Chapter 71: Situated Learning in Virtual Worlds and Immersive Simulations

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Abstract

Virtual worlds and immersive simulations are designed to create a compelling,
collaborative, and participatory experience for the user, and often contain a variety of
features not possible in the real world to enhance users' engagement and learning. Over
the past several years, an increasing number of immersive virtual environment
experiences have become available for both educational and entertainment purposes.
Participants in entertainment experiences now number hundreds of millions, yet adoption
in educational settings has been limited thus far. In this chapter, we review examples of
virtual worlds and immersive simulations that are designed, or adapted, to support
situated learning experiences, analyze their use for a variety of educational purposes,

explore theoretical foundations, identify learning affordances and limitations, and examine instructional design considerations.

Keywords

Chapter keywords: virtual worlds, simulations, situated learning, immersive technologies

1. Virtual worlds - immersive simulated environments in which a participant uses an avatar (a digital representation of oneself) to interact with digital agents, artifacts, and contexts.

2. Simulations – technological environments that simplify or enhance reality while retaining the fundamental validity of what is to be experienced or learned.

3. Situated learning – situated learning theory posits that all learning takes place within a specific context and the quality of the learning is a result of interactions among the people, places, objects, processes, and culture within and relative to that context.

4. Immersive technologies – immersion is the subjective impression that one is participating in a comprehensive, realistic experience. Technologies can induce immersion via the use of sensory stimuli, participants' abilities to influence what happens in the environment, and the use of narrative and symbolism.

Introduction

In the past several years, we have seen growing interest in the use of virtual worlds (VW) such as *Jibe* and *Minecraft*, and immersive simulations such as *SimCity* and *Quest Atlantis*, to support learning in new and innovative ways. Due to recent technological advances, an explosive growth has occurred in these types of technologies for both entertainment and, on a much smaller scale, educational purposes, with over a billion user accounts in hundreds of VWs as of 2012. As schools and educators seek to reengage and motivate students, prevent high drop-out rates, overcome issues of educational access, and provide more authentic learning and assessment opportunities, immersive environments offer unique and engaging environments to support situated learning.

Situated learning occurs when a student experiences and applies learning in a specific environment or setting that has its own social, physical and cultural contexts. Learners are often required to solve problems in the setting and then contribute their insights to improve the environment, thus building a bond with the community sharing the context and moving the learner from the periphery to engage at the center of the community (Schuh & Barab, 2008). For example, a student who manages a store can gain valuable knowledge and skills in business operations, customer relations, and marketing in a authentic way that one could not attain by reading a textbook and writing a paper. Their work then becomes one important contribution to the continuing success of the store and those affiliated with it.

Immersive technologies provide alternative environments for situated learning, because an almost endless variety of virtual contexts are available, or can be created, that give users a sense of "being there," (Slater, 2009; Gibson, 2010: Slater, 2009) and thus, the ability to apply learning in a plausible, unique context. The immersive sensation is

achieved through the use of sensory inputs (graphics, sounds, visual perceptions of moving through the environment; the ability to touch objects, maps providing geo-location clues), a variety of social communication layers (Warburton, 2009); avatar personalization; choice and autonomy in the storyline; the ability to design and build aspects of the environment itself; and by providing feedback mechanisms that help learners visualize their own progress in the environment (Dede, 2012).

A virtual world is an immersive environment in which a participant's avatar, a representation of the self in some form, interacts with digital agents, artifacts, and contexts. VWs are typically multiplayer; offer communication options such as chat, IM, and messaging; and may contain game or roleplaying elements. *Whyville* is a well known example of an educational VW where pre-teens gather online to socialize and play games. Content creation is possible in some VWs, such as *Minecraft* or *Kitely,* allowing users to make their own objects and media, and providing teachers and instructional designers the opportunity to incorporate a large variety of learning options in the environment, such as role-plays or scavenger hunts.

A subset of VWs, *immersive simulations,* use the above features to create model-based environments that simplify or enhance reality while retaining the validity of what needs to be learned. Some may facilitate learning through repetitive practice in a heavily contextualized environment integrating game and pedagogical elements (Aldrich, 2005). For example, *Spore* is a popular immersive game marketed as a simulation – unfortunately with numerous scientific inaccuracies -- where users can design and redesign creatures as they grow through five stages of evolution. The player observes the direct impact their creatures have on the ecosystem and can modify their designs accordingly.

In this chapter, we review examples of VWs and immersive simulations that are designed or adapted to support situated learning experiences, analyze their use for a variety of educational purposes, explore theoretical foundations, identify learning affordances and limitations, and examine instructional design considerations. This chapter does not review research on heavily game-based or massive multi-player online (MMO) environments, such as *Star Wars: The Old Republic*, or *World of Warcraft*, as they are covered elsewhere in this handbook.

