability of the findings. With a limited number of participants, the statistical power was constrained, potentially affecting the ability to detect significant effects for certain constructs, such as agency. Future research should aim to replicate this study with a larger and more diverse sample to strengthen the generalizability of the results.

While the findings of this study provide valuable insights into the role of VR in fostering transformative experiences, several limitations must be acknowledged. The study used a single group pre-post design, which limits the ability to draw causal conclusions. Future studies should consider using control groups to provide a clearer comparison and enhance the validity of the findings.

Another limitation involves the fact that the researcher also served as the instructor for the VR intervention. This dual role may have introduced bias, potentially influencing both the implementation of the intervention and the interpretation of its outcomes. To mitigate this limitation, steps were taken, such as involving an independent expert in the training process and using mixed methods to triangulate findings. Nonetheless, the potential for bias remains an important consideration.

Another limitation relates to the reliance on self-reported measures for assessing transformative experiences. While self-reports provide valuable insights into participants' perceptions and subjective experiences, they are susceptible to biases, such as social desirability and recall bias. These biases may have influenced the participants' responses, particularly when reflecting on the impact of the intervention. Future studies could incorporate additional objective measures, such as observational data or performance assessments, to provide a more comprehensive understanding of participants' learning and engagement.

To mitigate these limitations, several strategies were employed during the study. The mixed methods approach was used to triangulate data, addressing limitations related to the small sample size. Additionally, the TTES activities, knowledge tests, and all architectural content were designed under the guidance of a subject matter expert (SME) who was a faculty member at the College of Architecture, thereby providing validity to the study and minimizing the instructor effect. Furthermore, a second coder was involved in analyzing the qualitative data to ensure reliability and reduce potential bias in coding and interpreting participants' responses.

Recommendations for Future Research

Based on the findings and limitations of this study, several directions for future research can be proposed to further explore the potential of IVR-supported transformative experiences. To address the limitation of using a single-group design, future research should incorporate control groups or randomized controlled trials. The addition of a control group would provide a clearer basis for comparison and help in drawing more definitive causal conclusions about the effectiveness of IVR in fostering transformative experiences. Such experimental rigor is essential for understanding the unique contributions of VR in educational interventions compared to other learning methods.

Another important direction is increasing the diversity and size of the sample. This study involved a relatively small sample size, which restricted the generalizability of the findings. Future studies should include larger and more diverse participant groups, encompassing different cultural backgrounds and educational contexts, to provide a more nuanced understanding of how diverse populations engage with VR-based transformative learning. Expanding the sample size will also enhance the statistical power of the findings and strengthen the conclusions drawn.

The findings related to presence were highly positive, but the role of agency was less conclusive. Future research should explore instructional strategies that enhance agency by allowing learners greater autonomy. This could involve designing more open-ended VR tasks that offer students greater control over their learning environment. By increasing user autonomy and allowing for more exploratory experiences, learners may achieve a deeper sense of agency, which in turn could enhance their engagement and facilitate transformative experiences.

Additionally, future research could benefit from a longitudinal approach to assess the long-term effects of IVR-supported interventions. While the current study provided promising short-term findings, a longitudinal study would help determine whether the observed effects on transformative experiences are sustained over time. Understanding the durability of these effects is critical to establishing the enduring value of immersive learning tools in education.

Given the limitations of self-reported data, future research should incorporate more objective measures of engagement. For example, biometric data (e.g., eye tracking or physiological responses), observational data, or performance-based assessments could provide more concrete evidence of how students interact with the VR environment. Such objective measures would complement self-report data and provide a more comprehensive picture of the depth and quality of student engagement.

Furthermore, the practical challenges of implementing VR in educational settings, including the high costs and specialized equipment requirements, suggest the need for research into more cost-effective and scalable solutions. Future research should explore affordable VR alternatives or adaptations that maintain educational impact while being feasible for broader implementation. Identifying scalable solutions is critical for ensuring equitable access to transformative VR experiences across diverse educational institutions.

The dual role of the researcher as both instructor and investigator may have introduced bias in the study. Future research should examine how different instructional roles influence the effectiveness of VR interventions. Involving multiple instructors or independent facilitators could reduce bias and provide a more objective perspective on the outcomes of the intervention. Additionally, future studies could evaluate whether the expertise or teaching style of the instructor affects the impact of the VR-supported learning experience.

Finally, refining the design of VR interventions should be a priority. The current study highlighted the balance between structured learning objectives and the opportunity for student exploration. Future research could experiment with different configurations of learning activities, providing students with more freedom to manipulate virtual environments while ensuring alignment with clear educational goals. This balance could enhance both the immersive quality of the experience and its instructional value, thereby maximizing the transformative potential of VR-based learning.

