AIS Transactions on Human-Computer Interaction

Volume 15 | Issue 1 Article 3

3-31-2023

Gender Effects in Directed versus Incidental Learning in a 3D Virtual World Simulation

Surinder Kahai
SUNY Binghamton, kahai@binghamton.edu

Rebecca Jestice
Earlham College, jestire@earlham.edu

Rui Huang
University of Massachusetts at Dartmouth, rhuang@umassd.edu

Recommended Citation

Kahai, S., Jestice, R., & Huang, R. (2023). Gender Effects in Directed versus Incidental Learning in a 3D Virtual World Simulation. *AIS Transactions on Human-Computer Interaction, 15*(1), 55-82. https://doi.org/10.17705/1thci.00183

DOI: 10.17705/1thci.00183

Transactions on Human-Computer Interaction

Volume 15 Issue 1

03-2023

Gender Effects in Directed versus Incidental Learning in a 3D Virtual World Simulation

Surinder Kahai

School of Management, State University of New York at Binghamton, kahai@binghamton.edu

Rebecca Jestice

Business Department, Earlham College, jestire@earlham.edu

Rui Huang

Department of Decision & Information Sciences, University of Massachusetts Dartmouth, rhuang@umassd.edu

Recommended Citation

Kahai, S., Jestice, R., & Huang, R. (2023). Gender effects in directed versus incidental learning in a 3D virtual world simulation. *AIS Transactions on Human-Computer Interaction*, *15*(1), pp. 55-82.

DOI: 10.17705/1thci.00183

Available at http://aisel.aisnet.org/thci/vol15/iss1/3

Transactions on Human-Computer Interaction

Research Paper DOI: 10.17705/1thci.00183 ISSN: 1944-3900

Gender Effects in Directed versus Incidental Learning in a 3D Virtual World Simulation

Surinder Kahai
School of Management
State University of New York at Binghamton
kahai@binghamton.edu

Rebecca Jestice
Business Department
Earlham College

Rui Huang
Department of Decision & Information Sciences
University of Massachusetts Dartmouth

Abstract:

Virtual worlds have the potential to enable and enhance online learning outcomes. Because learning in three-dimensional (3D) designed learning spaces depends on learners' spatial processing abilities, we need to understand how these abilities may affect online learning outcomes. Building on the hunter-gatherer theory of gender difference in spatial abilities, we examined how gender interacts with learning type (directed vs. incidental) to affect learning in virtual world (VR) simulations of objects. Specifically, we theorized that men's and women's spatial abilities would lead to differential outcomes based on the type of learning that the instructor designed. Using a between-subjects 2 x 2 factorial design (directed vs. incidental learning and male vs. female), we found that incidental learning benefitted women and that directed learning benefitted men. Our findings counter the traditional view that males outperform females in learning tasks that engage spatial abilities in a virtual world. We urge educators to consider such gender effects on learning when employing VR simulations of objects.

Keywords: Virtual Worlds, Online Learning, Gender Effects, Directed Learning, Incidental Learning, Spatial Gender Differences, Virtual World Simulation.

Richard Johnson was the accepting senior editor for this paper.

1 Introduction

Online learning took center stage at educational institutions and organizations during the coronavirus disease of 2019 (COVID-19) pandemic. Moreover, online learning will remain in focus after the pandemic as educational institutions continue to integrate electronic media and organizations shift to hybrid work (Rapanta et al., 2021; Yang et al., 2021). For these reasons, and to optimize current technologies' learning potential, trainers and educators require sound design principles for delivering online learning.

One form of online learning uses virtual worlds to deliver course content (Barry & Kanematsu, 2020; Lederman, 2020; Singh et al., 2020). Virtual worlds refer to graphical, computer-based displays that allow users to feel like they exist in a different environment and to interact with objects and others in that environment without distance and space constraints (Schroeder, 2008). Virtual worlds are a form of non-immersive virtual reality (Mills & Noyes, 1999) and allow users to view their own avatars and the space they inhabit from a third-person perspective.

Virtual worlds have become popular because they provide a sense that one exists in a 3D space (Childs & Peachey, 2013; Tüzün & Özdinç, 2016). They afford realism and immersion that other online learning environments do not. Second Life, a popular virtual world, saw a 50 percent increase in usage for education and other purposes soon after the pandemic started (Joshi, 2020). While virtual worlds provide a unique affordance, they also impose a unique need for spatial processing. Learning in a virtual world tends to involve navigating through space, spatial reasoning and manipulation, and remembering locations and objects located in virtual space. Thus, in addition to individuals' ability to learn the material itself, their spatial abilities will also likely influence how well they perform on a learning task (Boechler et al., 2018; Ross et al., 2006).

In seeking to optimize learning in a virtual world, instructors should be aware of factors that affect a learner's spatial abilities and how they might affect learning. However, the existing literature on learning in virtual worlds offers little help to instructors. Past research that has evaluated virtual worlds in various educational domains has resulted in limited guidance for instructors on how to optimize learning (Wiecha et al., 2010). Furthermore, existing guidance does not acknowledge how spatial processing, which the sense that one exists in a 3D space triggers, may affect learning (e.g., Mystakidis et al., 2021; Zhang, 2013; but see Ross et al., 2006. Accordingly, we clearly require studies that examine the factors that affect a learner's spatial abilities and the role those factors may play in learning in a virtual world.

Gender represents an important factor that determines a learner's spatial ability (Coutrot et al., 2018; Mohler, 2008), and researchers have found males and females to differ in spatial abilities (Eals & Silverman, 1994). For many years, researchers believed men to perform better than women at spatial processing due to their superior wayfinding ability, which refers to "the process of finding your way to a destination in a familiar or unfamiliar setting using any cues given by the environment" (Farr et al., 2021, p. 715). However, Silverman and Eals (1992) suggested that it may be inaccurate to assume that males perform better at spatial processing than woman and separated the ability to navigate, which one needs for wayfinding, from the ability to remember and locate objects in 3D space. Using the hunter-gatherer theory, the authors argued that it may be more appropriate to view males as better at navigating and females as better at remembering and locating objects that they become aware of incidentally.

Studies suggest that gender differences in spatial abilities, and their effects on learning, may carry over from the real world to virtual worlds (Martens & Antonenko, 2012). However, researchers (e.g., Ross et al., 2006; Tlauka et al., 2005) made this assessment by examining navigation-related strategies and learning; learning in 3D space may also involve learning about objects located in it, which gender does not affect in the same way as navigation-related learning (Eals & Silverman, 1994). Little research has examined how gender may influence learning about objects in virtual 3D space (e.g., Paraskeva et al., 2012), which has led to a gap in understanding that we address in this study.

To produce precise research findings and guidance for educators, we examined whether directed or incidental learning interacted with gender to affect learning about objects in a virtual world. The motivation for studying the interaction between gender and type of learning stems from Silverman and Eals' (1992) finding that the effect that gender has on learning about objects in the real world depends on whether learning was directed or incidental. Directed and incidental learning differ in how much structure they provide and accompanying intentionality (Hulstijn & Trompetter, 1998; Marsick & Watkins, 2001; McGivern et al., 1998; Schugurensky, 2000; van Asselen et al., 2006). In directed learning, one receives guidance to acquire specific knowledge and one intentionally focuses on specified items. In incidental learning, one learns without receiving guidance to attend to it. Since directed and incidental learning differ in the guidance provided to the learner, understanding the differences between these learning types should generate implications for instructional design (Branch, 2009).

By exploring the interaction effect between gender and learning type in virtual worlds, our study extends the literature and alerts educators to learning differences that may arise depending on a learner's gender and the learning type. Our study helps educators optimize learning about objects in virtual worlds for both male and female learners. Our study also has implications for researchers who study whether virtual world simulations can help individuals learn about real-world objects. Specifically, researchers should consider spatial processing that may play a part in learning and how the interaction between gender and learning type influence it.

2 Literature Review

2.1 Educational Applications of 3D Virtual Worlds

Researchers have focused considerably on understanding virtual worlds' potential educational applications and value. They offer a unique and flexible learning environment that one can apply in various fields such as healthcare and medicine (Gazave & Hatcher, 2017), management (Chau et al., 2013), archeology (Sequeira & Morgado, 2013), and operations (Hudson & deGast-Kennedy, 2009). Virtual worlds allow experiences that one cannot have in the real world due to time, cost, distance, or physical laws, and they enable various instructional designs, such as learning with others and simulations (Ghanbarzadeh & Ghapanchi, 2018).

Even though virtual worlds have some downsides, such as reduced attention (Lim et al., 2006; Richards & Taylor, 2015), researchers have generally found them to be a valuable educational tool. Researchers have used both the learning experience and outcomes to assess their value. The learning experience refers to what one undergoes or feels during a learning activity (Reid, 2005), whereas outcomes refer to the cognitive, affective, and skill capacities that individuals develop from conducting an activity (Kraiger et al., 1993). In their study on learning from a 3D simulation, Nadolny et al. (2013) noted that participants found the simulation engaging and motivating and that they perceived an increase in the extent to which they understood and possessed knowledge about the topic. In another study (Tüzün & Özdinç, 2016), freshmen who received orientation in a virtual world reported a high level of presence. Ramírez et al. (2018) found that most students who practiced biotechnology procedures in a virtual world simulation expressed satisfaction with the experience and felt positive about the simulation's educational value.

When comparing learning in a virtual world to learning in person, researchers have found the former to lead to similar or better learning experiences and outcomes than the latter. Tüzün and Özdinç (2016) found that an orientation in a virtual world for first-year university students was associated with lower complexity but similar enjoyment levels, gains in conceptual understanding, and a better ability to recall spatial information compared to an orientation that a guide in the physical world led. When participants attended a course in a virtual world, they had similar exam scores compared to participants who attended a semester-long course in a traditional setting (Okutsu et al., 2013). Ramirez et al. (2018) found that students who learned biotechnology procedures in a virtual laboratory retained more knowledge than students who learned in a traditional laboratory.

2.2 Directed and Incidental Learning

Directed learning provides high levels of learning structure and guidance to learners. For example, directed learning in a virtual world would include a learner who received instructions to focus on a certain event. For instance, the learner may receive instructions to focus on airflow to observe how introducing higher capacity hardware in a raised floor cooling setup starved neighboring equipment of cool air. In contrast, incidental learning involves minimal guidance and provides learners with no opportunity to develop prior intentions; however, learners nevertheless end up gaining such an opportunity when working on larger or different activities. For example, incidental learning in a virtual may include a learner observing the higher capacity hardware and noticing that less cool air flowed to neighboring equipment without receiving specific directions to focus on any particular hardware or the airflow.

In general, researchers have found benefits and drawbacks to directed and incidental learning in various situations. Among incidental learning's benefits, learners can perform it anywhere at any time and without conscious effort. Incidental learning also adheres to constructivist and collaborative learning approaches (Nelson, 2007). On the other hand, using incidental learning for specific learning outcomes may require individuals to experience the context or environment several times to achieve the desired outcome(s) (Hulstijn & Trompetter, 1998). Guided learning can reduce student stress in uncertain times, such as during the COVID-19 pandemic (Sayeg-Sanchez et al., 2021). Research has shown guided approaches to increase specific knowledge retention and increase the extent to which individuals engage in learning activities. Conversely, research has shown more exposure to teacher guidance to distract or reduce learner engagement over time (Topu et al., 2018). Teacher guidance can increase student behavioral and cognitive engagement, but research has found mixed results for emotional engagement or task enjoyment (Tseng, 2021; Topu & Goktas, 2019).