Examples of Simulations and Virtual Worlds Designed for Learning

The below scenario provides an example of situated learning with fifth grade students using *Past/Present: 1906*, an immersive role-play simulation that looks much like a video game:

> Louisa and James are 5th graders who are ready to begin their history unit on the industrial revolution. They sit together at a laptop, log into the simulation, and play as Anna Caruso, an immigrant textile mill worker during turn-of-the-century America. As Louisa and James work together to move Anna's avatar down the streets of Eureka Falls, they encounter her family members, the newspaper boy, co-workers in the factory, and other characters in the simulation. These characters provide important background information, help create a holistic storyline, and offer Louisa and James the ability to interact, analyze, and problem solve by choosing responses to options in the storyline (see Figure 1).
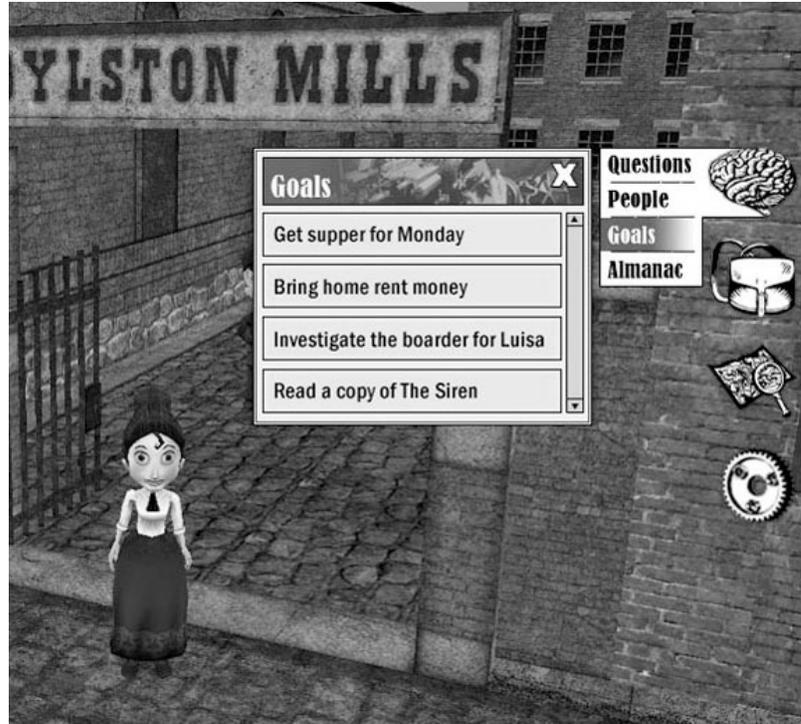
Figure 1. Avatar Anna Caruso in *Past/Present: 1906*, an historical role-playing simulation.

Anna has a job running looms in the textile mill. Her job is designed as a game inside the simulation, where Louisa and James will have to run Anna back and forth between the looms to keep them operating at an efficient pace. Based on their performance on the looms, Anna's salary will vary each day, and Louisa and James are then faced with making ongoing decisions about how to best earn and spend money to meet the needs of Anna's family.

This type of situated embodiment allows Louis and James to experience life as Anna in a time period and setting that no longer exists, and attain a variety of educational

objectives. By decision-making as the character Anna, they make choices that have an eventual impact on outcomes in the simulation, gaining insights about that historical period and about comparable issues today.

In Table 1 below, we see a representative sample of research-based VWs and simulations, and VW content authoring environments used for education.

Table 1. Examples of Educational VWs and Simulations

Name	Ages	Description
Active Worlds Educational Universe	Varies	A shell for constructing and hosting VWs in which users create 3D educational institutions, learning content, and explore new paradigms in social learning. http://www.activeworlds.com/edu/awedu.asp
America's Army	13+	An immersive game-based simulation created by the U.S. Army, players are bound by Rules of Engagement (ROE) and grow in experience as they navigate challenges in teamwork-based, multiplayer, force versus force operations. The simulation demonstrates values of loyalty, duty, respect, selfless service, honor, integrity and personal courage. http://www.americasarmy.com
Blue Mars	18+	A shell for constructing VWs in which users create 3D content; its emphasis is on high quality graphics and scaling capability. http://www.bluemarsonline.com/
EcoMUVE	12-14	A middle grades, one month, ecosystems science curriculum based on two immersive virtual ecosystems, for learning science concepts, inquiry, and complex causality http://ecomuve.gse.harvard.edu
Idea Seeker Universe	8-13	Players come together to chat, explore, and can participate in scientific expeditions and projects, learning to grow food in realistic timelines. http://www.kidscom.com/
Jibe	Varies	Players can host a VW on the OpenSim or Unity 3D platform; educational projects include language learning, scientific visualizations, walkthrough tours,

		distance learning. http://reactiongrid.com/
JumpStart	3-12	Immersive early childhood educational games and activities played using an avatar known as a "jumpie." http://www.jumpstart.com/
Past Present	12-14	Players assume the role of an immigrant textile mill worker in 1906, face challenges, and play games to earn money to live. http://muzzylane.com/project/pastpresent
Quest Atlantis	9-15	3D multi-user environment to immerse learners in rich narrative, role playing, and in educational tasks. http://atlantis.crlt.indiana.edu/
Real Lives	14-18	Players interact in this life simulation game that enables them to live one of billions of lives in any country in the world. http://www.educationalsimulations.com/
River City	12-14	Interactive simulation for middle grades science students to learn scientific inquiry and 21st century skills. http://muve.gse.harvard.edu/rivercityproject/
Second Life	13-adult	A shell for constructing VWs in which players can socialize, connect using voice and text chat, and participate in or create 3D educational sims such as EdTech Island, Jokaydia, and SciLands. http://secondlife.com
SimSchool	18+	Players assume the role of a teacher managing a class of students in this interactive classroom simulator. http://www.simschool.org/
Whyville	13-17	Players come together as citizens to learn, play, earn "clams" through educational activities, and have fun. http://www.whyville.net/smmk/nice

The wide variety of immersive environments illustrated above might leave a teacher or instructional designer wondering what specific environments are appropriate for their students and the learning goals they need to meet. As these environments continue to expand in type and variety, a good starting point is to ask how the intentionality of design will help meet desired learning outcomes, and what affordances and limitations will shape the design.