By pursuing these future research directions, researchers can build on the findings of this study to deepen the understanding of how immersive VR can be effectively used to facilitate transformative learning experiences. Addressing these aspects will not only enhance theoretical insights into immersive learning but also help develop practical, scalable, and inclusive educational solutions.

Conclusion

In conclusion, this study demonstrated the significant potential of immersive virtual reality (IVR) in enhancing transformative experiences (TE) through the Teaching for Transformative Experience in Science (TTES) model. By integrating IVR, this study found that elements such as presence and, to a lesser extent, agency, played pivotal roles in fostering transformative engagement with architectural content. The findings showed notable improvements in motivated use, expansion of perception, and experiential value, indicating that immersive environments can bridge the gap between classroom learning and real-world application.

This dissertation makes important contributions to Pugh's (2004) Transformative Experience theory and the TTES model (Pugh, 2011) by providing empirical evidence that supports the integration of immersive technologies to foster transformative experiences. The study extends Pugh's work by demonstrating how immersive VR, specifically through presence, can deepen students' engagement and expand their perception of educational content, making learning more personally meaningful. By applying the TTES model within an IVR context, this research illustrates the potential for immersive technologies to enrich the teaching strategies used to cultivate transformative experiences in science and other fields.

Moreover, this research contributes to the broader understanding of immersive learning theories, such as the Cognitive Affective Model of Immersive Learning (CAMIL) proposed by Makransky and Petersen (2021). The findings align with CAMIL's emphasis on the role of presence and emotional engagement in immersive environments, supporting the notion that cognitive and affective immersion are crucial for impactful learning. By highlighting the effectiveness of IVR in enhancing presence and its role in the transformative learning process, this dissertation underscores the value of immersive technologies as powerful tools for facilitating meaningful educational experiences that extend beyond classrooms. Overall, this dissertation contributes valuable theoretical and practical insights into the evolving landscape of immersive education, providing a path forward for using VR to foster deeper, more meaningful learning experiences that transcend existing educational boundaries.

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Appendices

Appendix A. Transformative Experience Scale

Instructions: For each question, select the response that best matches the extent to which you agree or disagree. "Outside of school" refers to your everyday life and experience when you are not in class or working on school assignments.

[Responses will be on a 5-point Likert scale, strongly disagree to strongly agree]

Motivated Use Items

1. I talk about architecture during my class.
2. I talk about architecture outside of class.
3. I talk about architecture just for the fun of it.
4. I think about architecture during my class.
5. I think about architecture when I do things like going downtown, historical buildings, or seeing a TV show about buildings or construction.
6. I think about architecture outside of class.
7. I find myself thinking about architecture in everyday situations.
8. I apply the knowledge I've learned about architecture during architecture class.
9. I apply the knowledge I've learned about architecture outside of school.
10. I apply the stuff I've learned about architecture even when I don't have to.
11. I seek out opportunities to apply my knowledge of architecture in my everyday life.

Expansion of Perception Items

12. During science class, I see things in terms of architecture.
13. When I am working on a class assignment about design or something related, I tend to think of them in terms of architecture.
14. If I see a really interesting building (either in real life, in a magazine, or on TV) then I think about it in terms of architecture.
15. I can't help but see any construction or design in terms of architecture now.
16. I notice examples of architecture during architecture class.
17. I notice examples of architecture outside of class.
18. I look for examples of architecture outside of class.

Experiential Value Items

19. The ideas of architecture are useful for me to learn for my future studies or work.
20. The ideas of architecture help me to better understand the world of architectural design.
21. Knowledge of architecture is useful in my current, everyday life.
22. I find that the ideas of architecture make my current, out-of-school experience more meaningful and interesting.
23. The ideas of architecture make buildings much more interesting.
24. During architecture class, I think the stuff we are learning about architecture is interesting.
25. I think architecture is an interesting topic.
26. I find it interesting in class when we talk about buildings and design in terms of architecture.
27. I'm interested when I hear things about architecture outside of school.
28. I find it exciting to think about architecture outside of school.

Appendix B. Igroup Presence Questionnaire (IPQ)

1. How aware were you of the real-world surroundings while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?
2. How real did the virtual world seem to you?
3. I had a sense of acting in the virtual space, rather than operating something from outside.
4. How much did your experience in the virtual environment seem consistent with your real-world experience?
5. How real did the virtual world seem to you?
6. I did not feel present in the virtual space.
7. I was not aware of my real environment.
8. In the computer-generated world I had a sense of "being there."
9. Somehow, I felt that the virtual world surrounded me.
10. I felt present in the virtual space.
11. I still paid attention to the real environment.
12. The virtual world seemed more realistic than the real world.
13. I felt like I was just perceiving pictures.
14. I was completely captivated by the virtual world.

