

From Engagement to User Experience: A Theoretical Perspective Towards Immersive Learning

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Engagement

User Experience

Learning Experience

Immersive Technology

As we see immersive technology becoming ever more prominent in education, from our mobile devices to highly immersive virtual reality headsets, there is a growing need to look beyond existing, pragmatic conceptualizations of the technology. We need to explore immersive technology from a theoretical perspective focused on the user and learner experience for it to make meaningful contributions to education. The way we experience technology often frames how we engage with it and determines whether we continue to use it. Immersive technology is often conceptualized based on the affordances provided to the user without any associations made back to theoretical underpinnings drawn from user experience and learning experience research. The authors take known conceptualizations of user experience and immersive technology and link them to the learning experience to form a working theoretical framework that can help develop an understanding of learner engagement with this emerging technology. We begin with concepts related to immersive technology, then build a theoretical framework and conclude with implications for learning approaches through examples from the spatial disciplines.

1. Introduction

Immersive technology is becoming more affordable, leading to increases in adoption for education, particularly in the spatial disciplines (Klippel et al., 2019). This increase in adoption necessitates that we look beyond existing conceptualizations to a more theoretical perspective of the user and learner experience. Our perceptions of technology often frame how we continue or discontinue engaging with it. Immersive technology places the user or learner in the center of the activity and provides an experience from a first-person perspective. Immersive technology takes the form of one of three types: virtual reality (VR), augmented reality (AR), and mixed reality. However, our understanding of experiences resulting from immersive technology use often differs based on the discipline. Therefore, we focus our efforts on a single discipline first—the spatial disciplines where design and spatial relationships are central to the use of immersive technology.

Currently, there are two broad perspectives towards immersive technology in learning; one is focused on learning effectiveness, and the other is focused on user experience (UX) from human-computer interaction (HCI). Both perspectives depend on engaging users or learners through technology. The learning effectiveness perspective emphasizes the benefits of immersive technology and examines whether learning occurs or not. The gap lies in

underestimating any downsides to immersive technology by focusing on hypothesized benefits without sufficient empirical backing. From a strictly UX perspective, learning is ill-defined, making it harder to validate if learning occurred. The UX perspective primarily focuses on achieving *presence* or *embodiment* as a way to gauge the success of immersive technology. As a result, much of the research investigating such technology tends to incorporate aspects from both but only at a conceptual level with no consideration for how they work together or how engagement does or does not occur.

With the rapidly changing nature of immersive technology, it has been challenging to formalize a singular theoretical framework that addresses discrepancies between both perspectives and their relationship towards engagement. It is particularly difficult when the focus is on the technology—the factor that constantly changes. For instance, positive results from a study using Google Glass, an older AR technology, may not necessarily hold true when repeated with a phone-based AR. While both can be conceptualized as AR technologies, their technology affordances are different. Similar issues can be found when referring to technology such as the CAVE or any head-mounted display such as Oculus Rift. Rather than using a black-box approach (i.e., treating technology as monolithic entities) to understand the connection between UX and learning experiences through immersive technology, we look at various technologies through the lens of affordances adopting a variable-centered approach proposed by Nass and Mason (1990). Looking at commonalities across the technology, in the form of various affordances, provides an easier way to now compare and understand technology in a way that stands the test of time and emergence of new technologies. This approach helps us address the challenge of formalizing a singular theoretical framework for immersive technology and learning. We illustrate this framework through work in the spatial disciplines.

Like other fields, the spatial disciplines such as architecture, geography, and geology increasingly use immersive technology based on the promise of several benefits from the experience of the *virtual place* (Bricken, 1990; Dalgarno & Lee, 2010). Such technology affords learners the ability to visit the ocean floor, the cells of the human body, or any location not possible or not easy to visit in real life (Dalgarno & Lee, 2010). Other benefits include reducing distractions commonly found in real-world learning experiences (e.g., weather, crowds, etc.; Robinson, 2009), providing multiple perspectives (Soto, 2013), and increasing engagement through activity (Procter, 2012). Depending on the type of technology and intended experience, these benefits are perceived to be widespread. However, for a systematic investigation of these technologies, we have to begin by defining what we term as immersive.

Immersion is a function of the technology that forms an experience—technological attributes or affordances as opposed to the individual perceptions of the experience (Slater, 1999). Immersion encompasses technical components that involve a user's senses (e.g., visual, audio, tactile, etc.). Technologies considered to be immersive often refers to a variety of technology that profoundly differs in functionality yet provides the same primary visual, auditory, and other sensory experiences. The differences between these technologies (AR to VR for instance) vary in terms of the degree of immersion provided or the number and form of technical attributes that enable the technology to be considered immersive. Additionally, such technology differs in how it involves the senses; AR utilizes the real world and enhances what already exists whereas VR uses a completely synthetic space creating only the sensory information necessary for experiencing that space. For more on the role of space as a catalyst in shaping the immersive experience in AR, VR, and MR, see Milgram and Kishino (1994). In our short introduction here, we provide a simplified table of immersive technology types and the technical and spatial attributes generally used for visual immersion, the most common and easily identifiable form of immersion (Table 1). For more on technical attributes of immersion, see LaViola, Kruijff, McMahan, Bowman, and Poupyrev (2017).