Intentionality of Design: Entertainment or Education?

What makes an immersive technology "educational?" VWs and simulations can be as complex as the physical world itself, incorporating varying degrees of virtuality, design intent, contexts, and layers of technology (Warburton, 2009), all influencing the nature of the immersive experience. Researchers have attempted to develop a variety of taxonomies to provide definitions or parameters of VWs and other immersive environments to assist instructional designers and researchers in their work, not without some debate due to rapid technological development and cross-functionality between emerging technologies (Bell, 2008; Richter & Dawley, 2010).

Because context is a critical aspect of situated learning, understanding the design intentionality of the platform is an important first step: Is the immersive technology designed for entertainment, education, or socialization purposes? Is it collaborative or competitive? Are the learning outcomes structured and explicit, or informal and tacit?

Some immersive simulations, such *Past/Present: 1906, Quest Atlantis,* and *NASA's Moonbase Alpha,* are designed to achieve specific educational purposes and goals. For example, in *Moonbase Alpha*, players are situated in a hypothetical lunar outpost as a crewmember, and have to participate in realistic mission challenges. Strengths of these types of environments include some level of assurance that curriculum is appropriately addressed according to standards, student safety is protected, the environment can be customized, and development is based on theoretical and empirical frameworks. Critics of these environments argue that, when education is the main focus as opposed to fun or socializing, motivation and engagement can decrease for the user (Akilli, 2007): the "chocolate covered broccoli" issue.

Other online worlds, such as *Idea Seeker Universe* or *JumpStart,* may be designed for social or entertainment purposes with a given age group, but they also integrate educational activities for their players, such as a virtual visit to the Chicago Museum, or reading storybooks with an adopted pet. The main characteristic of these environments is that an emphasis on "fun" comes first, and learning often happens as a by-product of interaction in the space, or has to be directed by the teacher (e.g., "Today you'll be growing vegetables in the virtual garden to get ingredients to make salsa.") These types of environments can be harder to integrate into a traditional school environment due to concerns with student safety resulting from exposure to unknown online players, design intent that only partially meets educational goals, and inability to customize the design (National Research Council, 2011).

Finally, hundreds of educational organizations have established learning communities or simulations in commercial content creation VWs, such as the AECT educator community in *Second Life*, or teachers who participate in the Massively Minecraft guild in *Minecraft.* In these VWs, the technology provides an authoring shell where the design intent is left open and leveraged by instructional developers and others who wish to create their own virtual environments. Adult learning and teacher training are popular educational activities in content creation worlds. An obvious strength of these worlds is the openness of the design possibilities—what your mind can imagine, your fingers can create. However, the newly christened are often left wondering where to begin, "Do I design a role play, a simulation, or a '"mirror world'"that looks like a real place? What types of learning activities and assessments should I include? How will students find those activities and get feedback on their accomplishments? What objects should I build into the environment?"

Some projects have used the strategy of allowing K-12 students to become the builders of the world itself, thus translating their learning into 3D. However, content creation worlds have experienced a higher adoption rate in higher education and organizational training, literally using the space as a 3D learning environment supporting distance education. As a result, many colleges and businesses use the platforms to support in-world conferencing, meetings, and workshops.

Growth and Use Trends by Age

As of 2012, there are estimated to be over 900 VWs, thousands of online simulations, and millions of users around the globe. This number was almost double over the prior year (deFrietas & Veletsianos;, 2010, KZero, 2011). A majority of VWs in the education sector cluster around the 10-15 year old age group, with over 500,000,000 registered user accounts (KZero, 2011). No education-specific VWs are noted for those over 20 years old. This conclusion is misleading, because the VWs commonly used for learning by adults, such as *Second Life* or *Active Worlds*, are authoring shells that were built with an open design intent. Figure 2 illustrates the top inhabited VWs and simulations by age group.

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- Jumpstart 4M
- Buildabearville 21M
- Barbie Girls 22M
- Poptropica 144M

Ages 3-10

- Whyville 7M
- Club Penguin 63M
- Neopets 65M
- Stardoll 94M

Ages 10-15

- Gaia 36M
- WeeWorld 40M
- IMVU 50M
- Habbo 200M

Ages 15-25

- eRepublic 2M
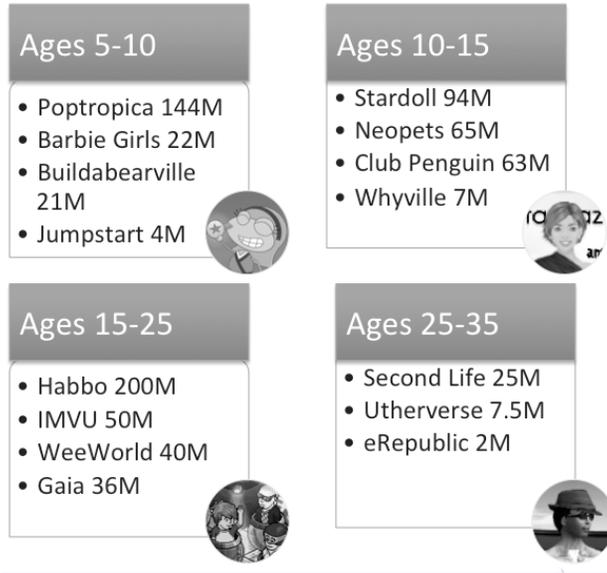- Utherverse 7.5M
- Second Life 25M

Ages 25-35

Figure 2. Top inhabited VWs by age, in millions of users, adapted using data from KZero (2011).