To review directed versus incidental learning in virtual worlds, we looked at studies that compared present versus absent guidance. Nelson (2007) and Goo et al. (2006) examined the effect that guidance from system prompts during learning in virtual worlds on learning in virtual worlds. Although Goo et al. (2006) reported improved learning in the guided versus unguided condition, Nelson (2007) found that improved learning outcomes resulted when participants actually used guidance rather than when the system simply provided it. Nelson (2007) also found that females had a higher likelihood to use reflective guidance that the virtual world system provided and that they outperformed males regardless of how much guidance they used. Researchers have also studied guidance from an instructor's avatar (Baydas et al., 2015; Topu & Goktas, 2019). Baydas et al. (2015) suggested that, when a learner has prior virtual world experience, guidance from an instructor's avatar may reduce knowledge retention and create a situation in which flow has no relationship with knowledge retention. In contrast, Topu and Goktas (2019) suggested that the guidance from an instructor's avatar may be beneficial. They found that guided students had better behavioral, cognitive, and affective engagement than unguided students and that their cognitive engagement correlated with the amount they learned.

2.3 Spatial Processing Differences between Men and Women

Gender affects various online learning issues, such as multimedia design (Dousay & Trujillo, 2019), engagement in learning (Rodríguez-Ardura & Meseguer-Artola, 2019), achievement level (Yukselturk & Bulut, 2009), and motivational strategies (Chen et al., 2016). To complement these findings, researchers (e.g., Hill & Knutzen, 2017; Park & Kim, 2020) have called for more work that examines gender differences in virtual world learning. Some studies have focused on the sense of physical space that virtual worlds afford and how gender differences in spatial abilities might introduce differences in performance (Waller, 2000; Sandstrom et al., 1998; Kallioniemi et al., 2015; Ross et al., 2006) or perceived skill levels (Nah & Eschenbrenner, 2016) in virtual worlds. These studies have tended to reinforce the male advantage in wayfinding and gender differences in wayfinding strategies that occur in real-world settings. Tlauka et al. (2005), for example, studied navigation through computer-simulated spaces and reported better male performance in making directional and distance estimates, map placement, and wayfinding. However, in their work, Pareskeva et al. (2012) took a different approach than others in that they examined the effect that gender had on individuals' ability to remember objects that they encountered incidentally in a virtual environment. They found that female participants correctly identified objects in their correct location more often than male participants.

Researchers have also examined gender and its effects in virtual world learning for reasons other than spatial processing ability. For example, Nelson (2007) explored using individualized, reflective guidance in a virtual world and found that female students used that guidance more often than male students. Some researchers have studied whether gender differences in abilities, attitudes, or preferences related to computers, computer games, and virtual worlds translate into gender differences in learning in virtual worlds. Specifically, researchers have found females to have lower computer self-efficacy (Huang, 2013) and less favorable attitudes toward computer games (Steiner et al., 2009), to require greater time to navigate in a virtual world (Lin et al., 2012), and to have less prior experience with virtual worlds (Lin et al., 2011). However, results do not always suggest that these differences cause females to learn at lower levels. For example, Lin et al. (2012) observed that females performed more poorly than males at navigating a virtual world, which had a marginal, negative effect on knowledge gains, but Nelson (2007) observed that female students outperformed male students in a virtual world. In another study, Lin et al. (2011) observed that gender had no effect on knowledge gains. Scullion et al. (2014) found no gender difference when they examined female and male gains in self-efficacy following experience with virtual worlds designed to enhance communication and collaboration skills.

2.4 Summary

Our review suggests that virtual worlds generally promote positive learning experiences and outcomes. Researchers have been interested in gender and its effects in virtual worlds, and they have found that gender differences in navigation ability in the real world extend to virtual worlds. However, while the way in which people use virtual world features may differ depending on gender, females do not necessarily have disadvantages in such an environment. Studies on guidance, a topic related to directed and incidental learning, indicate that virtual worlds can provide guidance in different ways (e.g., with prompts to enable reflection or from an instructor's avatar). Guidance may not have straightforward effects; rather, the effects will likely depend on other factors such as whether an individual uses guidance and prior virtual world experience. Although researchers have attempted to study how gender affects learning about objects in a virtual environment, they have not yet investigated the interaction between gender and directed versus incidental learning. This interaction occurs in the real world, and understanding whether it carries over to a virtual world could help educators optimize learning about objects simulated in virtual worlds. Our study addresses this gap.

To examine the interaction between gender and learning type, we focused on both learning experience and outcome. Researchers have blamed poor learning experiences for high dropout rates in online learning (Udo et al., 2011). Understanding an online learning experience with a particular technology can help counter the tendency to avoid it in future learning. We studied flow, a learning experience variable that plays a critical role in whether individuals will use technology-based learning methods in the future. The flow experience (Csikszentmihalyi, 2000) reflects a participant's engagement in the learning activity (Kiili, 2005). It affects an individual's attitude towards the learning method and intention to continue its use (Agarwal & Karahanna, 2000; Ahmad and Abdulkarim, 2019). Since individuals usually undertake learning activities to gain new knowledge, we focused on knowledge retention to indicate success. Kraiger et al. (1993) considered knowledge retention a critical cognitive outcome. Figure 1 depicts the variables and the relationships that we examined in our study.

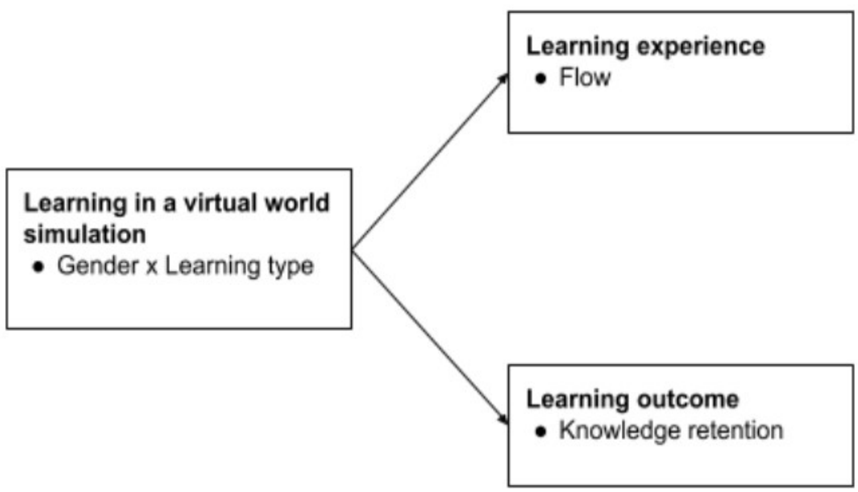

Figure 1. Variables and Relationships Studied

3 Theory

Learning in a virtual world involves spatial processing, and, thus, learners' spatial abilities will likely influence learning. For a long time, studies supported the view that males demonstrated better spatial processing than females because males generally outperformed females at wayfinding. Researchers believe this advantage to stem from male aptitude for 3D mental rotation (3DMR), which refers to "the ability to rotate quickly and accurately two- or three-dimensional figures in [one's] imagination" (Voyer et al., 1995, p. 250). However, Silverman and Eals (1992) suggested that it may be inaccurate to assume that males perform better at spatial processing. Instead, it may be more appropriate to see males and females as possessing different sets of spatial abilities. For instance, males can generally better orient themselves spatially using global reference points (Postma et al., 2004), whereas females can generally better remember and locate what they have observed spatially (Eals & Silverman, 1994). To describe differences in spatial abilities across genders, Silverman and Eals (1992) presented an evolutionary theory of spatial processing based on the hunter-gatherer theory of spatial sex differences. While not the only theory explaining differences in spatial abilities, it has received wide support (Hughes et al., 2014).

According to Silverman and Eals' (1992) theory, differences in spatial abilities across genders evolved from the labor division between males and females in the Pleistocene era. Males hunted highly mobile prey across vast, unfamiliar territory. To return home efficiently, males relied on an orientation strategy based on global reference points (north, south, east, and west) and metric distances. An overview or a "bird's eye-view" strategy served them well. Given the indirect path that prey would have taken, remembering details about the path itself would not have helped return home efficiently, but the ability to perform 3DMR would facilitate the orientation strategy. Indeed, researchers have found males to have a stronger 3DMR ability than females (Kimura, 2000; Voyer et al., 1995). Females, on the other hand, gathered and foraged for stationary food that varied in quality and quantity. Peripheral vision and unconscious processing would help a gatherer 1) maximize the yield at any location before moving to another and 2) note potentially promising locations for future picking. Thus, women would benefit from better peripheral perception and incidental memory for objects since these qualities would allow them to non-purposively assimilate the information they would need to successfully forage while focusing on the task at hand. Research that has found women to have larger visual fields and to be able to see much further in the periphery than men while fixating on a central point supports this interpretation (Burg, 1968). Research has also found women to excel at scanning tasks and possess greater perceptual speeds than men (Kimura, 2000).

Since past literature showed that males have better 3DMR ability than females, something that would be vital in hunting activities, Silverman and Eals (1992) compared genders in the ability to learn the content and arrangements of arrays of common objects. The authors expected women to perform better than men at recalling what they saw and whether it had moved from its original location consistent with what effective foraging would require. Results confirmed this expectation in multiple studies. Eals and Silverman (1994) followed up with additional studies in which they used uncommon objects to assess whether the female advantage that they observed in their previous studies arose due to their stronger verbal skills or an innate spatial ability arising from foraging requirements. The authors also observed that gender performance reversed with the learning type; females outperformed in incidental learning, whereas males outperformed in directed learning. While the authors expected females to perform better during incidental learning based on what successful foraging would require, they found it surprising that female performed less well during directed learning. The authors speculated that, because they directed female subjects to remember uncommon objects, they may have shifted to conscious processing. This shift may have caused their performance to drop by interfering with their ability to spontaneously memorize objects.

Other studies support the idea that females perform better at tasks that engage the spatial abilities required for effective foraging. McGivern et al. (1998) found that women could better recognize objects than men and that the result did not result from a greater verbal ability or greater compliance among women. The authors concluded that the females performed better than males because they better unconsciously processed environmental stimuli. Pacheco-Cobos et al. (2010) studied how men and women behaved during foraging in natural conditions. Although male and female mushroom gatherers from an indigenous Mexican community collected mushrooms in similar quantities, men did so at a significantly higher cost. Consistent with an explorative, trial-and-error-based strategy better suited for a hunting role, men traveled further and to greater altitudes and expended more energy than females. Women collected more species and visited more collection sites. These findings reinforce the idea that women, in a gathering role, have more suitable search strategies. New et al. (2007) tested the foraging hypothesis by studying whether women or men could better remember the location of food resources they were exposed to incidentally at a farmer's market. Results supported the hypothesis that females have an advantage in foraging for food resources. The authors also observed that females preferentially engaged their spatial memory for food items with higher nutritional value, which suggests that women not only remember what they observe and where but that they also associate relevant information with their observations and remember that as well.

4 Hypothesis

The above discussion has implications for how men and women learn about objects in a 3D space. According to the hunter-gatherer theory, women have evolved an unconscious yet effective ability to observe things around them. They make observations without specific directions and assimilate information about the objects they may focus on in addition to objects in their peripheral view. Thus, women will likely retain information quite well when they learn incidentally. Due to a balance between what incidental learning requires and women's capabilities, women are likely to find incidental learning to be efficient, under their control, and immersive (Csikszentmihalyi, 2000). Immersion in learning makes it easy to lose track of time. As women acquire more information with relative ease, a feeling of efficacy will emerge, which will make learning enjoyable. This feeling will also stimulate women to learn more and, thus, build their curiosity. In other words, when learning incidentally, women will likely experience conditions normally associated with flow (i.e., control, temporal dissociation, focused immersion, heightened enjoyment, and curiosity) (Agarwal & Karahanna, 2000).

Men will likely exhibit a different pattern during incidental learning and show poor learning outcomes relative to women. Incidental learning’s demands do not match the way men develop an overview rather than a detailed picture of what surrounds them. Men do not attend to surrounding objects for long. They observe one element of a phenomenon and then move quickly to the next and engage in selective learning by trial and error (to enable the quick processing that they need to catch the prey before it escapes). Consequently, due to the somewhat arbitrary hunting process, men will likely not retain as much knowledge of what surrounds them when asked to learn incidentally, and incidental learning by men will likely lack flow characteristics. Specifically, an erratic learning process will likely be associated with loss of control and frequent shifts in focus. With frequent shifts in focus, immersion and losing track of time will not likely occur. An erratic learning process will also likely induce feelings of inefficiency and inefficacy, which can curb enjoyment and demotivate further learning.