Table 1

Technology Type Attributes of Visual Immersion

Type	Description	Examples	Technical Attributes	Spatial Consideration

Augmented Reality (AR)	Enhances the real-world with information.	• Phone-based (QR Code) • Meta View Headset	• Field of view limited to the viewing angle of a phone/tablet/headset • No field of regard (no peripheral vision) • Level of detail (limited to phone/tablet processors)	• Enhances the real world with visual information	Reality
Mixed Reality (MR)	Moves between the real and virtual place.	• HoloLens • Windows MR Headset	• Field of view limited to the viewing angle of a headset • No field of regard (no peripheral vision) • Level of detail (limited to headset computing processor)	• Replaces items in the real world with visual information • Ability to move between the real world and the synthetic (e.g., real-world to 3D models)	to
Virtual Reality (VR)	Provides an entirely synthetic experience.	• Oculus Rift • Oculus GO • HTC Vive • CAVE • Google Cardboard	• Field of view limited to the viewing angle of a headset or screens/monitors used • Field of regard that includes the peripheral vision • Level of detail (limited to processors of computer/headset)	• Presents a synthetic world with various types of visuals (e.g., 360° images, 3D models, etc.)	Virtual

We also further clarify what we mean by immersive technology in the context of VR. From Google Cardboard to HTC Vive to Oculus Rift and many other technologies on the market, immersion is one differentiating factor from other forms of technology. Early adoption of VR in education took the form of desktop monitor-based environments referred to as Virtual Worlds, where learners control avatars to participate in learning activities within a synthetic environment (Dede, 2009; Nelson & Erlandson, 2012). Newer technology, however, provides capabilities afforded by immersion, such as field of regard (displays that include the user's peripheral vision) or wider fields of view (a wider viewing angle).

Additionally, immersion is accompanied by some form of interactive capability (Bowman & McMahan, 2007). Immersive technology allows students to view and interact with synthetic environments and objects in three-dimensional space (Piovesan et al., 2012). We limit the focus of our theoretical framework to immersive technologies, though our framework can be applied to less immersive technology to a certain degree. This focus avoids confusion with desktop-monitor technologies and avatar-based platforms such as Virtual Worlds (Nelson & Erlandson, 2012) which are focused on social interaction and communication rather than the technology that involves a user's perceptual senses. After clarifying the concept of immersion and introducing the various technology types, we now focus our attention to the other key concept in our discussion—learner engagement.

Learner engagement is an outcome often associated with immersive technology (Dede, 2009). Stemming from a broader concept of engagement, placing focus on the learner aligns better with educational outcomes. Our focus on learner engagement, therefore, is based on an established relationship between the use of a technical intervention and learning outcomes (Meggs et al., 2012) and research data showing sustained use and focus on a learning tool can improve learning outcomes (Dede, 2009). Our framework presents two ways in which the sustained experience can potentially lead to improved outcomes through engagement-focused attention on the learning content and through association with the real world using spatial relationships (a demonstrated way for how learners understand and apply knowledge in real-world situations).

We present a framework, the *immersive framework*, describing the role of UX in immersive technology and how it leads to learning, drawing from a variable-centered approach towards technology affordances. We then illustrate this framework utilizing concepts specific to immersive technology and its use in education within the spatial disciplines. This chapter continues with a description of key concepts related to immersive technology, UX, and learning. We discuss the immersive framework and the implications of its use in the context of learning. We conclude with the intended impact on engagement within learning scenarios that use immersive technology and how the immersive framework can be applied in other disciplines.

2. Conceptual Framework

To tackle developing a framework for immersive learning, we address both the UX and usability conceptualizations of the technology to ultimately lead to learner engagement, our framework's outcome. We present our conceptualization of learner engagement followed by key UX factors from user experience and usability. User experience has been at the forefront of HCI to determine the overall value of ideas such as aesthetics, affect, and fun (Hassenzahl & Tractinsky, 2006). We distinguished it from usability as necessary for continued engagement with technology. Specifically, usability focuses on the task, looking to efficiency and learnability of particular technology as a matter of performance. Conventional conceptualizations of usability include effectiveness, efficiency, and satisfaction (Monk et al., 2002). While effectiveness and efficiency are related to the user's ability to accomplish a task through technology, satisfaction presents a different perspective. User satisfaction encompasses many aspects that focus on a user's judgment of whether a technology meets particular needs and relates to learner engagement through motivation.

UX in the context of immersive technology additionally focuses on specific factors meant to involve users in the experience, ultimately improving and sustaining satisfaction, a differentiating factor between immersive and non-immersive technology. Newer technology offers first-person, ego-centric experiences that utilize physical user movement (e.g., head-turning, walking, etc.) and provide a sense of embodiment not possible through desktop monitors. Embodiment, in turn, improves the overall experience by acknowledging a sense of control over the interaction (e.g., the user must move their own body to interact). This control leads to improved affect or enjoyment of the experience, which are directly related to learner engagement (D'Mello et al., 2017). We focus on key factors relating to how users experience immersive technology, including presence, embodiment, enjoyment, and novelty.

2.1. Learner Engagement

Meaningful engagement is fundamental to the learning process (Martin, 2012) as a key component of active learning (Chi & Wylie, 2014). Yet, engagement remains a complex concept with multiple definitions (Glas & Pelachaud, 2015). Engagement is often used synonymously with motivation (Martin, 2012), interest, involvement, immersion, and user experience (Lehmann et al., 2012). These other concepts, while related, are not the same. However, they can influence how engagement forms. In education, focusing on the learner often frames how technology engagement is received. For this chapter, we refer to engagement as *learner engagement* and distinguish it from similar concepts of motivation, involvement, immersion, and user experience (inclusive of satisfaction). Continuous interaction with learning content underlies active learning and is essential to maintain sustained engagement (D'Mello et al., 2017). The relationship between engagement and learning outcomes is not straightforward; being engaged does not directly lead to improved learning outcomes but can increase the chances for it. Much of the relationship between engagement and learning

outcomes could be related to other factors including implementation, teaching method, learning content, and even the individual learner through additional factors of motivation, satisfaction, and interest.