By displaying KZero's (2011) data on an age timeline below (Figure 3), we are better able to see types of VW usage trends by market sectors.
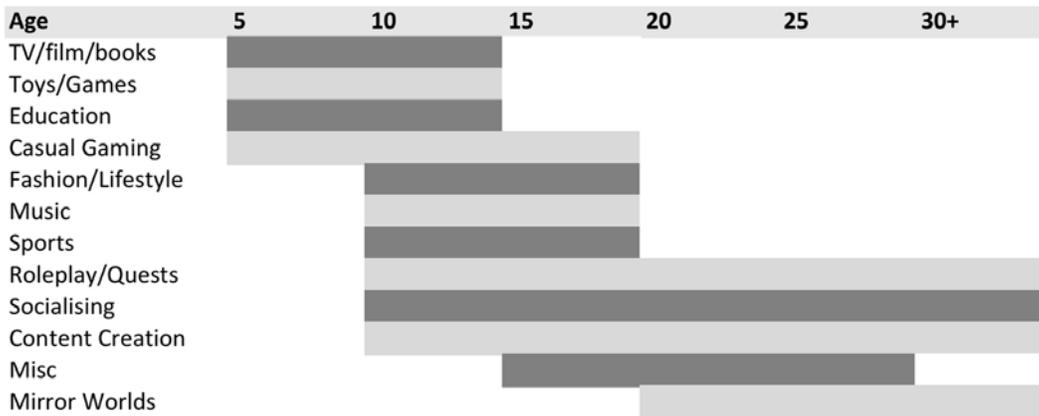

Figure 3. Types of VWs by age range, adapted using data from KZero, 2011.

Younger children are engaging in VWs that focus around games, toys, films, TV, and education, such as Disney's *Pixie Hollow* or DreamWork's *KungFu Panda World*. Tweens and teens are using VWs for casual gaming, fashion, music and sports, such as *NFL RushZone* or *GoSupermodel*. Two highly researched VW environments, *Second Life* and *ActiveWorlds*, are designated as "content creation" worlds, appealing to older teens and adults. Note that mirror worlds, such as *Google Earth*, provide a blend of VW and augmented reality (discussed in another chapter in this handbook) that appeals to a particularly adult audience. Understanding these types of immersive learning preferences and design considerations for a given age group is important for instructional developers and researchers. This knowledge can aid in determining whether to leverage existing VWs in various educational or entertainment sectors, or instead to design a new virtual world setting in a content creation shell such as *ActiveWorlds* or *InWorldz*.

Theoretical Foundations

As a cognitive tool or pedagogical approach, immersive technologies align well with situated and constructivist learning theory (Vygotsky, 1978), as these position the learner within an imaginary or real-world context (i.e., simulated physical environment). The immersive interface and associated content guides, scaffolds, and facilitates participatory and metacognitive learning processes such as authentic inquiry, active observation, peer coaching, reciprocal teaching and legitimate peripheral participation based on multiple modes of representation (~~Palincsar, 1998;~~ Dunleavy, Dede &, and Mitchell, 2009; Palincsar, 1998).

These technologies and their resulting contexts are often designed to promote situated embodiment (Barab et al., 2007), giving the learner a sense of projection into the context,

as well as a meaningful role, goals, and an ability to take actions that result in significant consequences. Although immersive technologies are not~~n't~~ inherently games, these types of situated embodiment are often purposely designed around game-like fantasy environments using rich narratives that are created to give players choice and purpose in their actions, and to promote generalizations across contexts. For example, Barab, Gresalfi and~~, &~~ Ingram-Goble (2010) dr~~e~~aw upon transformational play theory to inform their design of *Quest Atlantis*, inviting players to become active decision makers whose choices create meaningful cycles of social impact on both the player and the game as it unfolds.

For older teen and adult learners in particular, Siemens' (2005) theory of connectivism also helps to explain the appeal of educational VWs and immersive simulations. By emphasizing the existence of knowledge that resides outside the person via connective nodes, learning becomes a process of connecting information, which relies on a variety of strategies in decision and meaning making. Some immersive environments provide a technological infrastructure, including data feeds and social network communication mechanisms, to assist players in making linkages among these data sources.

The online, multiplayer of aspects of immersive technology, combined with game-like narratives that emphasize socio-technical structures, are often grounded in critical/transformation studies that examine age, gender, and culture differences, and underscore the need for ethical action in globally relevant concerns, such as global warming, genocide, and poverty (Barab, Dodge, Thomas, Jackson, & Tuzun, 2007; Kafai, 2010).