When directed, men and women will likely have opposite reactions. Learning implies that one acquires novel information, but consciously complying with directions to acquire novel information will likely interfere with a woman’s capability for spontaneous, unconscious processing (Eals & Silverman, 1994). For instance, women may consciously attempt to verbalize or associate new words with the novel material they encounter, which would likely inhibit their ability to retain new information when they engage in directed learning. Since this learning mode places demands on women that do not concur with their abilities, they will likely lack control over their learning, which will lead to inefficiency and prevent immersion. In situations with deliberate steps that slow learning, women will not likely lose track of time and feel efficacious, which, in turn, will reduce their motivation to learn and prevent them from becoming curios. Thus, they will likely not develop conditions normally associated with flow when they engage in directed learning.

When men engage in directed learning, the directions complement their overview tendencies and help them focus on things they would have missed had they relied on their natural tendencies and, thereby, to retain more information. Additionally, due to the focus that directions enable, men will likely achieve flow when learning via directed learning. Specifically, a focused learning process will likely be associated with a feeling of control and immersion. They will also likely lose track of time under such conditions. A focused learning process will also likely induce feelings of efficiency and efficacy, which can lead to enjoyment and motivate further learning.

In summary, during incidental learning, women likely experience greater flow and retain more knowledge than men, whereas, during directed learning, men likely experience greater flow and retain more knowledge than women. Due to these opposite learning patterns that occur when men and women engage in incidental versus directed learning about objects in a 3D space, we predict that a learner’s gender and the learning type will interact to influence both flow and knowledge retention in a virtual world simulation.

Although we make the above prediction based on how men and women behave in real spaces, we believe it will likely hold in a virtual world simulation because such a simulation would require the same spatial processing abilities as the physical world and past research indicates that spatial abilities carry over from the physical world to virtual worlds. Similarities in learning in the physical world and the virtual world also justify our prediction. First, both the virtual and physical worlds can have the same learning content (such as servers). Second, both worlds can have the same learning setting (such as how one lays out server arrays and their surroundings). Third, one can facilitate the learning process (such as receiving documentation, obtaining instructions, and walking through the area) in the same way in both worlds. Studies that have used 2D object arrays on paper (e.g., McGivern et al., 1997) further reinforce our prediction, which we make based on hunter-gatherer theory, for a virtual world. Similar to a virtual world simulation, representing objects in two dimensions also constitutes a simulation.

To be sure, 2D object arrays on paper do not contain animations similar to a virtual world simulation. However, we can consider animations to be multiple visual frames arranged in space, and, consequently, spatial abilities tends to affect how well one can learn from animations in 3D simulations (Garg et al., 1999; Levinson et al., 2007). Although the continuously changing frames have the potential to increase cognitive load (Lajevardi et al., 2017), a virtual world simulation can keep the load manageable by allowing the user to pause at discrete frames and replay earlier ones (Tversky et al., 2002). Based on the above discussion, we hypothesize:

> **H:** Gender and learning type will interact to influence how well individuals learn about objects in a virtual world simulation. Specifically, in incidental learning, women will experience greater flow and retain more knowledge than men. In directed learning, men will experience greater flow and retain more knowledge than women.

5 Method

5.1 Participants

We conducted a laboratory experiment to test our hypothesis. The sample comprised 60 graduate students from two course offerings (one year apart) of the introductory management information systems course in a master of business administration (MBA) program at a medium-sized university in the Northeastern United States (US). We can consider this sample to represent student population in graduate management programs in the US. The course served both national and international students as is typical in most graduate-level management programs in the US. Furthermore, participants engaged in a learning exercise related to their course for credit as a student might in the normal sequence of a management program. While we provided students the option to earn course credit by writing a paper on the learning topic in virtual worlds rather participating in the experiment, none exercised that option. Participants were 24.15 years old on average and 48.3 percent were female.

5.2 Procedure

The study used a between-subjects 2 x 2 factorial design (directed vs. incidental learning and male vs. female). To control for the effect that extraneous variables could have had on our results, we randomly assigned participants to the two learning conditions (directed: 13 males, 17 females; incidental: 18 males, 12 females). We gave them instructions to visit a simulation that depicted data center operations in Second Life, an online virtual world accessible via software that anyone can freely download. A major technology company set up the simulation, and it covered traditional data center operations and how one could optimize them for energy efficiency. The company used the data center simulation as an educational space for its own clients, so its use as a learning scenario in our study aligned with its intended use. We instructed all participants to learn as much as possible from the simulation. We also told them that they would take a timed quiz after their learning exercise and that we expected them to perform at a minimal level (which we did not specify) to earn the maximum grade for their participation in the study. As we describe in Section 5.2.1, depending on the learning condition that we assigned participants to, the instructions in the simulation varied in how much detail they contained.

We show the data center simulation in Figure 2. The simulation comprised 18 text panels that described traditional and optimized data centers. Behind the panels, a model data center employed animations to demonstrate the cooling processes that the panel text described. Participants could move their avatars freely through the simulation area and could click on any panel, which activated visible changes in the model data center. The simulation compared raised floor cooling to newer, more-efficient cooling methods. Clicking on a written panel caused the selected panel to light up and become focused for reading. Simultaneously, the model of cooling center elements changed to illustrate what the panel text described. The illustrations contained animations that showed problems that the cooling setup in a traditional data center caused and changes in the equipment and phenomena (e.g., flow of hot air) when one installed newer cooling systems. For instance, when participants activated the “Raised Floor Cooling” panel, they could see red animated air currents that depicted the restricted flow of hot air. In another instance, when participants activated the “In-Row Cooling” panel, they could see added chillers in the middle of the computer equipment rows. Participants could visit the equipment area behind the panels to observe the changes closely. The panels and the simulation took a visitor through 1) a typical raised floor design and the problems it creates (such as under-floor crowding and turbulence in airflow); 2) newer solutions based on central cable management, in-row cooling, containment, and wire management, and power buses; 3) how newer solutions help cool a data center efficiently and future-proof it; and 4) alternative cooling methods that include drape containment, Liebert XDV cooling, and these methods in combination.

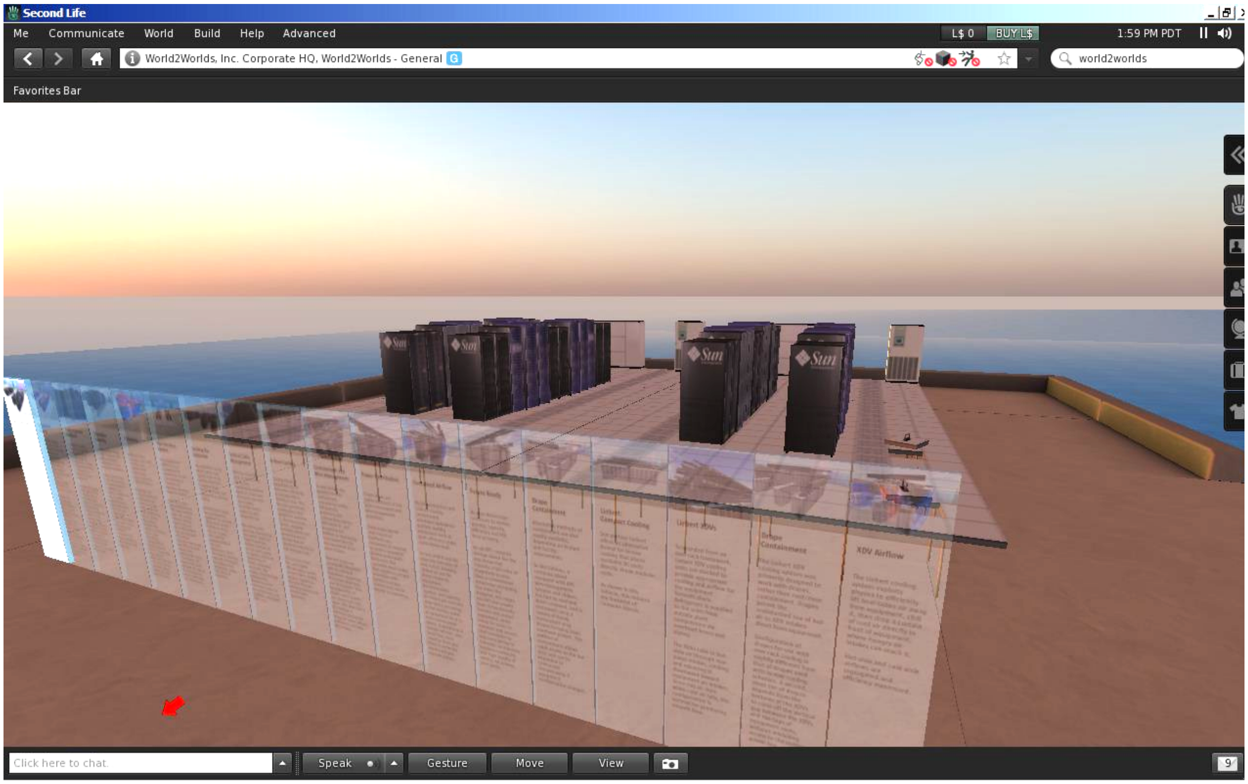

Figure 2. Front View of the Data Center in Second Life

5.2.1 Learning Type Manipulation

We provided participants in the directed learning condition with explicit instructions that directed them to touch a particular panel and visit a particular computer equipment area behind the panels (see Figure 3). Specifically, we directed participants to repeat the following process for all panels starting with the first: activate the panel, read the text on the panel, and then go into the equipment area to observe specified items (e.g., cables under the floor), happenings (e.g., flow of hot air coming from the computing equipment), and changes (e.g., addition of higher capacity servers). For some panels, the information did not have accompanying changes in the equipment area. In such cases, we directed participants to the subsequent panel as the next step.

In the incidental learning condition, we simply told participants that they needed to click on the panels, read the information on them, and observe associated changes in the simulation running in the background. We told them that, for better observation, they should get closer to the data center and walk around and in it. We did not direct them to examine specific panels or specific items, happenings, or changes in the equipment area as in the directed learning condition. Our condition equates to a female food gatherer in Silverman and Eals' (1992) hunter-gatherer model who learns incidentally. The gatherer seeks to gather food but does not receive any direction to any item per se. When picking a certain item, she unconsciously notices items in her peripheral view that may be ready in the future. Likewise, a learner in the incidental learning condition in our study had a goal to learn but did not receive direction to specific panels or specific items, happenings, or changes in the equipment area. When a learner examined the raised floor cooling system and noticed that it comprised a raised floor and cooling AC units (something the learner might make a note of to prepare for the quiz), the learner might unconsciously observe (without the intention of preparing for the quiz) that the AC units resided at the data center's perimeter. Thus, participants in the incidental learning condition could make certain observations in the equipment area unconsciously without prior intention or immediate purpose in mind. Note that, in the directed learning condition, participants received guidance to not only all panels but also items, happenings, and changes in the equipment room. Thus, we can consider the way in which they learnt the material as intentional and, therefore, as less likely to be unconscious or incidental.