2.2. Presence

The concept of *presence* or the feeling of "being there" (Slater & Wilbur, 1997) within a virtual place is central to UX in the context of immersive technology. In the spatial disciplines, we can focus more narrowly on the feeling of "being in a space", commonly referred to as *spatial presence*. See Balakrishnan, Muramoto, and Kalisperis (2007) for a more detailed definition of spatial presence within the context of spatial disciplines. This feeling is highly subjective and dependent on several factors ranging from the content of the virtual place, the overall technology experience, and even the disposition of the user. The mechanism underlying the sense of presence is still not fully understood and therefore makes it one of the most prominent UX concepts explored with regards to immersive technology. Presence occurs most often when attention is focused on the virtual place to block out indicators of the real world and allow the user to feel like the simulated space is real (Wirth et al., 2007).

In the learning community, presence as related to immersive technology has been hypothesized as highly influential and necessary. Despite this belief over the years, its role and contribution to learning are still debated (Makransky et al., 2019; Markowitz et al., 2018). Focusing specifically on spatial presence, we can conceptualize its role in learning design. Presence helps to achieve situatedness, establishing a location and context for learning to occur. The spatial component of presence helps to establish place markers or references between objects and other content through the spatial relationships experienced. This is similar to the real world where aspects of navigation, scale, distance, and organization play a role in how learners understand and remember actions that occur. An example of this would be visiting a new city, where known knowledge of navigation is often used and relearned based on the experience. Presence, from a UX perspective, occurs on a scale and grows and diminishes as the experience continues. This suggests a dependency of presence on other UX factors to extend the experience. As such, there is a need to force continued engagement through variation, much like in active learning.

2.3. Embodiment

Embodiment provides a sense of familiarity by using a user's own body as a frame of reference to participate in an activity (Kilteni et al., 2012). We make a distinction from the term's use to refer to the phenomena experienced when a user embodies the actions of an avatar as his/her own (Dede, 2009). Embodiment occurs when a user can seamlessly interact with the virtual place as if they were using their own body. In newer immersive technology, physical movement is now tracked, enabling a greater sense of embodiment to occur as users can actually walk around a virtual place, stand at their individual height, and even turn their heads to look around.

Through desktop-based virtual worlds, the learning community has capitalized on the role of avatars as a means of embodied learning, to relate actions to an identity a learner assumes (Schultze, 2010). Therefore, little has been done to investigate the role of the actual user's body being involved in the learning experience. The closest form of embodiment as found in immersive technology is the use of field trips and fieldwork, where the learner is physically involved in an activity and limited by his/her bodily limitations. For example, geology students learn about the slope and scale of rock faces by actually standing next to them or climbing on them because they can use their height to establish how large or how angled a surface is compared to their own body. The use of AR in the field has contributed to the sense of embodiment in the experience—allowing learners to overlay and interact with digital information while on-site using their own body as a reference (Carbonell Carrera & Bermejo Asensio, 2017).

2.4. Enjoyment

Common UX factors include emotion or affect, which is often operationalized as the degree of valence that occurs (Vorderer et al., 2004). With immersive technology, however, successful exposure leads to overly positive affect and emotions and therefore should be explored independently of commonly measured affect and emotion. Enjoyment is an accepted outcome measure in response to immersive technology. Specifically, enjoyment creates a sub-scale of positive affect with degrees of enjoyment or fun when the experience occurs. Enjoyment is strongly related to usability

and considered a factor leading to learner engagement (Ainley & Ainley, 2011). Features of a technology experience that become overly complex or difficult to use can reduce enjoyment.

Enjoyable experiences in education lead to improved outcomes. The role of fun and play have been well established in education as motivation for sustained learning (Bisson & Luckner, 1996). The nuances of fun and the subjectivity of what eventually motivates a learner, however, can cause variation in how well enjoyment improves learning. With increased motivation through fun and play, learning challenges can be increased, forcing a learner to engage with learning content through higher-order thinking skills. The downside to enjoyment in learning can be twofold: a) that experience can be so enjoyable but never increase the challenge such that learners become bored and b) that challenge increases too quickly, and learning becomes frustrating. Focusing on enjoyment alone can additionally lead to poor learning outcomes, and therefore should be balanced with other factors related to learning content (Clark, 1982). Optimal enjoyment of learning content requires aligning the challenge to skill level and requires constant feedback. Learners should be made aware of their capabilities at any given time and be provided timely assistance where their capabilities fall short in order to increase enjoyment.