Theories about motivation from social psychology describe various reasons why participants might become highly engaged in a VW or immersive simulation and might be motivated to frequently seek out this experience. Aspects of a videogame experience that promote intrinsic motivation include intrapersonal factors such as challenge, control, fantasy, and curiosity as well as interpersonal factors such as competition, cooperation, and recognition (Bartle, 2003). The challenge dimension of engagement is heightened when a participant achieves a state of flow through facing challenges that are difficult, but surmountable at their current level of skill (Csikszentmihalyi, 1988). Other generic, intrinsic factors that heighten motivation include the perceived instrumental value of an activity (Brophy, 1999), perceived personal competence in accomplishing the goals of an activity (Dweck, 2002) and autonomy in making choices within an activity (Ryan & Deci, 2000). Lepper and& Henderlong (2000) described various ways that extrinsic incentives used to promote participating in an activity, but unrelated to the intrinsic nature of the experience, can undercut learning and intrinsic motivation, if overdone. Both they and Habgood and& Ainsworth (2011) suggested strategies for ensuring that educational experiences such as games culminate in participants having strong intrinsic motivation. Przybylski, et al. (2010) summarized these dimensions of motivation as applied to videogames.

Learning Affordances & Limitations

Research on the design, use, and impact of VWs and immersive simulations in education goes back over a decade. However, the ways in which VWs are effective as learning environments is still unclear, as much of the research is descriptive, relying on self-reporting data (Hew & Chueng, 2010), rather than theoretically based and experimental.

Virtual worlds can be used to create learning spaces that are applicable to almost all disciplines, subjects, or areas of study (Johnson, Levine, & Smith, 2007). In their meta-analysis of 470 studies, Hew and& Cheung (2010) identified three uses of VW in K-12 and higher education environments: 1) communication spaces, 2) simulation of physical spaces, and 3) experiential spaces. Their research suggesteds that K-12 students like using VWs because they can fly and move around freely in a 3-D space, meet new people, and experience virtual field trips and simulations. Similarly, adult learners and teachers have reported great enthusiasm when learning in immersive spaces (Dickey, 2011).

Learning affordances and limitations in immersive environments will vary depending on the interplay between the technology's design intent, functionality and the needs of the learner (Dickey, 2011).   This section presents findings from research emphasizing teaching and learning affordances and limitations of these environments, as well as design mechanics, including: identity exploration, communication and collaboration, spatial simulation, experiential spaces, and assessment.

Identity Exploration through Virtual Embodiment

The experience of situated embodiment lies at the heart of immersive experiences in which one feels psychologically present in a context that is not where the person is physically located (Winn, 2003). In VWs and immersive simulations, situated embodiment is based on the willing suspension of disbelief (Dede, 2009). Motivational factors that encourage this mental state include empowering the participant in an experience to initiate actions that have novel, intriguing consequences, invoking powerful semantic associations and cultural archetypes via the content of an experience, and

sensory immersion through extensive visual and auditory stimuli. Situated embodiment in virtual environments and immersive simulations offers the potential for identity exploration, in which a participant plays a role different than that portrayed by that person in everyday life. Laurel (1993) and Murray (1997) described design strategies that can enhance participants' identity exploration, such as providing options to modify the avatar's appearance, gender or clothing; creating role-play opportunities in historical or fantasy-based settings; and experiential learning opportunities to be someone other than yourself and reflect on the experience. However, freedom to play with identity can cause confusion, and users must learn to manage their reputation when using ~~institutional~~ avatars in professional contexts such as teacher, or that are associated with their institution or organization (Warburton, 2009).

Communication and Collaboration Spaces

Many VWs and simulations provide opportunity for social interactions between individuals, and among members of communities, as well as more limited interactions with objects and with agents who are scripted by the computer (Warburton, 2009). Typically, the user creates an avatar who may or may not have an identified role in the world, providing the user a vehicle for situated embodiment in the setting and a sense of "being in the world" (Barab~~, Zuiker, Warren, Hickey, Ingram Goble, Kwon, Kouper, &~~ ~~Herring~~et al., 2007). Avatars can communicate nonverbally using gestures, appearance, and avatar postures, as well as verbally through the use of text-based chat, IM, voice chat, and group communication tools. Social cues in the VW, such as eye-gaze while talking, are governed by the same norms as those in the physical world (Yee, Bailenson, Urbanek, Chang, & Merget, 2007).

Because the communication space is virtual and multi-player, it provides an alternative

delivery format for distance education students (deFreitas, Rebolledo-Mendez, Liarokapis, Majoulas, & Poulovassilis, 2010). The opportunity to interact with users from around the world in a shared immersive setting can promote cultural sensitivity and awareness of global issues. Through the use of translation technology available in some VWs, language barriers can be overcome, increasing communication options.

Dawley (2009) lists overs 15 in-world and out-of-world communication mechanisms available in VWs. In-world communication mechanisms can include private messaging, group chat, newsletters, global chat, etc. Out-of-world communication mechanisms are tools that can be accessed while in a virtual world, but are hosted elsewhere on the internet, such as Twitter, blogs, websites, and even calling someone's mobile phone while logged in as an avatar. When leveraged effectively, these communication options can support increased engagement and motivation, group action, individual transformation, and shared meaning-making opportunities. Community presence to induce a sense of belonging and group purpose is another affordance supported through communication mechanisms such as groups, guilds, and clans (Warburton, 2009). Sub-cultures such as goths, furries, griefers, educators, and superheroes can create strong identity affiliations, promoting persistence in the VW space. However, communities can be hard to locate, if guidance is not provided for the user, communities can be hard to locate and learning the norms for participation takes time.