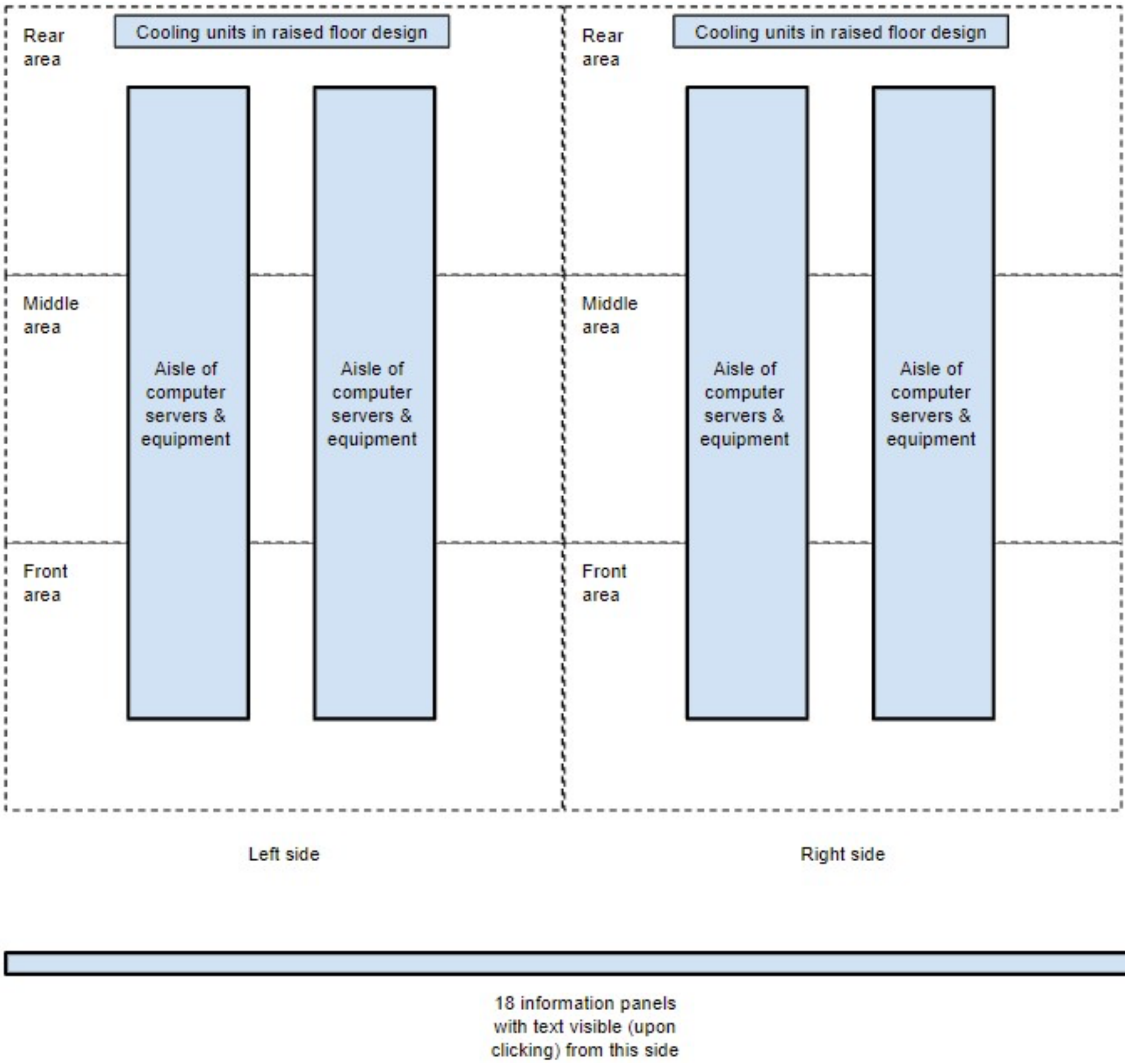

Figure 3. Top View of Information Panels and Equipment Areas

5.2.2 Research Phases

The study had two phases, a training phase, and a learning phase, both of which we implemented via the Blackboard course management system. Figure 4 shows the timeline that these phases and the activities followed. Participants completed both phases from their personal computers at a location they chose to mimic distance/online learning. During their training, participants received a document with instructions to 1) download and install Second Life, set up an account, and select an avatar, 2) complete a tutorial provided by Second Life for new users, and 3) explore two areas in Second Life that comprised simulations similar to the data center simulation in complexity and operation. One area simulated a nuclear power plant and the other simulated a spaceflight center. We provided participants with actions to carry out in the two simulations and had to turn in screenshots that showed their avatar completing the specified actions. After their training exercise, participants responded to a survey about their demographic profile and prior experience with virtual world technology. We instructed participants not to return to Second Life until the learning phase.

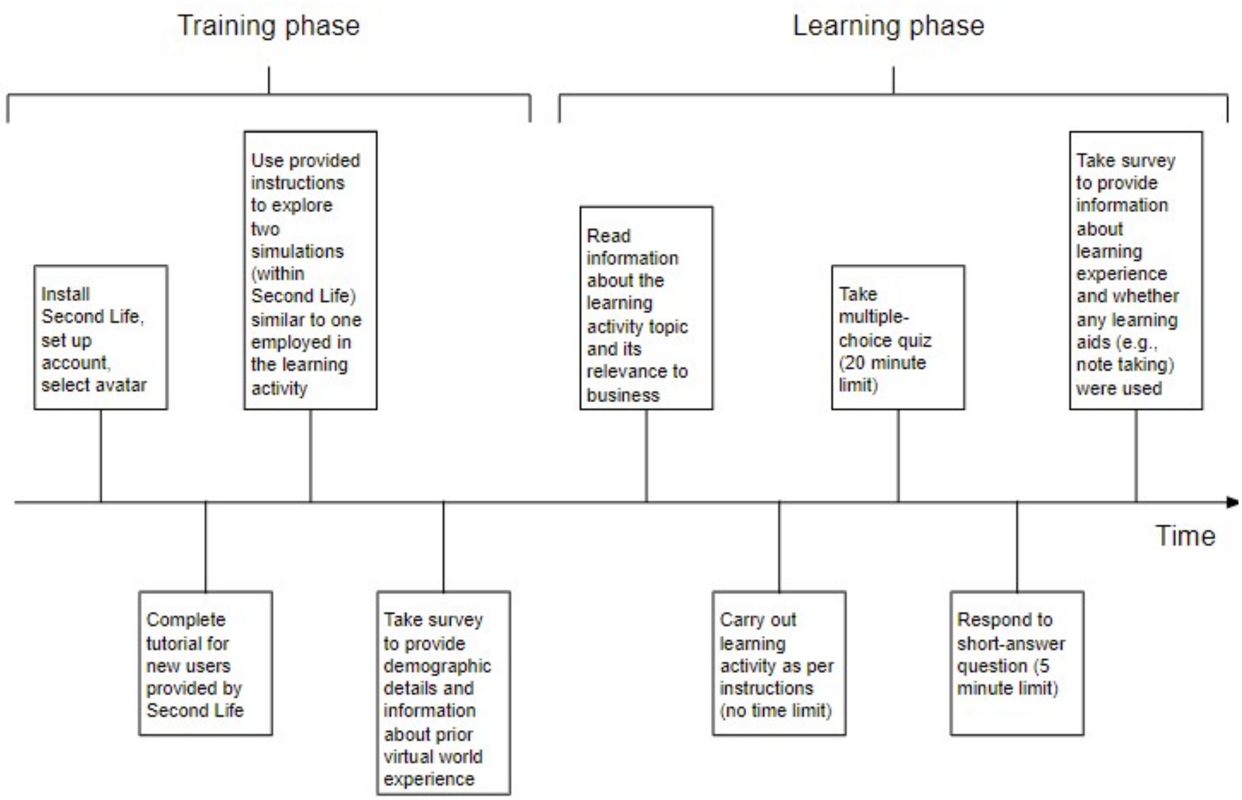

Figure 4. Timeline of Study Phases and Activities in Them

In the learning phase, participants received information about the topic and its relevance to business. Next, participants followed written instructions for the directed or incidental learning exercise. These instructions also reminded the participants that, after their learning exercise, they would take a timed quiz. Participants could spend as much time as they wanted in the simulation. We told them that they could not visit the simulation during the quiz and that we logged their visits to the simulation and would disqualify their participation if they visited the simulation during the quiz. To give subjects some sense about how much detail the quiz would involve, we gave them sample questions.

After completing the learning exercise, participants took a multiple-choice quiz that comprised 15 questions. We imposed a 20-minute time limit to complete the quiz to discourage participants from visiting the simulation to answer the questions. Graduate teaching assistants who had visited the simulation also took the quiz and indicated that the time limit did not impose undue pressure or provide an opportunity to visit the simulation and respond to the test. Participants took 12 minutes on average to respond to the quiz (range: 4 minutes and 7 seconds to 20 minutes; median = 11 minutes and 1 second). After the multiple-choice quiz, participants answered a timed, five-minute short-answer question that asked them to describe data center operations as they would to a job interviewer. Simulation and Blackboard access logs showed no overlap between when participants visited the simulation and when participants took the quiz or responded to the short-answer question. Participants ended the learning phase by responding to a post-test questionnaire, which measured their experience during the learning exercise and whether they used any aids, such as taking notes, to remember what they learned during the exercise. We used responses to the question about the aid use to create a control variable in the data analysis.

5.3 Measures

5.3.1 Knowledge Retention

We used two measures that focused on remembering and understanding categories in Bloom's revised taxonomy (Forehand, 2012): multiple-choice quiz performance and the richness of an answer to a short-answer question. As in past studies that have examined gender differences in processing information about the content and configuration of an array of objects (Eals & Silverman, 1994; New et al., 2007), we expected the participants to remember the objects in the virtual 3D space, their location, and role in data center cooling. Thus, the quiz questions belonged to the remembering category in Bloom's revised taxonomy (Forehand, 2012). Ten questions focused on factual knowledge and five on conceptual knowledge. For example, a factual knowledge question included: "In a sub-optimal raised floor cooling system, where are the cooling AC units?". Participants could select an answer from four alternatives: 1) under the floor, 2) at the perimeter of the data center, 3) in a separate room from which cool air is pumped, or 4) there are no AC units. (Correct answer: B). An example conceptual knowledge question included "Your company is upgrading its equipment with new, higher-capacity servers. You have a traditional raised-floor style data center. What are some results you might expect from the addition of the new hardware?". Participants could select an answer from four alternatives: 1) the electricity demands of your data center will increase, 2) a higher volume of cooling air will be necessary to keep the room cool, 3) the new servers will emit more heat into the data center, and 4) all of the above. (Correct answer: D). In the short-answer question, we expected participants to explain data center operations. By requiring students to describe what they learned in their own words, this question tapped into the cognitive understanding process in Bloom's revised taxonomy (Forehand, 2012) and required the participants to have factual and conceptual knowledge about objects that they observed in the virtual 3D space. We assumed that how much explanation participants provided in the answer indicated their understanding level.

We used past studies as a starting point to measure the explanation amount. Studies on online reviews have often used the numbers of words and characters in reviews to indicate how much explanation they provide (Chevalier & Mayzlin, 2006; Mudambi & Schiff, 2010). One could argue that the number of sentences and ideas in an answer also represent relevant indicators. A sentence constitutes a complete thought; thus, different sentences in an answer represented the various thoughts that participants employed to explain the phenomena they observed. Likewise, the number of ideas that participants provided indicated the various features that they understood and conveyed (Bayus, 2013). The number of ideas differs from the number of sentences because a sentence can convey more than one idea (e.g., a participant could list different benefits of a data center cooling technique in a single sentence).

While one can easily count the number of sentences, words, and characters in an answer, we need to explain how we measured number of ideas. Two graduate student assistants graded the answers to the short question using a coding scheme. This scheme assessed the extent to which an answer incorporated the ideas covered in the simulation. We provided a comprehensive list of all ideas obtainable from the simulation to the coders, which they used to count how many ideas an answer contained. The intra-class correlation coefficient computed to assess inter-rater reliability was 0.936. We employed the average number of ideas that the two assistants found to measure ideas per answer.

Principal axis factoring of the numbers of words, characters, sentences, and ideas extracted a single factor that explained 72 percent of the variance. Therefore, we created a single scale that averaged the standardized values of words, characters, sentences, and ideas in an answer to measure the answer's richness ($\alpha = 0.88$).