2.5. Novelty

A particular experience that is entirely new for a user can have profound effects on the initial satisfaction, so much that users often will forgive issues of usability or ignore the content of the experience (Roussou, 2000). Novelty as a UX concept is a unique characteristic compared to other concepts in that it dissipates as the experience persists. It is, therefore, sometimes framed as a negative aspect of the UX experience that must be resolved for effective learning to occur (Dalgarno & Lee, 2010). However, with newer devices and applications being developed, novelty should not be ignored. Users experiencing immersive technology for the first time can experience an overwhelming sense of curiosity and awe, an emotion that can have both positive and negative effects (Chirico et al., 2016). Novelty, while a fleeting experience, generates high levels of engagement from users which can quickly dissipate over some time, providing a false sense of success with a technology experience (Merchant et al., 2014). Novelty impacts engagement through a combination of intrinsic motivation and expectation. The key to effectively integrating novelty in an educational setting, aligning with other media used in learning, is to continually provide something new so the positive aspects of the experience can increase and sustain learner engagement. Keeping the learning experience consistently new can help stimulate a learner's ability to adapt and apply knowledge learned to different situations, much like a repeated virtual simulation can continue to distract patients from pain in therapy sessions (Rutter et al., 2009). In such situations, the novel experience must be sustained to keep patients distracted from the pain they feel. This notion of sustaining the novelty of an experience can potentially help instill higher-order thinking skills as learners have to think through the changing experience. The positives of creating new learning experiences to engage and stimulate higher-order thinking can be similarly applied to the experience of immersive technology. One can hypothesize that the positive effects of novelty in a sustained way could maintain engagement.

3. Theoretical Framework

In this section, we present our theoretical framework, the immersive framework, consisting of UX factors of immersive technology that indirectly lead to learner engagement through constructs that hold meaning for both UX and learning. We explain the theoretical linkages that connect two key characteristics of immersive technology with the UX concepts discussed in the previous section and illustrate how it can lead to learner engagement. We focus on the learning content presented as a representation abstracted from the real-world (representational abstraction) that situates learners through cognitive involvement, akin to experiential and place-based learning. Such experiences afford a sense of agency through active participation in the learning scenario while providing timely feedback to boost motivation and maintain attention. In accomplishing these goals with our curated experience, learners experience UX factors of presence, embodiment, enjoyment, and novelty, to varying degrees, depending on the immersive technology used. These aspects may occur together or individually. Each factor uniquely impacts learner engagement positively or negatively, often depending on the user, the type of technology, and the situation in which the technology is implemented. For example, using such technology in the field through AR to reinforce content covered in lectures will

produce different levels of each factor compared to using VR in the classroom on a rainy day because a field trip was canceled. The results of these two examples will inevitably have different outcomes because of the differences in the situations for implementing different technology. We begin with a description of each aspect of the immersive framework.

3.1. Representational Abstraction

The immersive framework starts with representational abstraction, the symbolic encoding of information to be learned that is presented through the immersive technology. Representational abstractions come in many forms from text to drawings. Bricken (1990) links symbolic processing in learning specifically to reality generation or the simulated experience. The representational part of the abstraction focuses on the attributes of the technology; in this case, those attributes enhance immersion—field of view, field of regard, level of detail, and many others. These attributes, or affordances, of the technology involve the user's senses as a means to build and present a representation. The other aspect of this concept is the abstraction itself, the content. Not only is the multimodal presentation (multiple-senses) a large part of the abstraction but so is the symbolic information provided. Content in this framework refers to the symbolic information communicated through immersive technology; it is the focus of the learning activity and the surrounding environment—be it the real environment as in AR or a completely synthetic one for VR. According to learning design, the content and context must be defined and related to the intended activity to work with the representation. For example, content on animal habits could be contextualized within the setting of a zoo and presented through immersive technology in ways suitable to the intended learning activity (e.g., if a real zoo was inaccessible), VR could manufacture the experience or AR could be used within a zoo to simulate content in the real-world context. Content is inclusive of anything meant to be interacted with (e.g., tables, graphs, 3D objects, and even textbook passages). Context is the space that holds the content—including the interface for accessing and interacting with content. As in the zoo example described above, the actual zoo would be the context for the additional content using AR while a virtual zoo would contain the same content in VR.

3.2. Interactivity

As noted earlier, immersive technologies are not entirely passive experiences; immersion is often accompanied by some degree of interaction even if the learning experience is primarily designed as a passive one (i.e., virtual tours still afford the learner to look around or click on objects). The ability to act and enact change within a virtual space adds numerous possibilities to the experience (Bucy & Tao, 2007). Sundar (2004) distinguishes between interactivity as a function of the technology and interaction as a user's perception of their ability to enact change through their actions. Interactivity provides a way for learners to act within the virtual place. Interactivity occurs in two ways: the actual system characteristics inherent in the devices used and the metaphor applied to added capability not explicitly tied to the device (Kalawsky, 1999). For example, characteristics inherent in the devices can refer to aspects such as a gyroscope that enables 360° motion of a user's head or physically moving a phone to look around. Added capability, on the other hand, could be a feature within a point and click interface that shifts perspective as a metaphor for walking in a virtual place. Both kinds of interactivity involve the user in the content through taking some form of action and provide varying degrees of control and agency to the user. User agency, akin to learner agency, is the cornerstone of interactivity and represents the user's capability and freedom to control action within the environment. The amount of agency granted to a user can both increase and decrease UX factors of immersive technology, suggesting a need for balance in the amount of control a user has at any given point in an immersive experience. Agency and therefore interactivity are highly tied to motivation and intention, much the same as found with learner agency. Additionally, interactivity relies on feedback to illustrate that an interaction has occurred. Whether as a change in the viewing angle from turning one's head or highlighting an object in an environment, feedback informs users that something has happened (i.e., the user's interaction has done something as well as whether a user has done something right or wrong). A technology's mode of interactivity and method of feedback is directly tied to usability, which can either increase or decrease satisfaction, enjoyment, and learner engagement. Similarly, learner feedback from interaction with an activity can impact the overall learning experience by its timing and incorporation of remediation.