Social Network Knowledge Construction (SNKC) is a pedagogical model for VW learning (Dawley, 2009). SNKC takes advantage of the various social network communication mechanisms that are available to older participants in VWs, leading learners through a five-stage process: identify, lurk, contribute, create, and lead. Learners begin as neophytes, working through the cycle to eventually become mentor/leader on a

given topic. SNKC begins with learners identifying relevant social networks in and around the VW that will support their inquiries in a given course of study. They learn to lurk and recognize cultural norms and rules for participation. Eventually, they begin to offer small contributions of information or their time to the network. As they gain experience and credibility in the network, "avatar capital," (Castronova, 2006), they shift into positions where they have the opportunity to create their own work, buildings, exhibits, etc. Finally, the cycle completes in the learner taking leadership, either of a network by mentoring neophytes, or by managing a group, thus supporting an ongoing viral cycle with a new set of neophyte learners.

Spatial Simulation

Immersive technologies are effective when learners need practice with repetitive tasks where it may not be possible or realistic to repeat these tasks in real life, such as practicing take off and landings in a plane simulator, or practicing administering medications to a patient in a simulated hospital setting. Spatial simulation is one of the fundamental affordances of VW environments (Hew & Chueng, 2010). This is the context in which "being there" occurs. Spatial simulation involves the ability to recreate authentic content and culture, as well as the creation of content that may be historically unavailable, imaginary, futuristic, or too expensive to produce in real life (Warburton, 2009). In role-play simulations such as *simSchool,* or a nursing simulation in *Second Life*, the spatial simulation is central as a pre-training experience for neophytes, familiarizing them with the physical space, tools, and structure of their future workplace prior to assuming their duties in the physical world.

Experiential Learning

In experiential learning, avatars learn by doing: "acting" on the world, observing the results of their actions, and testing their hypotheses (Hew & Cheung, 2009). In medical and school simulation scenarios, for example, learners can conduct repetitive tasks in the environment (such as sanitary protocols), take risks, and try alternative strategies at no cost and without fear of harming the students or patients (Gibson, Aldrich, & Prensky, 2007). Participants are able to experience learning first-hand, as opposed to viewing a video or reading a text about student management or patient care.

Educational activities in VWs emphasize experience and exploration over recall strategies. The participant experience is choreographed to emphasize learner control, engagement, learner-generated content, and peer-based learning that may, or may not, be based in a narrative storyline (deFreitas, Rebolledo-Mendez, Liarokapis, Majoulas, & Poulovassilis, 2010). Educational activities can be rich and varied, including role-play and simulation, walk-through tutorials, displays and showcases, historical recreations, artistic performances, machinima (animated video) production, scavenger hunts, immersive language instruction, and writing and book production (Dawley, 2009; Warburton, 2009). The ability to design, build, and own content in the VW is a noted powerful motivator (Warburton, 2009).

Assessment

A final affordance of VW lies in opportunities for assessment. Clarke-Midura and& Dede (2010) suggest that virtual performance assessments provide new vehicles for innovative observation and sophisticated analysis of complex student performances. They outlined the quandary associated with using national tests that do notn't align with the content they are supposed to be measuring, and suggested that immersive environments excel as tools for observation of authentic student behaviors, choices, and performance on tasks.

For example, they illustrate a learner who logs into a virtual Alaskan ecosystem, encounters kelp depletion, and begins to collect and analyze data to identify the problem. This type of assessment is difficult to conduct using traditional paper-and-pencil, item-based assessments, which neither richly evoke constructs to be measured nor provide a detailed stream of evidence about what the learner does and does not know. In contrast, in an immersive environment, the assessment is rich and performances are detailed, yet assessment is unobtrusive because players leave "information trails" (Loh, 2007) as they move through the virtual space, interact with objects, and chat. These behaviors can be recorded in data streams for analysis using data and text mining techniques (Dede, 2009) In learning environments, as opposed to assessment, feedback can made available in real-time for the participant to enable progressive improvement (Dede, 2012).

Additional Limitations

Teachers and instructional designers are often uncertain about what immersive environments are suitable for their students and how to design immersive learning. Also, cost, the time required to learn a new technology, student safety and privacy issues, and institutional barriers to adoption all pose challenges (Dawley, 2009).

Dissatisfaction with VWs and simulations often revolves around technical problems with equipment, internet connectivity, scalability of the platforms, and institutional firewalls, as well as prohibition of the use of VWs in public computers (deFreitas, Rebolledo-Mendez, Liarokapis, Majoulas, & Poulovassilis, 2010; Hew & Cheung, 2010; Warburton, 2009). Users also express concerns regarding the need for fast typing and the requirement to quickly formulate responses in chat communication. Of particular concern for K-12 learners are issues of student safety and data privacy issues (Dawley, 2009). Other challenges include:

1. *Collaboration*: Trust, eye contact, and virtual presence are all important components to build effective collaboration. Asynchronous communication mechanisms such as a discussion forum or wiki are required to promote ongoing persistence for group activities, especially when users live in multiple time zones. Collaboration may need purposeful scaffolding.

2. *Time*: Simple tasks, such as speaking, walking, or changing clothes, can take a long time to learn to do efficiently. Instructors must learn design and technical management skills.

3. *Economics*: VWs and simulations may be based on varying forms of business models, often requiring the user to either purchase a premium level of service, or participate in inworld activities or "jobs" that will generate revenue for the vendor.

4. *Standards*: Lack of open design standards creates issues for developers who want to integrate other technologies and resources.

5. *Persistence and social discovery*: Unlike other social networks such as Facebook, most VWs hide the user's larger social network, keeping them at the center of the network, unable to see friends of friends. While the VW is persistent, the avatar maintains persistence only when logged in.