5.3.2 Flow

We operationalized flow using Agarwal and Karahanna's (2000) multi-dimensional conceptualization that incorporates temporal dissociation, focused immersion, heightened enjoyment, curiosity, and control. We measured these dimensions using the post-test questionnaire items that we show in Table 1. We adapted items for all dimensions except control from Agarwal and Karahanna (2000) to fit the learning activity in our study. We measured control using seven items: a summary measure that we adapted from Agarwal and Karahanna (2000) and six that we developed to reflect the control a learner can exercise in a virtual world setting. Learner control refers to the extent to which a learner has the latitude to decide or select effort intensity, repetition for practice, speed, sequencing, and feedback (Ford et al., 1998; Schmidt & Ford, 2003). In a virtual world setting, being able to manipulate an object to learn about it also becomes relevant (Gazzard, 2009). We computed the scales for flow's different dimensions by averaging the responses to items, and they showed adequate reliability (see Table 1). We computed flow by averaging the scales ($\alpha = 0.83$).

5.3.3 Gender

We obtained each participant's gender (male = 0, female = 1) in the survey that we administered at the end of the Second Life training.

5.3.4 Control Variables

We employed several control variables. We obtained one set, which comprised the participant's age, international status, and prior experience with virtual worlds, from the "end of training" survey. We used control variables for several reasons. First, research suggests that age influences learning (e.g., Naveh-Benjamin et al., 2009). In an e-learning environment, age can also affect learning by influencing whether one adopts and uses learning technology (e.g., Morris & Venkatesh, 2000; Tarhini et al., 2014). Second, the international status item captured whether participants received their education mostly outside the US or not (1 if they received it outside; 0 otherwise). All students educated outside the US came from countries in which people do not typically speak English as a first language. Language difficulties can cause underperformance in international students (Liu, 2001). We employed the international status item to control for this possibility. Lastly, we computed prior experience with virtual worlds by averaging the responses to two items designed to capture this experience (see Table 1). Prior experience with virtual worlds can affect participants' facility with the interface, which can help them engage more with the learning material rather than focusing on the actions they need to perform to navigate the virtual world.

Table 1. Questionnaire-Based Scales, Items, and Reliabilities

Scale	Items[1]	Cronbach's alpha
Temporal dissociation	I lost track of time during the learning exercise. Time appeared to go by quickly during the learning exercise. Time flew during the learning exercise.	0.83
Curiosity	The learning exercise made me eager to learn more about data center operations. The learning exercise stimulated my interest in data center operations. The learning exercise excited my curiosity about data center operations.	0.93
Focused immersion	I was absorbed in learning about data center operations during the learning exercise. During the learning exercise, I was able to block out most distractions. My attention was largely on data center operations during the learning exercise.	0.64
Heightened enjoyment	I enjoyed learning about data center operations. I had fun learning about data center operations. Learning about data center operations was exciting.	0.91
Perceived control	During the learning exercise, I was able to adjust the time I spent on different aspects of data center operations. I was able to repeat my learning of any aspect of data center operations. I was able to adjust the sequence in which I learned about different aspects of data center operations. During the learning exercise, I was able to control how much effort I put into the different aspects of data center operations. During the learning exercise, I was able to check if I was learning correctly. During the learning exercise, I was able to manipulate the item I was learning about. I had control over the learning I did during today's learning exercise about data centers.	0.78
Prior virtual world experience	Prior to the training today, what was your level of experience with Second Life? Prior to the training today, what was your level of experience with virtual worlds, in general?	0.69
Perception of being guided	I had clear directions about which aspects of data center operations I should focus on. I had clear directions about the specific information I should acquire during my visit.	0.81

[1]Response anchors: for prior virtual world experience questions: 1 = extremely low, 2 = quite low, 3 = slightly low, 4 = neither high nor low, 5 = slightly high, 6 = quite high, 7 = extremely high. For the remaining questions: 1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = neither agree nor disagree, 5 = slightly agree, 6 = agree, 7 = strongly agree

We employed two additional control variables in the second set. We used a dummy variable to identify each semester in which we conducted the study. While we attempted to ensure we implemented the study in a consistent manner (e.g., by offering participation in the study at the same time during the semester), inadvertent differences in implementation and differences in the course offerings may have arisen. Furthermore, a class can develop a dynamic that influences students' mood or inclination to learn the subject matter. Another dummy variable captured participants' response to an open-ended question about the aids the used to remember the material and take the quiz (e.g., whether they took notes, whether they copied and pasted images of the simulation in a document, and so on). We coded aid use, which could potentially influence knowledge retention in addition to gender or type of learning, as 1; otherwise, we coded this variable as 0.

5.3.5 Manipulation Check Measures

We assessed the learning manipulation with three measures that indicated guidance during the learning activity. Greater guidance promotes intentional and deliberate rather than unintentional and unconscious learning (Marsick & Watkins, 2015). The first measure assessed the perception that one received guidance. We computed it by averaging the responses to two post-test questionnaire items designed to capture this perception (see Table 1).

The second measure captured the extent to which participants engaged in guided learning. A more successful manipulation meant that participants likely more comprehensively touched the panels, visited the areas, and transitioned between the areas in the directed rather than in the incidental learning condition. From examining logs, we could count how many times participants touched a panel, entered an area, and transitioned from touching a panel to visiting an area and vice versa. We summed these counts to obtain a score. We expected higher values for this score, which we refer to as structuredness in learning, for participants who engaged in guided learning to a higher extent.

The third measure did not count actions but considered the sequence that a participant followed. We based it on the sequential variety measurement that Pentland (2003) proposed. Sequential variety reflects different patterns that one follows when executing a process, such as the learning process from a simulation. To obtain a score for sequential variety in the learning condition, we 1) computed the Euclidean distance from the Markov chain for observed sequence data in that condition to the Markov chain for the directed sequence provided to participants in the directed learning condition and 2) normalized the distance so that the final score did not exceed 1. In a successful manipulation, sequences in the directed learning condition, rather than those in the incidental learning condition, will be closer to the directed sequence. Consequently, the normalized Euclidean distance and, therefore, the score for sequential variety will be lower for directed learning than for incidental learning.

6 Data Analysis and Results

6.1 Factor Analysis

We conducted exploratory factor analysis to validate the perceptual measures that we employed to test our hypothesis (i.e., flow and prior virtual world experience). Since we created the measure of flow from the scales for different flow dimensions, we subjected them to factor analysis along with the two measures of prior virtual world experience. Both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.69) and the results of Bartlett's test of sphericity ($\chi^2 = 103.476$; $df = 21$; $p = 0.00$) indicated the suitability of the data for factor analysis. We used two criteria to indicate the sample's suitability: the ratio of the number of participants (N) to the number of variables factored (p) by the factor analysis, which equaled 8.57, and Gorsuch's (1983) recommendation that $N{:}p \geq 5$, which the sample satisfied. Principal axis factoring with varimax rotation yielded two factors that accounted for 65 percent of the variance. The scales representing flow dimensions loaded on one factor and the measures of prior virtual world experience loaded on the other factor. Except for the control (0.64) and temporal dissociation (0.65), the remaining flow dimensions and the items for prior virtual world experience had loadings that exceeded 0.7. No cross-factor loadings exceeded 0.17. These results indicate that the perceptual measures we employed to test our hypothesis exhibited reasonable validity.

6.2 Manipulation Check

Checks indicated that we successfully manipulated the learning conditions. Participants in the directed learning condition perceived being guided by directions during their data center visit to a greater degree than participants in the incidental learning condition ($M = 5.07$ vs. 4.15, $F = 7.14$, $p < 0.01$). Additionally, structuredness in learning, which reflects the activities that directed learning participants received guidance to engage in (touching panels, visiting areas at the back of the panels, and transitioning from panels to areas and vice versa) was higher in the directed than in the incidental learning condition ($M = 26.97$ vs. 17.84, $F = 4.139$, $p < 0.05$). Finally, the sequential variety score, which reflects the variety in patterns that participants followed, was lower in the directed than in the incidental learning condition (0.213 vs. 0.288).

6.3 Hypothesis Testing

We used MANCOVA to test our hypothesis because 1) we expected the dependent variables to covary due to the interaction between gender and learning condition and 2) our testing included control variables, some of which we modeled as covariates. Table 2 presents descriptive statistics. Table 3 provides cell means and standard deviations for dependent variables. Table 4 shows the MANCOVA results. These results indicated a significant effect of the gender × learning type interaction (F = 4.844, p = 0.005), which permitted the univariate analyses that we show in Table 5.

The pattern of dependent variable scores described in Table 3 concurred with our expectations. In the directed learning condition, males (M = 5.05, SD = 0.76) had a higher mean score for flow than females (M = 4.34, SD = 0.83). In the incidental learning condition, females (M = 4.45, SD = 0.88) had a higher mean score for flow than males (M = 4.25, SD = .99). In the directed learning condition, males (M = 12.08, SD = 1.75) scored higher on the post-simulation quiz than females (M = 10.59 SD = 2.21). In the incidental learning condition, females (M = 12.25, SD = 1.22) scored higher on the post-simulation quiz than males (M = 11.17, SD = 1.43). We observed a similar pattern in the richness of short answers. In the directed learning condition, males (M = 0.40, SD = 1.09) provided richer answers than females (M = -0.3, SD = 0.59). In the incidental learning condition, females (M = 0.32, SD = 0.80) provided richer answers than males (M = -0.03, SD = 0.59). Univariate analyses indicated significant gender × learning type interaction effects on flow (F = 4.568, p = 0.037), quiz scores (F = 8.162, p = 0.006), and short-answer richness scores (F = 4.389, p = 0.041). Figures 5-7 show that learning type and gender had consistent effects with the predicted pattern. Figure 5 shows that, while women experienced greater flow than men in incidental learning, men experienced greater flow than women in directed learning. Figures 6 and 7 indicate that, while women retained greater knowledge than men in incidental learning (based on higher quiz scores and richer short answers), men retained more knowledge than women in directed learning. These results support our hypothesis.