The immersive framework (Figure 1) shows a layout of all of the listed concepts with the theoretical linkages from the main components of a curated learning experience using any immersive technology. Representational abstraction (technology + learning content) and interactivity work together to influence several UX factors that increase engagement with the technology experience and ultimately the learning experience. In this framework, we focus on the interplay of our two concepts influencing UX factors to formulate learner engagement and discuss the potential implications for learning.

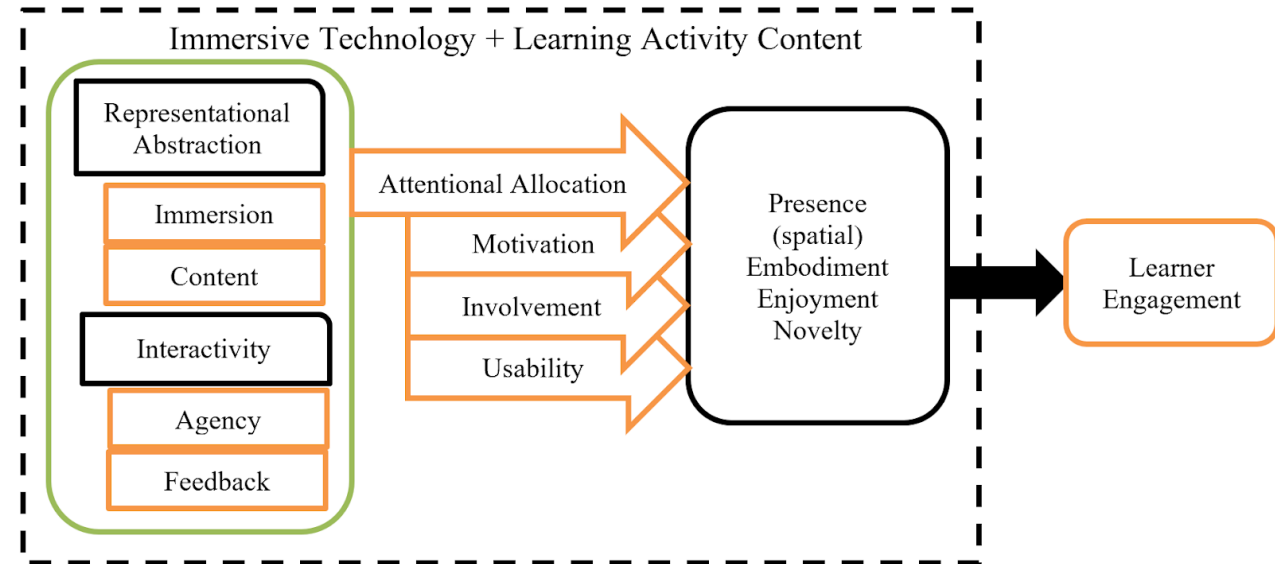


Figure 1

Immersive Framework for UX and Learning in Immersive Technology for Learner Engagement

3.3. Attentional Allocation

A central factor to representational abstraction and interactivity successfully influencing UX factors and learning is attention. Attentional allocation plays a vital role in maintaining the focus a learner gives to an activity or experience (Wirth et al., 2007). Learners provide an initial allotment of attention to an activity or experience, but this allotment then varies as a function of UX and individual factors. For instance, as presence occurs, a higher allotment of attention is given towards the experience so that a learner is not distracted by things outside of the experience, regardless of the distraction. This idea of a focused allotment of attention holds similarities to the concept of flow (Nakamura & Csikszentmihalyi, 2009). Attentional allocation is helped by the physical factors of the technology. Headsets, for example, physically block seeing the outside world whereas a mobile phone interface does not. However, mobile phones can use flashing lights and other sensory cues to sustain attention. Similarly, headphones direct sound of the experience towards a user's ears overriding sounds from the real world around him/her. A technology's isolating factors, however, can have adverse effects in certain contexts. For example, collaborative experiences require the ambient noise of others to feel engaged and present. As a result, understanding the immersive attributes of each technology is crucial to aligning the right technology with a specific learning scenario. Similar to UX, learner experience is based on an allocation of attention towards the learning content, often seeking to reduce split-attention to improve a learner's information processing capability (Kalyuga et al., 2000). Oftentimes, attention is attained through a combination of different learning strategies that fundamentally work from the same theoretical linkages as UX from immersive technology: involvement, motivation, and usability.

3.3.1. Involvement

Involvement is the degree a user participates in an activity (Schuemie et al., 2001). From a learning perspective, involvement considers external factors that provide cognitive stimulation, physical interaction, control, potential exploration, and varying challenges (Wishart, 2001). Cognitively, learners are tasked with challenging existing mental

models to form new ones through active learning. Similarly, physical interaction challenges learners to involve their bodies, embodying the learning activity through movement and physically interacting with the material. The involvement of the senses through immersive technology provides the learner with a greater sense of agency that results in enhanced interactivity with activities meant to develop or enhance mental models. Interactivity in an immersive environment (the learning place when immersive technology is used) allows for learners to physically involve their bodies to situate mental models within a real-world context. This can cognitively engage and enhance mental models when compared to learning media that rely on more abstracted information. For example, giving directions using the cardinal directions (survey knowledge) as opposed to unique buildings/monuments (landmark knowledge) is much harder without the proper mental models and surrounding context.