Unique Affordances for Instructional Design

Smart, Cascio, & Paffendorf (2007) outlined infrastructure similarities common to all VWs:

- Persistent in-world environment
- Shared, multi-player space
- Virtual embodiment using an avatar
- Interactions between avatars and objects

- Real time actions, interactions, and reactions
- Similarities to the real world, such as topography, movement, and physics.

However, because VWs and simulations vary greatly in their design and functionality, some researchers have developed typologies to identify the range of design options (Messinger, Stroulia, ~~E.~~ & Lyons, 2008). deFreitas~~,~~, et al. (2010) propose~~d~~ the *Four Dimensional Framework* for considering the design and development of VWs:

1. the learner (their profile, role, and competencies),
2. the pedagogical models used (associative, cognitive, and social/situative),
3. the representation used (fidelity, interactivity, and immersion), and
4. the context (environment, access to learning, supporting resources) where learning occurs.

This framework provides a way to consider various effective instructional design strategies for VW and simulations, as shown in Table 2.

Table 2. VW and Simulation Instructional Design Strategies

Framework Dimension	Instructional Design Strategy	Research Study
Learner	Create roles that let learners meld their identity with the game role	Barab, ~~Zuiker,~~ et al.~~,~~ 2007
Pedagogical Models	Rich narrative activities establish the need for embedded formalisms and embodied participation	Barab, et al., 2007~~Barab, Zuiker, et al, 2007~~
Pedagogical Models	Apply formalisms to problems close at hand, then proximal, then those that are more distal	Barab, et al., 2007~~Barab, Zuiker, et al, 2007~~
Learner	Game is responsive to player's decisions, both game and player change as the game progresses	Barab, et al., 2010~~Barab, Gresalfi, et al, 2010~~
Representation	Culturally, ethically sensitive designs should provide options in outcomes, with	Barab, Dodge, et al., 2007

	the preferred outcome providing the most favourable results	
Pedagogical Models	Integrate progressive use of in-world and out-of-world social network communication mechanisms to support active knowledge construction, persistence, and a shift from neophyte to mentor	Dawley, 2009
Learner	Match the design of the VW or sim to the needs and competencies of the learners	deFreitas et al., 2010
Context	Use in-world observations and downloaded data streams to triangulate assessment of complex learning	Clarke-Midura & Dede, 2009
Representation	Use spoken text vs. printed-text as a feedback mechanism in simulation design to promote decision-making performance	Fiorella, Vogel-Walcutt & Schatz, 2011
Pedagogical Models	Use a case study as the basis for a simulation design	Kahn, 2007
Learner	Compare alternative strategies for learning to see what works for whom, when	Ketelhut et al., 2010
Context	Embed guidance unobtrusively and make usage optional	Nelson, 2007
Representation	Manage sensory complexity and cognitive load; design for a middle ground including a combination of relevant visual information and immersive elements (such as sidewalks, streetlamps) without creating cognitive overload	Nelson & Erdlandson, 2008
Representation	Address three layers of presence (physical, communication, status) to create a strong immersive experience	Warburton, 2009
Context	Consider access to newer technology, bandwidth, firewalls as part of the design	Warburton, 2009
Representation	Leverage avatar opportunities for interaction among each other and objects	Warburton, 2009
Pedagogical Models	Provide avatar space, training, and authentic reasons for constructing in 3D	Warburton, 2009

Interested in creating your own VW or simulation? TheFor those interested in creating their own virtual world or simulation, the less technologically savvy builder can first learn to build start in existing content creation worlds such as *Active Worlds*, *Jibe*, *Second Life* or *Minecraft*. Builders are often self-taught using YouTube™ videos, or learn by taking in-world workshops, often hosted at no cost to players.

There are several popular companies such as *Kitely, ReactionGrid*, and *InWorldz* that host virtual worlds using the OpenSim platform. The benefit of OpenSim is that one can create their own virtual world without programming knowledge, and environments can be restricted to specific users, a feature that can be very important for younger users and schools districts worried about student privacy. Users such as Linda Kellie at http://lindakellie.com provide free downloadable OpenSim content so new builders don't have to create everything from scratch.

For those with programming experience, For those with programming experience, OpenSim and Unity 3D is aare popular game engines used in simulation design, and ReactionGrid is a company that can provide hosting of a Unity simulation.

Design-based research

Because of the emergent nature of these technologies, many designers/researchers are using design-based research methodologies, working in iterative cycles of needs analysis, design, data collection and analysis, and generation back to theory that informs the design (Dede, 2005; Design-Based Research Collective, 2003). Design-based research is a mixed methods approach that tests and refines "educational designs based on theoretical

principles derived from prior research" (Collins, Joseph, & Bielaczyc, 2004, p. 18). Less emphasis is placed on generating truths that would apply across all VWs or all simulations; rather, research data is used to inform the on-going development of specific interventions or technologies, as well as their guiding theoretical frameworks.