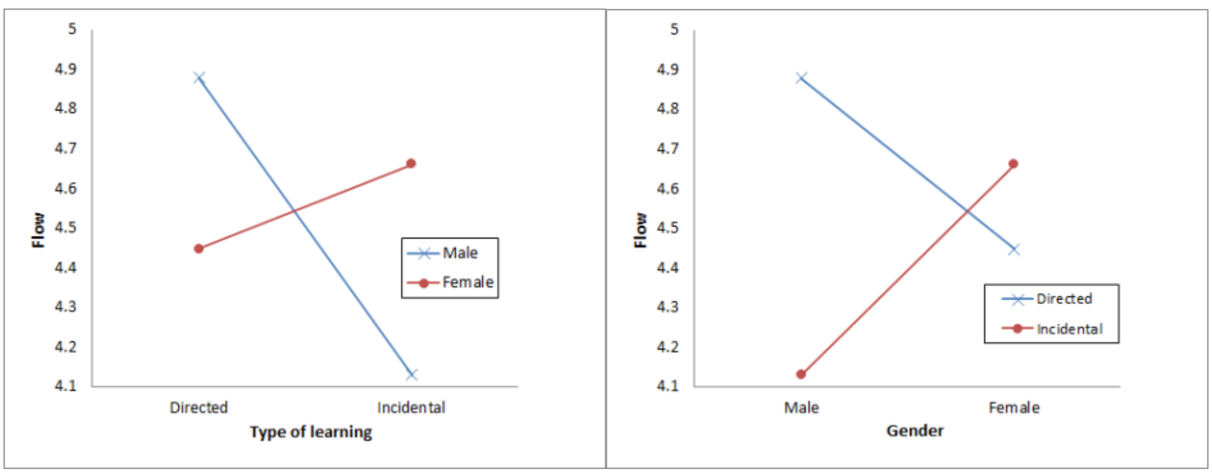

Figure 5. Gender x Learning Type Interaction Effect on Flow

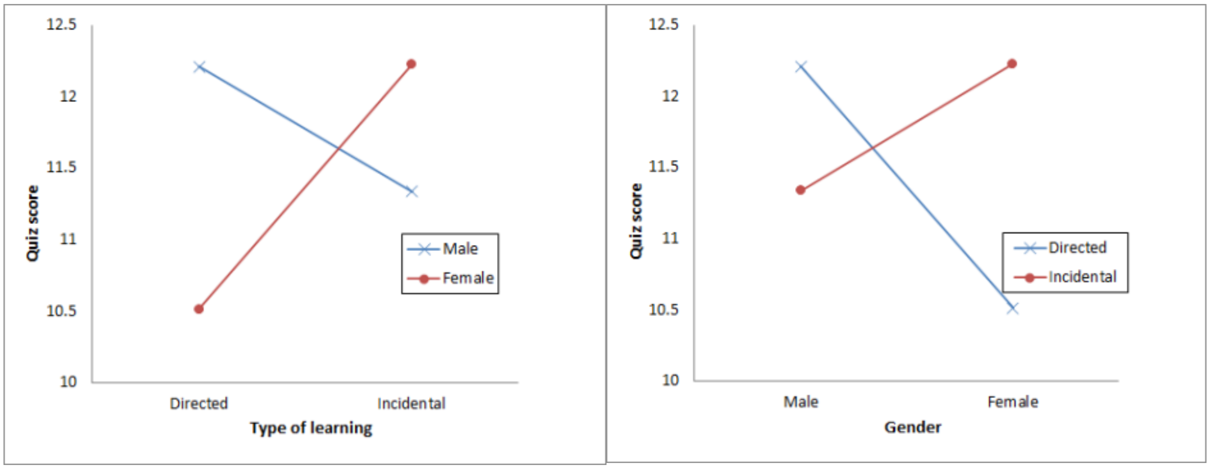

Figure 6. Gender x Learning Type Interaction Effect on Quiz Scores

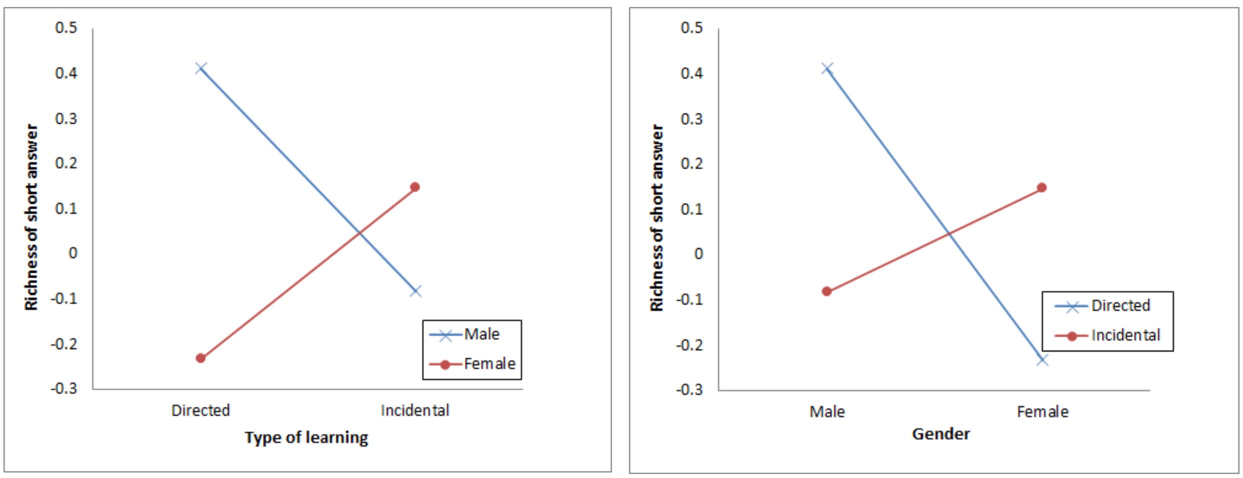

Figure 7. Gender x Learning Type Interaction Effect on Short Answer Richness

7 Discussion

Virtual worlds enable online learning in the ongoing pandemic. They offer tremendous educational promise due to their ability to engage learners in an authentic experience by offering the sense of being in a 3D space. This promise has led more educators to deploy virtual worlds to support their online teaching efforts during the pandemic (Lederman, 2020). However, enabling learning in a virtual world constitutes a costly affair because it requires significant technical expertise and time (Richards & Taylor, 2015). Thus, we clearly require more research on optimizing the benefits that learning in a virtual world can provide in return for these high costs.

Compared to other learning technologies, virtual worlds differ in the sense of space that they offer. This sense of space may bring into play the same spatial abilities that users invoke in the real world. Thus, various factors that modify spatial processing, such as gender and learning type, may affect learning in virtual worlds. Our results provide reasonable support for our hypothesis based on the hunter-gatherer theory of differences in spatial abilities between males and females. Gender and learning type interacted to significantly affect flow, quiz scores, and short answer richness. We observed that women had a better learning experience and learned more than men in incidental learning, while men had a better learning experience and learned more than women in directed learning.

Table 1. Descriptive Statistics

Variable*	M	SD	n	1	2	3	4	5	6	7	8	9	10
1) Gender	0.48	0.50	60	--									
2) Learning type	0.50	0.50	60	-0.17	--								
3) Semester	0.38	0.49	60	*0.33*	0.03	--							
4) International status	0.45	0.50	60	0.13	-0.10	-0.16	--						
5) Memory aids use	0.58	0.50	60	*0.34*	-0.17	-0.10	*0.42*	--					
6) Age	24.15	2.85	60	-0.03	0.11	0.14	*0.27*	0.16	--				
7) Prior virtual world experience	2.08	1.24	60	-0.19	-0.15	-0.18	-0.03	-0.05	-0.03	**0.69**			
8) Flow	4.49	0.91	60	-0.11	-0.18	*-0.26*	0.17	-0.04	0.02	*0.28*	**0.83**		
9. Quiz score	11.42	1.81	60	-0.08	0.10	0.16	-0.19	-0.07	-0.12	0.10	0.11	--	
10) Richness of short answer	0.00	0.86	60	-0.18	-0.01	0.12	*-0.35*	*-0.28*	-0.12	0.24	0.02	*0.30*	**0.88**

Note: diagonal elements in bold are Cronbach's alphas. Italicized correlations are significant at $p \leq .05$.
* Gender: 0 = male, 1 = female; Learning type: 0 = directed, 1 = incidental; Semester: 0 = first, 1 = second; International status: 0 = US, 1 = Non-US; Memory aids use: 0 = none, 1 = some.

Table 2. Cell Means, Standard Deviations, and Sizes for Dependent Variables

Variable		Males			Females		
		M	SD	n	M	SD	n
Flow	Directed learning	5.05	0.76	13	4.34	0.83	17
	Incidental learning	4.25	0.99	18	4.45	0.88	12
Quiz score	Directed learning	12.08	1.75	13	10.59	2.21	17
	Incidental learning	11.17	1.43	18	12.25	1.22	12
Richness of short answer	Directed learning	0.40	1.09	13	-0.30	0.59	17
	Incidental learning	-0.03	0.88	18	0.32	0.80	12

7.1 Study Contributions

Our study makes several contributions. It counters the prevailing idea that males outperform females when they engage their spatial processing abilities in virtual worlds (Martens & Antonenko, 2012). Our results suggest that neither gender performs universally better or worse at spatial processing in a virtual world. Specifically, when one asks males and females to learn about novel objects located in a 3D space simulated in a virtual world, their learning performance depends on the type of learning task. To our knowledge, only Eals and Silverman (1994) have previously demonstrated this reversal across genders although in a non-virtual world setting. Thus, our study provides valuable support for Eals and Silverman's hunter-gatherer theory of gender differences in spatial abilities. Our study also extends their theory to a 3D virtual world. This extension has much significance given that a virtual world simulation differs from the real-world setting that Eals and Silverman examined in their study due to the presence of animations and the potential for additional cognitive load. Additionally, the learning from our simulation went beyond the learning that occurred in Eals and Silverman's study. In the latter, participants made observations about objects' presence and location; in our study, participants also had exposure to relevant information about the objects (e.g., their role in data center cooling). Yet, despite these differences, the virtual world simulation engaged their ability to learn about the content and configuration of an array of objects as they would in a real-world setting.

Table 4. Hypothesis Testing: Multivariate Analysis Results

Effect	F*	p
Gender	0.384	0.765
Learning type	0.855	0.471
Gender x Learning type	**4.844**	**0.005**
Semester	2.056	0.118
International status	1.760	0.167
Memory aids use	0.998	0.402
Age	0.356	0.785
Prior virtual world experience	2.378	0.081
Note: *df = (3,49); significant effects (p < 0.05) appear in bold		

Table 5. Cell Means, Standard Deviations, and Sizes for Dependent Variables

Effect	Flow		Quiz score		Richness of short answer	
	F*	p	F*	p	F*	p
Gender	0.036	0.850	0.579	0.450	0.731	0.397
Learning type	1.362	0.249	0.823	0.368	0.073	0.788
Gender x learning type	**4.568**	**0.037**	**8.162**	**0.006**	**4.389**	**0.041**
Semester	2.418	0.126	2.713	0.106	1.399	0.242
International status	1.423	0.238	0.956	0.333	3.602	0.063
Memory aids use	1.752	0.191	0.180	0.673	0.724	0.399
Age	0.408	0.526	0.591	0.445	0.023	0.879
Prior virtual world experience	3.164	0.081	1.208	0.277	3.404	0.071
Note. *df = (1,51); significant effects (p < 0.05) appear in bold.						

7.2 Study Strengths and Limitations and Future Research Opportunities

Among this study's strengths, we observed consistent results across multiple variables. Specifically, flow, quiz scores, and short answer richness showed a similar pattern in the effect that learning type had on male and female learners despite differences in these variables and the methods we employed to measure them. The consistent result pattern across measures that represented two different aspects of learning (experience and outcome) and that we obtained from different sources (multiple choice quiz, short answer question, and Likert-type questionnaire items) should alleviate any concerns that the gender and learning type interaction that we observed in this study occurred based on chance or that researchers may not be able to reproduce them in another study. Our experimental design and the fact we used students as subjects represent additional study strengths. These features promote generalization to situations in which educators consider using a virtual world to simulate "before" and "after" states to help their students learn about the impact of some new technology or process.

However, as with any study, this one has some limitations. First, we did not examine the specific actions that participants in different conditions took as they went about their learning task. Doing so would provide deeper insights into how gender and learning type combine to influence learning in a virtual world. In accord with expectations for spatial abilities that have evolved differently, Pacheco-Cobos et al. (2010) found specific differences in how males and females behaved during foraging. Men tended to behave in a more explorative manner than women and, thus, covered more distance and collected fewer species of the items for which they foraged. We do not know whether such differences transfer to a virtual world simulation in which participants move around and determine which objects to observe in a manner similar to foraging. We can answer this question only by studying specific actions that learners take in a virtual world simulation. Future studies should examine this question.

Second, one could consider our study's modest sample size a limitation. However, our findings demonstrated a consistent pattern across different variables, which should boost confidence in our results' validity. Third, we observed learners' cognitive performance right after the learning task; we did not look at long-term knowledge retention, which would have been critical for female gatherers (a flower would need considerable time to grow into a fruit that one could consume). To the extent that spatial abilities in males and females result from our ancestral roles as hunters and gatherers, we might expect women to possess more long-term knowledge retention. Because prey would not likely appear in the same place (due to mobility), long-term retention likely lacked relevance for whether males could hunt effectively. Therefore, it may make sense to expect differences in long-term retention between males and females when they learn from a virtual world simulation. Future studies should examine this expectation.

Fourth, the directed nature of the Second Life training, which asked participants to explore two simulations similar in complexity and in the actions they needed to perform in the data center simulation, may have also limited our study by priming or training participants to expect a more directed approach and, thus narrowed the separation between the incidental and directed learning conditions in the data center simulation. However, we offer two arguments that may counter this potential limitation counter this. First, the manipulation checks revealed that participants in the directed learning condition not only perceived being guided to a greater extent but also actually behaved in a more guided manner. Second, we observed reasonable support for the study's hypothesis. Thus, even if the separation between the incidental and directed learning conditions narrowed due to the training simulations, that narrowing was not significant enough to be of major concern.