3.3.2. Motivation

Ryan and Deci (2000) suggest that the incentive to participate in a learning event can be internal or external. Internal motivation guides a learner to exclusively focus on a learning goal and ignore issues and other external factors which may detract from the experience. UX concepts of affect and fun/enjoyment directly impact a learner's internal motivation and provide insights into how a learner remains invested in an experience. For example, enjoyment of an experience leads to a learner's heightened investment and capacity to ignore inconsistencies and even bad interface design. External motivators, more commonly found in traditional learning environments, consist of reward-based systems to encourage participation. Grades are often an external form of encouragement to perform well in a learning event and even motivate learners to succeed despite poor design and issues with a technology system. Within active learning, different approaches are used to establish positive experiences through aspects of extrinsic motivation. For example, positive experiences due to subjective outcomes of fun and play are highly correlated with the UX factor of enjoyment (Fontijn & Hoonhout, 2007). A key factor with maintaining motivation from a learning perspective is the balance of challenge to reward (Garris et al., 2002). As a whole, motivation provides the means to engage and continue to sustain a student in a learning activity. In summary, UX capitalizes on motivation through factors of novelty or involvement of the senses to heighten investment with the learning experience. Understanding the relationship between UX and motivation is vital when building activities that develop a sense of involvement and enjoyment to improve learner engagement.

3.3.3. Usability

Usability plays an integral role in how technology influences the experience. Commonly, usability is tied to the satisfaction component of the user experience; however, other aspects of usability can adversely impact satisfaction. Within this study, satisfaction is defined as the rating of usability that can lead to improved or diminished engagement with a technology. There are similarities and distinctions between usability in learning (pedagogical usability) and HCI. Pedagogical usability is similar to HCI's usability factors but focuses on the ability of a learning intervention to address objectives (Ardito et al., 2006). The components of pedagogical usability include everything from the content to the interface and tasks. Consequently, the influence of usability issues in UX can fall under the umbrella of pedagogical usability but with the added need to relate to the learning objectives. Poor UI has similar results to weak instructional guidance in a classroom; if a learner cannot learn the interface, the poor experience will obstruct achievement of the learning object and decrease learner engagement. Good usability within an immersive technology will blend seamlessly into the experience, allowing the learner to focus on the task. Combining good technical usability with the proper design of activities should additionally free up mental resources to focus on the construction of new knowledge from the experience. However, if any single aspect of the experience is not well designed, some learners may not excel in meeting learning objectives as a result of not fully engaging with the content.

4. Implications in Learning Approaches

Learning through immersive technology has focused primarily on a constructivist approach (Bricken, 1990; Dalgarno & Lee, 2010) hinting towards the positive aspects of active learning. The high degree of activity embedded into the immersive experience makes it possible for learners to construct new knowledge through any number of combinations

of situated (Dede, 2009), place-based (Klippel et al., 2019), exploratory (De Freitas & Neumann, 2009), and experiential (Abdulwahed & Nagy, 2009) means. In understanding the roles of learning approaches, we focus on how the framework discussed above helps to bridge the two ideologies towards learning through immersive technology with implications to improve learner engagement and ultimately learning.

De Freitas and Neumann (2009) explain the learning cycle as consisting of three approaches: associative, cognitive, and situative. Associative learning makes use of immediate feedback and transfers to other contexts. Cognitive learning focuses on abstraction and experimentation that builds on the technology experience. Lastly, situative learning focuses on interaction with others, establishing a community of practice. Each approach occurs within a learning event and can overlap depending on the alignment of learning objectives, activities, and outcomes defined. With our framework combining factors relating to both learning and UX, we can provide more technical implications that work within these three approaches. This suggests that different learning approaches can be integrated into the immersive framework to improve learner engagement.

Interactivity through good usability practices and design can improve immediate feedback on learning performance and incorporate remediation in a variety of ways. Good interface design combined with varied activity types can improve transfer from the simulated learning context to the real-world, improving the associative learning approach. Increased agency of movement and learning through free exploration can combine with virtual content and immersive factors to offset the cognitive load of mental abstraction (Chen & Ismail, 2008). This offloading frees up a learner's mental capacity to experiment and develop newer mental models, addressing the cognitive learning approach. Lastly, immersive technology has only recently started to facilitate collaborative experiences (Wallgrün et al., 2019) but does incorporate a connection to an environment, whether real or synthetic, that can house collaborations. The immersive affordances and cognitive involvement, both increasing a sense of presence, can help to establish a connection to the simulated environment—a goal found in the spatial disciplines but increasingly in other disciplines such as medicine and engineering. For example, to help nurses learn an emergency room layout quickly, immersive technology can situate the learner in the environment with indicators of where essential instruments are located. While not forming a community of practice with other learners, the single learner can establish an understanding of the spatial layout – addressing the situative approach.

5. Building Learner Engagement through Immersive Technologies

In this section, we take a look at two innovative examples of immersive technologies being used to enhance learner engagement in the spatial disciplines. We draw our first example from architecture. Design students often find themselves working with smaller-scale, abstract drawings and 3D models that are meant to represent buildings and interior spaces in the real world. During the initial years in a design studio, students develop the foundational skill to visualize the real-world scale of buildings under design. Students acquire this skill through a curriculum focusing on manual tools (e.g., hand drafting, building scaled physical models) and guidance from faculty and peer reviews. However, even with this training, some novice design students still find this skill difficult to acquire. During the design process, novice design students are challenged with understanding the qualities of space, spatial dimensions, and relationships between spaces. Additionally, novice students in architecture and related design disciplines find it challenging to visualize organizational, dimensional, and experiential aspects of built environments (Kalisperis et al., 2002; Otto et al., 2003). Additionally, novice students in architecture and related design disciplines find it challenging to visualize organizational, dimensional, and experiential aspects of built environments (Kalisperis et al., 2002; Otto et al., 2003). Traditional computer-aided design (CAD) tools, often learned and used in the design profession, do not represent built-environments at full-scale, but rather at the scale provided by the size of computer monitor a given student is using. These tools additionally place design students outside of their digital drawings, forcing them to take a mental leap to envision the above aspects *without* any relation to their bodies. However, immersive technologies, through a sense of presence, allow students to *inhabit* the spaces under design and evaluate their experiential qualities.