Appendix C. Sense of Agency Rating Scale (SOARS) (Polito et al., 2013)

Item	Subscale
1. *Doing what I was meant to was hard	Effortlessness
2. I chose how to respond	Involuntariness
3. *My experiences and actions felt self-generated	Involuntariness
4. I went along with my experiences freely	Effortlessness
5. *My experiences and actions were under my control	Involuntariness
6. I felt that my experiences and actions were not caused by me	Involuntariness
7. My experiences and actions occurred effortlessly	Effortlessness
8. I was mostly absorbed in what was going on	Effortlessness
9. My responses were involuntarily	Involuntariness
10. *I was reluctant to go along with my experiences	Effortlessness

*These items are reverse scored

Appendix D. Interest Scales

Situational Interest Survey (Linnenbrink-Garcia et al., 2010)

Think about your architecture course and please circle the words that most accurately represent how much you agree or disagree with each of the following statements.

[Responses will be on a 5-point Likert scale, strongly disagree to strongly agree]

1. My architecture teacher is exciting.
2. In my architecture class, my teacher does things to grab my attention.
3. My architecture class is often entertaining.
4. My architecture class is so exciting it's easy to pay attention.
5. What I am learning in my architecture class is fascinating to me.
6. I am excited about what I am learning in my architecture class.
7. I like what I am learning in my architecture class.
8. find what I am learning in my architecture class interesting.
9. What I am studying in my architecture class is useful for me to know.
10. The things I am studying in my architecture class are important to me.
11. What I am learning in my architecture class can be applied to real life.
12. I am learning valuable things in my architecture class.

Individual Interest Scale (Linnenbrink-Garcia et al., 2010)

1. The topics in my architecture class are practical for me to know.
2. The topics in my architecture class help me in my life outside of school.
3. It is important to me to be a person who knows the topics in my architecture class.
4. Knowing the topics in my architecture class is an important part of who I am.
5. I enjoy the topics in my architecture class.
6. I like the topics in my architecture class.
7. I enjoy learning the topics in my architecture class.
8. The topics in my architecture class are exciting to me.

Appendix E. Knowledge Assessment

1. What is a key factor that differentiates architecture from a mere building?

   a) The height of the building

   b) The cost of the building

   c) The presence of artistic and aesthetic considerations

   d) The location of the building

   e) The age of the building

2. When observing a building, which of the following should be considered to determine its architectural value?

   a) The color of the paint used

   b) The materials and their usage

   c) The number of floors

   d) The type of windows

   e) The age of the building

3. What is the primary purpose of architectural critique?

   a) To identify the most expensive buildings

   b) To appreciate and evaluate the design, functionality, and aesthetics

   c) To determine the structural integrity

   d) To compare buildings based on their size

   e) To find faults in construction techniques

4. Which of the following elements would NOT typically be a focus when critiquing a building's architectural design?

   a) Structural stability

   b) Functional layout

   c) Aesthetic appeal

   d) Brand of construction materials

   e) Context within its environment

5. What is the term for the basic structural framework of a building that ensures it stands up?

   a) Facade

   b) Foundation

   c) Skeleton

   d) Roof

   e) Interior design

6. How can the context of a building influence its architectural significance?

   a) It dictates the color scheme

   b) It affects the building's height restrictions

   c) It shapes the design to complement its surroundings

   d) It determines the type of materials used

   e) It does not influence architectural significance

7. When looking at a building, why is it important to consider the use of space?

   a) To determine how many people can live there

   b) To evaluate the efficiency and functionality of the design

   c) To assess the exterior aesthetic

   d) To calculate the construction cost

   e) To measure the height of the ceilings

8. What role does sustainability play in modern architecture?

   a) It increases the construction cost

   b) It ensures buildings are more aesthetically pleasing

   c) It integrates eco-friendly practices and materials

   d) It limits the design options available

   e) It focuses solely on the use of renewable energy

9. Which of the following is an example of a simple structure that supports buildings?

   a) Decorative columns

   b) Facades

   c) Beams and columns

d) Windows

e) Interior walls

10. When examining the aesthetic qualities of a building, what should you look for?

a) The age of the building

b) The function of the building

c) The harmony of proportions and use of materials

d) The cost of construction

e) The geographical location of the building

Appendix F. Qualitative Follow-up Interview Protocol

Hi [First Name],

Thank you very much for agreeing to participate in this follow-up interview, and I appreciate you making time for me today. As we discussed before, the interview will take up around 60 minutes of your time, and I would like to audio record this interview to capture the details of our conversation fully. After the interview is transcribed, I will erase the file. Your responses will be kept confidential, and you may discontinue participation any time.