Future research can add to this study by examining additional effects on learning experiences and outcomes. For instance, we examined the effect on knowledge retention, a cognitive learning outcome. Future research can examine affective and skills-based outcomes (Kraiger et al., 1993). It could also examine longitudinal effects. Longitudinal examinations may be especially relevant for affective variables that likely require repetitive learning to develop, such as self-efficacy in using acquired knowledge. Another future research avenue would involve examining how learning experience influences outcomes and virtual world simulations for learning.

8 Conclusions

We conducted a study to examine how learning from a 3D simulation in a virtual world varied for males and females in incidental versus directed learning conditions. While women experienced greater flow and retained more knowledge than men in incidental learning, men experienced greater flow and retained more knowledge than women in directed learning. Our results have implications for both practice and research.

For efforts to pedagogically design online learning, our findings suggest that, when one delivers learning content through 3D virtual worlds via simulated objects to achieve heightened flow and knowledge retention in learners, one should consider learning type in relation to gender. Consistent with recommendations from prior research (e.g., Dickey, 2006; Cheryan et al., 2011), one could construct the 3D learning environment differently for male and female learners to give them varying opportunities to explore and learn. Specifically, our findings indicate that males require more guidance and directions, whereas females should have the opportunity to engage in incidental learning. In single-gender learning environments, one could implement gender-specific support based on these findings. For example, one could introduce highly structured and detailed guidance in learning tool packages for male students in 3D virtual worlds but use general and unstructured guidance for female students. Since incidental learning can occur naturally from collaboration and social interactions via stimulation from other individuals (Marsick & Watkins, 1997), one could emphasize features enabling socialization and discourse in virtual worlds for female learners. In mixed-gender learning environments, instructors could create instructions for both guided and incidental learning, briefly explain why the different instructions may benefit different learners, and then allow learners to self-select which instructions they use. These individualized scaffolding strategies may provide necessary assistance to optimize learning about objects simulated in virtual worlds for both male and female learners.

In environments where one cannot offer different instructions or create separate learning environments, instructors can focus their attention on ensuring that the instructional design provides learners with opportunities to engage in both incidental and directed learning. Instructors can allocate assignment sections or learning time for directed exploration via detailed instructions and systematic steps that learners can follow in the virtual environment. Instructors can direct learners to particular areas and draw their attention to particular aspects of the learning space. Instructors can promote incidental learning as part of the instructional design by creating time and offering tools for collaborating with others and for discussing experiences or solutions in the virtual world (Gaved et al., 2013). Time for personal reflection on one's experiences may also promote incidental learning. Additionally, one can heighten incidental learning when designing a virtual environment by making important information more salient to participants via visual design cues, such as bolding important text (Thomas et al., 2012).

When researchers examine learning from simulations in 3D virtual worlds, they must factor in the role that gender and type of learning likely play. If they do not, researchers risk generating hypotheses that they do not find empirical support for due to the potentially overpowering effect of the interaction between gender and learning type. Researchers must acknowledge the assumption that underlies this risk: neither gender has a better spatial processing ability than the other in a 3D virtual world, and spatial processing may vary due to the type of learning one engages in.

In sum, this study provides timely information for educators who explore options for online learning. It also highlights important considerations for researchers as they study learning from simulations in 3D virtual worlds.

References

Agarwal, R., & Karahanna, E. (2000). Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage. *MIS Quarterly*, *24*(4), 665-694.

Ahmad, N., & Abdulkarim, H. (2019). The impact of flow experience and personality type on the intention to use virtual world. *International Journal of Human-Computer Interaction*, *35*(12), 1074-1085.

Barry, D. M., & Kanematsu, H. (2020). *Teaching during the COVID-19 Pandemic*. Retrieved from https://files.eric.ed.gov/fulltext/ED606017.pdf

Baydas, O., Karakus, T., Topu, F. B., Yilmaz, R., Ozturk, M. E., & Goktas, Y. (2015). Retention and flow under guided and unguided learning experience in 3D virtual worlds. *Computers in Human Behavior*, *44*, 96-102.

Bayus, B. L. (2013). Crowdsourcing new product ideas over time: An analysis of the Dell IdeaStorm community. *Management Science*, *59*(1), 226-244.

Boechler, P., Gautreau, H., deJong, E., & Sterling, P. (2018). Towards a psychological model for learning in avatar-based virtual environments: How important is spatial processing? In T. Bastiaens, J. Van Braak, M. Brown, L. Cantoni, M. Castro, R. Christensen, & O. Zawacki-Richter (Eds.), *Proceedings of EdMedia: World Conference on Educational Media and Technology* (pp. 2075-2083). Association for the Advancement of Computing in Education.

Branch, R. M. (2009). *Instructional design: The ADDIE approach* (vol. 722). Springer.

Burg, A. (1968). Lateral visual field as related to age and sex. *Journal of Applied Psychology*, *52*(1), 10-15.

Chau, M., Wong, A., Wang, M., Lai, S., Chan, K. W., Li, T. M., Chu, D., Chan, I. K., & Sung, W. K. (2013). Using 3D virtual environments to facilitate students in constructivist learning. *Decision Support Systems*, *56*, 115-121.

Chen, S. C., Yang, S. J., & Hsiao, C. C. (2016). Exploring student perceptions, learning outcome and gender differences in a flipped mathematics course. *British Journal of Educational Technology*, *47*(6), 1096-1112.

Cheryan, S., Meltzoff, A., & Kim, S. (2011). Classrooms matter: The design of virtual classrooms influences gender disparities in computer science classes. *Computers & Education*, *57*, 1825-1835.

Chevalier, J. A., & Mayzlin, D. (2006). The effect of word of mouth on sales: Online book reviews. *Journal of Marketing Research*, *43*(3), 345-354.

Childs, M., & Peachey, A. (2013). Editors' introduction: Understanding learning in virtual worlds. In M. Childs & A. Peachey (Eds.), *Understanding Learning in Virtual Worlds* (pp. v-xiii). Springer.

Coutrot, A., Silva, R., Manley, E., De Cothi, W., Sami, S., Bohbot, V. D., Wiener, J. M., Holscher, C., Dalton, R. C., Hornberger, M., & Spiers, H. J. (2018). Global determinants of navigation ability. *Current Biology, 28*(17), 2861-2866.

Csikszentmihalyi, M. (2000). *Beyond boredom and anxiety: Experiencing flow in work and play*. Jossey Bass.

Dickey, M. (2006). Girl gamers: The controversy of girl games and the relevance of female-oriented game design for instructional design. *British Journal of Educational Technology*, 37(5), 785-793.

Dousay, T. A., & Trujillo, N. P. (2019). An examination of gender and situational interest in multimedia learning environments. *British Journal of Educational Technology*, *50*(2), 876-887.

Eals, M., & Silverman, I. (1994). The hunter-gatherer theory of spatial sex differences: Proximate factors mediating the female advantage in recall of object arrays. *Ethology and Sociobiology*, *15*(2), 95-105.

Farr, A. C., Kleinschmidt, T., Yarlagadda, P., & Mengersen, K. (2012). Wayfinding: A simple concept, a complex process. *Transport Reviews, 32*(6), 715-743.

Forehand, M. (2012). Bloom's taxonomy. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology* (pp. 41-47).

Ford, J. K., Smith, E. M., Weissbein, D. A., Gully, S. M., & Salas, E. (1998). Relationships of goal orientation, metacognitive activity, and practice strategies with learning outcomes and transfer. *Journal of Applied Psychology*, *83*(2), 218-233.

Garg, A., Norman, G. R., Spero, L., & Maheshwari, P. (1999). Do virtual computer models hinder anatomy learning? *Academic Medicine, 74*(10), S87-S89.

Gaved, M., Kukulska-Hulme, A., Jones, A., Scanlon, E., Dunwell, I., Lameras, P., & Akiki, O. (2013). Creating coherent incidental learning journeys on mobile devices through feedback and progress indicators. In *Proceedings of the 12th World Conference on Mobile and Contextual Learning.*

Gazave, C. M., & Hatcher, A. R. (2017). Evaluating the use of Second Life for virtual team-based learning in an online undergraduate anatomy course. *Medical Science Educator*, *27*(2), 217-227.

Gazzard, A. (2009). The avatar and the player: Understanding the relationship beyond the screen. In *Proceedings of the Conference in Games and Virtual Worlds for Serious Applications*.

Ghanbarzadeh, R., & Ghapanchi, A. H. (2018). Investigating various application areas of three-dimensional virtual worlds for higher education. *British Journal of Educational Technology*, *49*(3), 370-384.

Goo J. J., Park, K. S., Lee, M., Park, J., Hahn, M., Ahn, H., & Picard, R. W. (2006) Effects of guided and unguided style learning on user attention in a virtual environment. In *Proceedings of the International Conference on Technologies for E-Learning and Digital Entertainment* (LNCS vol. 3942, pp. 1208-1222). Springer.

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). Erlbaum.

Hill, V., & Knutzen, K. B. (2017). Virtual world global collaboration: An educational quest. *Information and Learning Science, 118*(9/10), 547-565.

Huang, C. (2013). Gender differences in academic self-efficacy: A meta-analysis. *European Journal of Psychology of Education, 28*(1), 1-35.

Hudson, K., & deGast-Kennedy, K. (2009). Canadian border simulation at Loyalist College. *Journal of Virtual Worlds Research*, *2*(1), 3-11.

Hughes, M. A., Sulikowski, D., & Burke, D. (2014). Correlations between spatial skills: A test of the hunter-gatherer hypothesis. *Journal of Evolutionary Psychology*, *12*(1), 19-44.

Hulstijn, J. H., & Trompetter, P. (1998). Incidental learning of second-language vocabulary in computer-assisted reading and writing tasks. In D. Albrechtsen, B. Henrikse, I. M. Mees, & E. Poulsen (Eds.), *Perspectives on foreign and second language pedagogy* (pp. 191-200). Odense University Press.

Joshi, S. (2020). Virtual reality is going to change live events culture forever. *Vice*. Retrieved from https://www.vice.com/en_in/article/4aydzg/virtual-reality-is-going-to-change-live-events-culture-forever

Kallioniemi, P., Heimonen, T., Turunen, M., Hakulinen, J., Keskinen, T., Pihkala-Posti, L., & Raisamo, R. (2015). Collaborative navigation in virtual worlds: How gender and game experience influence user behavior. In *Proceedings of the 21st ACM Symposium on Virtual Reality Software and Technology*.

Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education*, *8*(1), 13-24.

Kimura, D. (2000). *Sex and cognition*. MIT Press.

Kraiger, K., Ford, J. K., & Salas, E. (1993). Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. *Journal of Applied Psychology*, *78*(2), 311-328.

Lajevardi, N., Narang, N. S., Marcus, N., & Ayres, P. (2017). Can mimicking gestures facilitate learning from instructional animations and static graphics? *Computers & Education, 110*, 64-76.

Lederman, D. (2020). Ideas for a fluid fall: Readers respond. *Inside Higher Ed*. Retrieved from https://www.insidehighered.com/digital-learning/article/2020/07/15/readers-offer-ideas-responding-fluid-fall-college-teaching-and

Levinson, A. J., Weaver, B., Garside, S., McGinn, H., & Norman, G. R. (2007). Virtual reality and brain anatomy: A randomised trial of e-learning instructional designs. *Medical Education, 41*(5), 495-501.

Lim, C. P., Nonis, D., & Hedberg, J. (2006). Gaming in a 3D multiuser virtual environment: Engaging students in science lessons. *British Journal of Educational Technology*, *37*(2), 211-231.

Lin, M. C., Tutwiler, M. S., & Chang, C. Y. (2011). Exploring the relationship between virtual learning environment preference, use, and learning outcomes in 10th grade earth science students. *Learning, Media and Technology*, *36*(4), 399-417.

Lin, M. C., Tutwiler, M. S., & Chang, C. Y. (2012). Gender bias in virtual learning environments: An exploratory study. *British Journal of Educational Technology*, *43*(2), E59-E63.