To address this issue for beginning architecture students, we utilized immersive technology in the form of VR because design students learn without an actual environment. The Immersive Visualization Lab (iLab) at the University of Missouri and the Immersive Environments Lab (IEL) at Penn State University are based on a cost-effective desktop VR approach using readily available hardware components including large-screen displays, a familiar desktop computing environment, and affordably priced software (Figure 2). The selection of VR technology focused on teaching scale; large screen VR displays use the student's body height compared to the size of the 6' screens for a more embodied reference. Furthermore, multiple screens provided a better opportunity for the field of regard (or inclusion of the student's periphery) to aid in connecting spaces and enhancing the sense of presence through a focus on only the designed space. These immersive systems allow design students to translate their CAD models into an interactive, immersive experience on large-screen, 3D-capable displays. The added stereoscopic 3D capability further enabled students to explore their design ideas through 3D glasses at more accurate scales via interactive walkthroughs from the first-person point of view than from their desktop monitors. The attentional focus produced by full-scale models enabled students to make more associations with their designs and more informed decisions based on not needing to mentally abstract the scale of the design. The overall pedagogical value of the offset of the mental abstraction through the representation (Kalisperis et al., 2002; Otto et al., 2003), as well as the positive impact on spatial understanding and presence of these immersive environments (Balakrishnan et al., 2012; Balakrishnan & Sundar, 2011; Kalisperis et al., 2006; Oprean, 2014), has been demonstrated through controlled experiments as beneficial to the education of beginning design students. The students not only find the experience engaging but also find the novel format helpful to explore their designs and make better design decisions. These experiments specifically looked at the impact of VR on spatial understanding and spatial presence systematically as a function of various affordances of immersive technology including stereoscopy (e.g., the 3D effect), the field of view, level of detail, and navigability among others to identify the actual value of each for design students. For instance, the field of view was the most influential attribute of immersive technology for learning scale, navigability was influential for engaging with the content, and the usability of the system's navigation and setup made the use of the immersive systems successful or unsuccessful. Motivation in this example was intrinsically provided by the student's interest in improving their designs through a different experiential medium than the traditional CAD tools and physical models. Overall, students were more engaged with the design experience when using the immersive systems as it forced them to think through their design decisions made while working on a smaller desktop computer.

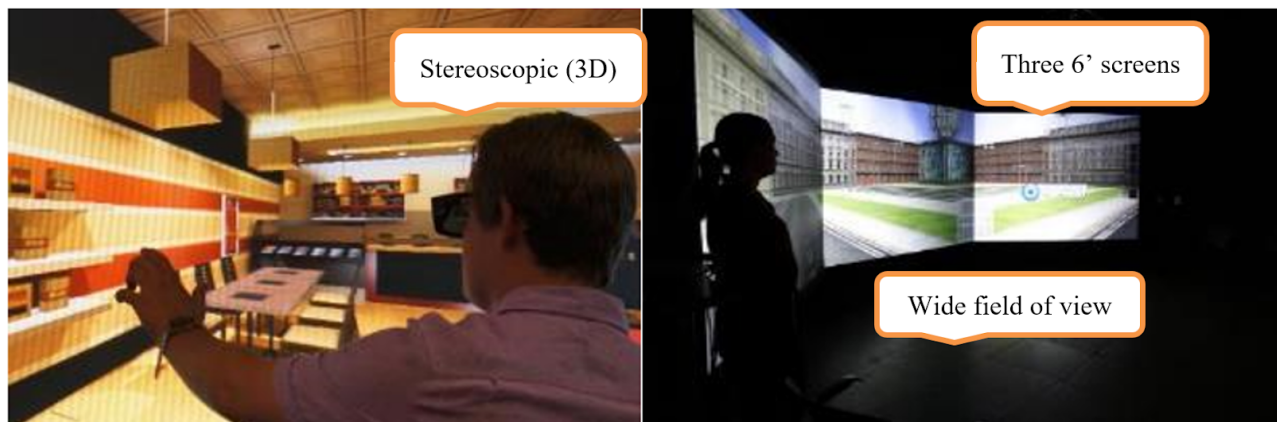


Figure 2

Design Explorations in the iLab (left) and the IEL (right)