Do I still have your permission to audio record the interview? (Begin recording)

I have a few major questions and will probe into each to have you further elaborate on your experience of the architecture class with VR activities you engaged in before. There is no right or wrong answer. I would appreciate your candid responses as I want to learn from you and your experience.

[The questions that follow are examples of the kind of questions that will be asked during the interview. These questions may change due to the nature of qualitative research, but all questions will focus on the IVR-supported TE activities and out-of-class TE instances.

1. Can you tell me your overall experience with these activities where you learned about architecture?
2. Did you ever think about or apply the things you learned about architecture during the VR session in your everyday life? By everyday life, I mean your life outside of school.
    - Did you ever think about how architectural design works?
    - Did you notice any examples? Can you give me an example of architecture in your everyday life?
    - Did you notice any other examples?
    - Is that something you thought about in the moment or something you thought about just now [i.e., prompted by the interview]?

- Did you talk to anyone else about architecture outside of school?
- When you were talking to [someone], were you just answering a question [they] had, or were you talking about [topic] because you found it interesting?
- Did you watch any shows on TV/videos on social media about architecture?
- Would you say you paid more attention to [architectural objects] than you did before the unit?
- Did you watch that show/video because architecture class got you interested in it, or would you have watched it anyway?
- Did you read anything on your own about architecture, and by on your own? I mean, did you choose to read something even though it wasn't required for school?

3. Do you think about architecture differently than you did before?
    - Now that you learned about architecture, would you say that you think differently about how some things work or why some things happen?
    - How do you think about [it] differently?
    - Can you give me an example/think of a specific example of how you think about it differently?
4. Are the ideas you learned about architecture interesting?
    - Did learning about architecture make the world or your life more interesting or exciting?
    - Could you give me an example?
    - Did it make you interested in how things work or any particular events?
    - Are the ideas you learned about architecture useful?
    - Do you think it's useful for your current everyday experience or useful for the future?
5. Can you tell me a little bit about your experience with VR activities?
    - Do you remember the details of places you visited in VR?
    - How real it felt for you when you were in VR?
    - Did you feel like having control in completing the activities in VR?

- Did you try to remember VR places when you recognized architect out of class or watching videos?
- Would you prefer to continue learning about architecture in virtual reality?

6. What else should I know about your experience?

Thank you so much for your time. I appreciate you sharing your experiences.

Appendix G. IVR+TTES Intervention Session Plans

Session 1 Flow (30 minutes)

Timing	**Activity**	**Description**
5 mins	Introduction + Consent	Brief students about the study purpose and introduce the VR headset. Have students complete the consent form if they agree to continue.
10 mins	Pre-survey	Students take pre-survey tests on a designated device
15 mins	VR Tutorial	Each student completes the ¨First Steps Quest 2¨ and ¨Wooorld VR¨ tutorials. Schedule next session.

Session 2 Flow (60 minutes)

Timing	**Activity**	**Description**
30 minutes	Model Transformative Experiences	Start talking about childhood interest in building and drawing. Take students to different locations in England to recreate the backpacking trip results with TE experience.
10 minutes	Frame content as ideas	Talk about how architecture became a compelling idea that was exciting to apply to real life by being more than a concept learned in class at the end of the England trip.
15 minutes	Scaffold re-seeing	Students will freely explore a city of their choice as a group to explore architecture and report their experience back at the end. Students might want to visit a location they visited before.
5 minutes		Encourage students to look for architecture and capture TE moments until next session. (Don't

		assign as homework)

Session 3 Flow (60 minutes)

Timing	**Activity**	**Description**
30 minutes	Scaffold re-seeing	Start a discussion centered on students' reflections, or "captures," of Transformative Experience (TE) episodes. The researcher asked students about their week, specifically if they had noticed any architectural features. Each student takes control of the virtual space and talk about their TE experiences.
10 minutes	Model Transformative Experiences	Talk about how architecture became a compelling idea that was exciting to apply to real life by being more than a concept learned in class at the end of the England trip.
5 minutes	Frame content as ideas	Remind and emphasize how architecture is a compelling idea that is exciting to apply to real life by being more than a concept learned in class.
10 minutes	Scaffold engagement	Students will freely explore a city of their choice as a group to explore architecture and report their experience back at the end. Students might want to visit a location they visited before.
5 minutes		Encourage students to look for architecture and capture TE moments until next session. (Don't assign as homework)

Session 4 Flow (45 minutes)

Timing	**Activity**	**Description**
5 minutes	Scaffold re-seeing	Start a discussion centered on students' reflections, or "captures," of Transformative Experience (TE) episodes. The researcher asked students about their week, specifically if they had noticed any architectural features.

30 minutes	Reflection on IVR+TTES intervention	Students talk about their experiences with IVR and TTES activities.
10 minutes	Post survey	Students complete the study by completing the closing survey.