Liu, J. (2001). *Asian students' classroom communication patterns in U.S. universities: An emic perspective.* Greenwood Publishing Group.

Marsick, V. J., & Watkins, K. E. (1997). Lessons from informal and incidental learning. In J. Burgoyne & M. Reynolds (Eds.), *Management learning: Integrating perspectives in theory and practice* (pp. 295-311). Sage.

Marsick, V. J., & Watkins, K. E. (2001). Informal and incidental learning. *New Directions for Adult and Continuing Education*, *89*, 25-34.

Martens, J., & Antonenko, P. D. (2012). Narrowing gender-based performance gaps in virtual environment navigation. *Computers in Human Behavior, 28*(3), 809-819.

Marsick, V. J., & Watkins, K. (2015). *Informal and in the workplace*. Routledge.

McGivern, R. F., Huston, J. P., Byrd, D., King, T., Siegle, G. J., & Reilly, J. (1997). Sex differences in visual recognition memory: Support for a sex-related difference in attention in adults and children. *Brain and Cognition*, *34*(3), 323-336.

McGivern, R. F., Mutter, K. L., Anderson, J., Wideman, G., Bodnar, M., & Huston, P. J. (1998). Gender differences in incidental learning and visual recognition memory: Support for a sex difference in unconscious environmental awareness. *Personality and Individual Differences*, *25*(2), 223-232.

Mills, S., & Noyes, J. (1999). Virtual reality: An overview of user-related design issues. *Interacting with Computers*, *11*(4), 375-386.

Mohler, J. L. (2008). A review of spatial ability research. *The Engineering Design Graphics Journal, 72*(3), 19-30.

Morris, M. G., & Venkatesh, V. (2000). Age differences in technology adoption decisions: Implications for a changing work force. *Personnel Psychology*, *53*(2), 375-403.

Mystakidis, S., Berki, E., & Valtanen, J. P. (2021). Deep and meaningful e-learning with social virtual reality environments in higher education: A systematic literature review. *Applied Sciences, 11*(5).

Mudambi, S. M., & Schuff, D. (2010). What makes a helpful online review? A study of customer reviews on Amazon.com. *MIS Quarterly, 34*(1), 185-200.

Nadolny, L., Woolfrey, J., Pierlott, M., & Kahn, S. (2013). SciEthics interactive: Science and ethics learning in a virtual environment. *Educational Technology Research and Development*, *61*(6), 979-999.

Nah, F. F. H., & Eschenbrenner, B. (2016). Understanding gender differences in media perceptions of hedonic systems: A comparison of 2D versus 3D media. *Journal of Database Management, 27*(3), 23-37.

Naveh-Benjamin, M., Shing, Y. L., Kilb, A., Werkle-Bergner, M., Lindenberger, U., & Li, S. C. (2009). Adult age differences in memory for name-face associations: The effects of intentional and incidental learning. *Memory*, *17*(2), 220-232.

Nelson, B. C. (2007). Exploring the use of individualized, reflective guidance in an educational multi-user virtual environment. *Journal of Science Education and Technology*, *16*(1), 83-97.

New, J., Krasnow, M. M., Truxaw, D., & Gaulin, S. J. (2007). Spatial adaptations for plant foraging: Women excel and calories count. *Proceeding of the Royal Society B, 274*, 2679-2684.

Okutsu, M., DeLaurentis, D., Brophy, S., & Lambert, J. (2013). Teaching an aerospace engineering design course via virtual worlds: A comparative assessment of learning outcomes. *Computers & Education*, *60*(1), 288-298.

Pacheco-Cobos, L., Rosetti, M., Cuatianquiz, C., & Hudson, R. (2010). Sex differences in mushroom gathering: Men expend more energy to obtain equivalent benefits. *Evolution and Human Behavior*, *31*(4), 289-297.

Paraskeva, C., Koulieris, G. A., Coxon, M., & Mania, K. (2012). Gender differences in spatial awareness in immersive virtual environments: a preliminary investigation. In *Proceedings of the 11th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry*.

Park, C., & Kim, D. G. (2020). Exploring the roles of social presence and gender difference in online learning. *Decision Sciences Journal of Innovative Education, 18*(2), 291-312.

Pentland, B. T. (2003). Conceptualizing and measuring variety in the execution of organizational work processes. *Management Science*, *49*(7), 857-870.

Postma, A., Jager, G., Kessels, R. P., Koppeschaar, H. P., & van Honk, J. (2004). Sex differences for selective forms of spatial memory. *Brain and Cognition*, *54*(1), 24-34.

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2021). Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, *3*(3), 715-742.

Ramírez, J., Rico, M., Riofrío-Luzcando, D., Berrocal-Lobo, M., & de Antonio, A. (2018). Students' evaluation of a virtual world for procedural training in a tertiary-education course. *Journal of Educational Computing Research*, *56*(1), 23-47.

Reid, G. (2005). *Learning styles and inclusion*. Sage.

Richards, D., & Taylor, M. (2015). A comparison of learning gains when using a 2D simulation tool versus a 3D virtual world: An experiment to find the right representation involving the Marginal Value Theorem. *Computers & Education*, *86*, 157-171.

Rodríguez-Ardura, I., & Meseguer-Artola, A. (2019). Flow experiences in personalised e-learning environments and the role of gender and academic performance. *Interactive Learning Environments*, *29*(1), 59-82.

Ross, S. P., Skelton, R. W., & Mueller, S. C. (2006). Gender differences in spatial navigation in virtual space: implications when using virtual environments in instruction and assessment. *Virtual Reality, 10*(3-4), 175-184.

Sandstrom, N. J., Kaufman, J., & Huettel, S. A. (1998). Males and females use different distal cues in a virtual environment navigation task. *Cognitive Brain Research*, *6*(4), 351-360.

Sayeg-Sánchez, G., Rodríguez-Paz, M. X., & Valencia-Marquez, D. (2021). Guided learning sequences as an e-learning enhancer during COVID-19 emergency conditions. In Proceedings of the *ASEE Virtual Annual Conference.*

Schmidt, A. M., & Ford, J. K. (2003). Learning within a learner control training environment: The interactive effects of goal orientation and metacognitive instruction on learning outcomes. *Personnel Psychology*, *56*(2), 405-429.

Schroeder, R. (2008). Defining virtual worlds and virtual environments. *Journal of Virtual Worlds Research, 1*(1), 2-3.

Schugurensky, D. (2000). *The forms of informal learning: Towards a conceptualization of the field*. Center for the Study of Education and Work.

Scullion, J., Stansfieldil, M., & Baxterli, G. (2014). Gender differences in self-efficacy relating to collaborative learning in a 3D virtual world. In Proceedings of the *E-iED Conference.*

Sequeira, L. M., & Morgado, L. C. (2013). Virtual archaeology in second life and open simulator. *Journal of Virtual Worlds Research*, *6*(1).

Singh, R. P., Javaid, M., Kataria, R., Tyagi, M., Haleem, A., & Suman, R. (2020). Significant applications of virtual reality for COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 14*(4), 661-664.

Silverman, I., & Eals, M. (1992). Sex differences in spatial abilities: Evolutionary theory and data. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: evolutionary psychology and the generation of culture* (pp. 533-549). Oxford University Press.

Steiner, C. M., Kickmeier-Rust, M. D., & Albert, D. (2009). Little big difference: Gender aspects and gender-based adaptation in educational games. In *Proceedings of the International Conference on Technologies for E-Learning and Digital Entertainment* (LNCS vol. 5670, pp. 150-161). Springer.

Tarhini, A., Hone, K., & Liu, X. (2014). The effects of individual differences on e-learning users' behaviour in developing countries: A structural equation model. *Computers in Human Behavior*, *41*, 153-163.

Thomas, W., Boechler, P., deJong, E., Stroulia, E., & Delaney, M. (2012). Incidental learning and salience in virtual worlds. In *Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*.

Tlauka, M., Brolese, A., Pomeroy, D., & Hobbs, W. (2005). Gender differences in spatial knowledge acquired through simulated exploration of a virtual shopping centre. *Journal of Environmental Psychology*, *25*(1), 111-118.

Topu, F. B., & Goktas, Y. (2019). The effects of guided-unguided learning in 3D virtual environment on students' engagement and achievement. *Computers in Human Behavior*, *92*, 1-10.

Topu, F. B., Reisoğlu, İ., Yılmaz, T. K., & Göktaş, Y. (2018). Information retention's relationships with flow, presence and engagement in guided 3D virtual environments. *Education and Information Technologies*, *23*(4), 1621-1637.

Tseng, S. S. (2021). The influence of teacher annotations on student learning engagement and video watching behaviors. *International Journal of Educational Technology in Higher Education*, *18*(1), 1-17.

Tüzün, H., & Özdinç, F. (2016). The effects of 3D multi-user virtual environments on freshmen university students' conceptual and spatial learning and presence in departmental orientation. *Computers & Education, 94*, 228-240.

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: Can it facilitate? *International Journal of Human-Computer Studies, 57*(4), 247-262.

Udo, G. J., Bagchi, K. K., & Kirs, P. J. (2011). Using SERVQUAL to assess the quality of e-learning experience. *Computers in Human Behavior, 27*(3), 1272-1283.

van Asselen, M., Fritschy, E., & Postma, A. (2006). The influence of intentional and incidental learning on acquiring spatial knowledge during navigation. *Psychological Research*, *70*(2), 151-156.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*(2), 250-270.

Waller, D. (2000). Individual differences in spatial learning from computer-simulated environments. *Journal of Experimental Psychology: Applied*, *6*(4), 307-321.

Wiecha, J., Heyden, R., Sternthal, E., & Merialdi, M. (2010). Learning in a virtual world: Experience with using second life for medical education. *Journal of Medical Internet Research*, *12*(1).

Yang, L., Holtz, D., Jaffe, S., Suri, S., Sinha, S., Weston, J., Joyce, C., Shah, N., Sherman, K., Hecht, B., & Teevan, J. (2021). The effects of remote work on collaboration among information workers. *Nature Human Behaviour*, *6*, 43-54.

Yukselturk, E., & Bulut, S. (2009). Gender differences in self-regulated online learning environment. *Educational Technology & Society*, *12*(3), 12-22.

Zhang, H. (2013). Pedagogical challenges of spoken English learning in the Second Life virtual world: A case study. *British Journal of Educational Technology, 44*(2), 243-254.

About the Authors

Surinder Kahai is an Associate Professor and a Fellow at the Center for Leadership Studies at Binghamton University, State University of New York (SUNY). He has a program of research that spans over 30 years and attempts to understand how information and communication technologies mediate leadership, collaborative work, and learning. His work has been funded by the National Science Foundation and UNISYS. He has disseminated his research findings through numerous research papers, many of which have appeared in prestigious journals and have been presented at selective conferences. He has employed his research to coach many business leaders and university teachers about how IT can mediate what they do and influence their performance. He has earned numerous awards and honors for his teaching, including the statewide SUNY Chancellor's Award for Excellence in Teaching and his selection as one of the 50 Best Undergraduate Professors by Poets & Quants in 2020.

Rebecca Jestice is an Associate Professor and Director of the Business program at Earlham College in Richmond, Indiana. She received her PhD in Management with a concentration in Management Information Systems from Binghamton University. Her research centers on how virtual worlds can be used effectively in leadership development and education. She teaches courses in leadership, organizational change, and social entrepreneurship.

Rui Huang is a full time lecturer in the Department of Decision & Information Sciences at University of Massachusetts Dartmouth. She received her PhD in Business Administration with a concentration on Management Information Systems (MIS) from the University of Oklahoma. Prior to joining UMass Dartmouth, she was an Assistant Professor in MIS at Binghamton University. She focuses her research interests on emerging technologies, e-commerce, IT leadership and IT governance. She has published her work in top-tier academic journals such as *European Journal of Information Systems, Group & Organization Management*, and *International Journal of Information Management*. She has also presented papers at national and international conferences. Her teaching specializes in Introduction to MIS, IT strategy, ERP, systems analysis and design, project management, and database management.