A second and third example from architecture focuses on another aspect learned in the first years of design education –composition and exploration of design (or ideation). Given the challenge in learning and applying both composition and exploration of design in early studies, the framework applies not only one immersive technology but two. Nine Cube VR (Hopfenblatt & Balakrishnan, 2018) is a digital learning tool consisting of two modes, desktop VR and headset VR, for beginning design students in architecture to learn basic principles of 3D composition and design exploration. The Nine Cube VR is an immersive virtual reality implementation of a classic foundation studio course exercise developed

by Hejduk (1985) that provides students with a "kit of parts" along with several constraints on dimensions and transformations for design exploration. This well-established design studio exercise provided the learning content while the two immersive technologies involved provided varying levels of representation to assist with the different parts of the learning scenario. In addition to the pedagogical goals related to 3D composition, form, and design, the immersive virtual reality tool takes advantage of newer mediums such as stereoscopic 3D displays and interactive input devices. These mediums have the ability to switch between smaller scales that architects work with during composition and massing explorations at full-scale. It also allows students to experiment with interactive lighting studies relative to the level of detail available in VR. The combination of technical attributes helps to establish a sense of presence in the open virtual place where the design content can be manipulated as part of the learning activity. Unlike with the large-scale screens used in the other example, embodiment is not as present with the fixed display and narrower field of view from Nine Cube VR's desktop-mode but is compensated through the use of the HTC Vive VR headset (Figure 3). As a result, the involvement in the desktop mode is dependent on the interaction with the content in the virtual place, but embodied interaction drives the VR headset experience. Feedback from students and instructors was positive and pointed out its potential for improving student designs through the engagement resulting from being able to address both the experiential and composition stages of design ideation.

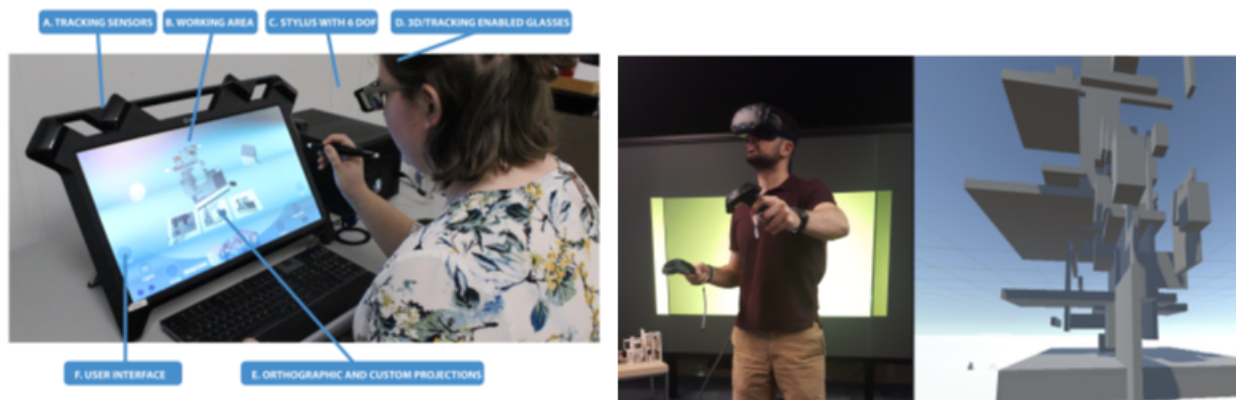


Figure 3

Comparison of the Nine Cube VR in the Desktop Mode (left) and the Real-Scale Mode (right)

6. Conclusion

The immersive framework presented in this chapter addresses the perspective of UX factors impacting learning by influencing the degree of learner engagement. We discussed several known UX factors and their ability to impact learner engagement, particularly the role of spatial presence and its ability to situate learners. The immersive framework serves to address the growing tendency in education to implement immersive technology and focus exclusively on either learning effectiveness or the technology. Immersive technology comes in several forms and should be considered based on the commonalities that lead to immersion. Using a variable-centered approach, we looked at how the technology's attributes enable key concepts in UX, usability, and learning to establish learner engagement. In this chapter, we covered select technical attributes that comprise immersion and focused on primary factors of visual immersion as an illustrative means for the immersive framework.

In the application of the immersive framework, we note that usability factors cannot be ignored because UX and usability are closely connected and can highly impact learner engagement. In the case of novelty, we find that some aspects of usability do not carry as much weight in the overall experience rating. Therefore, in applying this framework, usability should always be considered to reduce any undue influence of poor interface design which reduces satisfaction and ultimately learner engagement. The examples described in the previous section illustrate use-cases in architectural education where immersive technology has been effectively implemented to improve learning outcomes.

Limitations we noted in the immersive framework include the need for well-designed learning activities and clearly identified learner needs before applying the framework to select and implement immersive technology. For the implementation of the immersive framework beyond the spatial disciplines, the choice of immersive technology should support the intended learning scenario (e.g., field trips augmented with AR or replacing field trips with a VR experience). Each option presents a different way to approach content covered in a field trip but through different technology. This choice comes down to aligning the design of the intended learning activity with the format of the representation and content with the interaction. In cases such as the Nine Cube VR example, two forms of VR were used to accomplish the intended learning need, and the framework was applied to both technical attributes implemented to sustain learner engagement. Another possible limitation pertains to the numerous learning approaches that address how learning occurs as the immersive framework focuses on technical implementation. Despite the push for immersive technologies to be used for active learning, passive approaches can be used as well (e.g., virtual tours as opposed to virtual activities). Alternatively, the strengths of the immersive framework help to shape our understanding of how various immersive technologies can form and sustain learner engagement through each technology's different attributes. This strength explains how different immersive technology can be used for the same activity but provide different levels of learner engagement. Overall, the immersive framework helps provide a better understanding of the attributes specific to immersive technology and how they work to impact factors leading to learner engagement.

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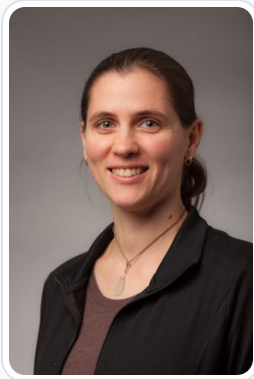
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