Although VW and simulations lend themselves to traditional research methods, it is noteworthy that these technologies have evolved in ways that now provide scholars the opportunity to collect and analyze data to support the research-design process. It is typical, and often desirable, for researchers to use mixed methods strategies for understanding mixed realities (Feldon & Kafai, 2008). The cloud-based architecture of these technologies provides the opportunity to capture user activity behaviour and logs, including chat dialogues, interactions with items, time and date stamps of events, avatar trail tracking through the virtual space, IP logins, geo-spatial locations, and more. This user activity can be downloaded and "cleaned" in a data mining process, with results often viewable using graphic visualizations. For example, Figure 4 below illustrates a heat-map showing avatar activity over a one week period on a simulation in Second Life. Each dot on the heat map represents one minute of avatar tracking in a particular zone of the VW.
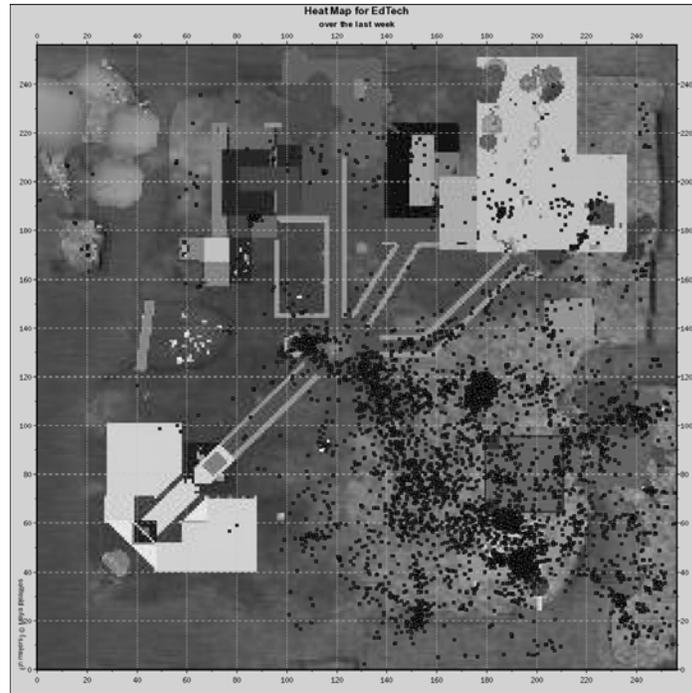
Figure 4. Heat map illustrating user activity in a VW.

In much the same way that a web designer might use site statistics to inform decisions about website design, this specific form of visual data can be useful to instructional designers who seek to understand the use of space in immersive environments and where design changes may be needed in the environment.

The intentionality of the VW design often frames the design-research process (Richter & Dawley, 2010). For example, Kafai's (2010) work in *Whyville*, a social VW for pre-teens, explores the nature of the social interaction among gender, and the resulting implications for instructional management. This type of research on "what do kids learn in informal VWs" produces different types of results than educational design-based

research in a specific VW developed to achieve distinct learning goals (Barab, Gresalfi, & Ingram-Goble, 2010; Clarke-Midura & Dede, 2010; Barab, Gresalfi & Ingram Goble, 2010). In the former, the research is done to answer a larger global research question. In the latter, research is collected to inform the design itself.

Conclusions

The body of research on VWs and immersive simulations has grown substantially, with hundreds of education-related studies published over the last five years. Researchers have documented that situated learning in VWs can be an important and engaging component in an educational program for various reasons and purposes. Transfer of learning from the VW or simulation to other contexts does occur and can be purposefully designed by using rich narratives and contexts, and by giving the user decision-making roles that impact the environment. Ownership and leadership in the learning process can be supported through the careful integration and leveraging of social network communication mechanisms associated with a VW. However, there are definite limitations to the use of these technologies in education, including issues of access, technical problems, appropriateness, and needing to match learning goals to design intent.

Scholars are still determining the full extent to which VWs and simulations can support learning. VW projects developed using a mixed-methods design-based research approach, and supported with observation, data mining, and text mining from user activity logs, are providing strong evidence of what is learned and the extent to which the knowledge can be used or applied. However, a large amount of published research still relies on user self-reporting as a main data collection strategy.

New technology developments show continued promise for the use of VWs and simulations. Immersive technologies are experiencing huge commercial growth, with new market sectors and uses appearing as the technologies themselves evolve. As commercial opportunities continue to grow, so will engagement for educational purposes. Trends in immersive technology growth include more cross-platform development between VWs and entertainment (TV, movies, books and toys), spaces for visual artists and celebrities, content creation and science fiction for adults, and additional social network integration across platforms (KZero, 2011). Open-source viewers, advanced visualization and haptic devices, and developing consensus over open standards and specifications may support better interoperability in the near future to provide more personalized learning experiences and allow avatar-users to cross platforms (deFreitas, Rebolledo-Mendez, Liarokapis, Majoulas, & Poulovassilis, 2010; Warburton, 2009).

As enrollments in online education increase, and the emphasis on blended schooling continues to expand, immersive technologies will play an important and growing role to augment the virtual learning experience. These developments have implications for educational professionals: teachers need training in pedagogical and technical skills; instructional designers require professional development in the appropriate use and application of immersive technologies; design-based researchers need training in mixed-methods data collection and strategies for data mining; and network administrators will have to work to overcome technical limitations of bandwidth, access, firewalls, and out-dated computers.

Many areas are ripe for future research in educational immersive technologies. As our emphasis in education shifts away from the memorization of decontextualized facts and toward the personalized learning experiences to develop human beings who can problem-

solve across a variety of scenarios, immersive environments may support this objective. As design studies begin to shift away from randomized controlled trials toward the use of mixed-methods design research integrating observation and data mining, our understanding of the learner evolves, as well as our understanding of how to build a better learning system.

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