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Social Processes of Learning in Virtual Reality

Handbook of Learning in Virtual Reality

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1 Introduction

Learning processes are often social. Whether in classrooms to study with peers or through role playing to develop social skills, learning in the presence of others offers many benefits, including a greater sense of companionship (Strohmann et al., 2023) and increased opportunities for collaborative learning activities (Laal & Ghodsi, 2012). Unsurprisingly, virtual reality (VR), with its ability to facilitate social interactions by immersing individuals in virtual environments, has garnered great interest for its potential to enhance learning across various social contexts.

In VR, it is possible to create realistic virtual classrooms and translate activities typically organized in physical classrooms into the virtual domain (Schroeder, 2001). Instead of interacting with peers and instructors in the same physical space, virtual classrooms can facilitate learning and social activities through embodied avatars and yield interactive virtual experiences similar to those in face-to-face ones (Maloney, Freeman, & Wohn, 2020; Smith & Neff, 2018). As in the case with face-to-face scenarios, learning can also take place in virtual social scenarios beyond the classroom setting. For example, many have built systems for simulating training scenarios to develop skills concerning social interactions (Park et al., 2011; Parsons & Mitchell, 2002) and safety awareness (Shi et al., 2018). Across these domains, it is common to see virtual avatars, which are characters controlled by humans, and virtual agents, which are controlled by computers. Oftentimes, these characters are used to augment learning processes, taking on the role of peer learners, instructors, and medical patients.

VR also offers benefits to researchers studying the social processes of learning. Notably, these benefits include the ability to leverage motion tracking data to enrich analyses of social dynamics (Williamson et al., 2021) and augment nonverbal behavior beyond what is possible in face-to-face interactions (Bailenson et al., 2006). These affordances enable researchers to explore how learning occurs in social contexts within VR and how to design social interactions to enhance the learning experience. The latter question is of particular interest, as organizing learning experiences in VR can yield undesirable effects that are often dependent on factors such as the behavior and appearance of virtual agents (Chang et al., 2019; Hasenbein et al., 2022), as well as the characteristics of the spatial context (Han et al., 2023).

In this chapter, we present evidence concerning how learning occurs in social processes in VR. We organize the chapter as follows. First, we provide a historical overview of VR research on the social processes of learning and highlight recent trends in technology influencing the types of empirical work currently being conducted. Then, we discuss four research themes related to social processes of learning, namely the roles of motivation and interest (Section 3.1), virtual agents (Section 3.2), learning in the presence of others (Section 3.3), and how collaboration facilitates learning through a constructivist perspective (Section 3.4). Within each theme, we present the theoretical context and synthesize its empirical evidence. Finally, we summarize trends, issues and future directions and conclude with a discussion on practical implications.

2 Historical Overview

Many early VR learning systems featured social components, such as allowing elementary students to collaborate in a garden tending task (Roussos et al., 1999) or helping students to interact with pedagogical agents teaching operation and maintenance skills (Rickel & Johnson, 1998). VR was regarded as an emerging tool for connecting multiple users by placing them into the same virtual environment and rendering the virtual space to each user from their own perspective. This allowed users to engage in group discussions (Monahan et al., 2008) and competition across teams (Roussos et al., 1999). To a certain degree, the growing interest in developing and studying these immersive networked systems paralleled the excitement surrounding video games and non-immersive virtual worlds such as Second Life (Kaplan & Haenlein, 2009). With VR holding the promise of higher levels of immersion and presence compared to non-immersive systems (Slater & Wilbur, 1997), scholars began studying how we can facilitate more realistic and enjoyable social interactions through this medium, and how this technology can be leveraged for educational purposes.

Another early use of immersive systems for learning was through interactions with virtual pedagogical agents (Rickel & Johnson, 1998). At the turn of the century, virtual agents were becoming more realistic and adaptive through advancements in avatar rendering and animations (Badler et al., 1999; Kalra et al., 1998), as well as in systems for understanding user input and determining appropriate avatar behavior (Badler, 1997; Rickel & Johnson, 1998). Now, with the capability of deploying virtual agents in immersive virtual environments, researchers were able to conduct more controlled studies as individuals could be exposed to identical stimuli in VR, and also work towards a better understanding of how virtual agents can facilitate learning. Though immersive virtual environments can prompt psychological processes similar to those in face-to-face scenarios (Blascovich et al., 2002), it was also important for researchers to identify the boundaries and nuances of how interactions with virtual beings may differ from real-world ones. Pedagogical agents are now possible, but how can we implement them to enhance the quality of learning experiences?

Fast forward to over twenty years later since some of the first systems were developed for learning in immersive social settings, advances in technology have continued to influence the types of research being conducted. With the introduction of commercially available VR headsets such as the Meta Quest series and more recently the Apple Vision Pro, users now have greater access to social and educational immersive content. This ease of access also facilitated the process of conducting VR studies remotely and at scale. Additionally, users were now able to use social VR platforms (e.g., VRChat, ENGAGE XR) to interact with others in customizable virtual spaces. This reduced the technical barrier for organizing educational activities and allowed learning processes to occur in settings falling beyond traditional classrooms. Finally, with the growing body of literature in artificial intelligence, particularly as it relates to behavior generation for virtual agents (e.g., Park et al., 2023), these agents continue to evolve, offering opportunities to support more complex social interactions for learning.

3 Theoretical Framework and Empirical Evidence

3.1 Honing Interest and Motivation

Interest and motivation are two crucial factors in the learning process. The early work of Hidi and Renninger (2006) introduced the four-phase model of interest development of learners. The model breaks down interest development into the initial stage of triggered interest, followed by maintained situational interest, then emerging self interest, and finally well-developed self interest. Honing and developing self interest is particularly important when learners interact with new technologies as the novelty effect of the experience can fade over time (Chen et al., 2016). In the case of VR, while its ability to allow users to embody different avatars and explore impossible spaces can instill awe, the technology’s long-term impact is crucially dependent on how well it can foster individual interests beyond initial curiosity. Such a problem is not unique to VR, and findings from computer-based virtual worlds for cultivating self interest have pointed to autonomy and competence (i.e., learning tasks with an optimal level of difficulty) as important factors to consider (Dede et al., 2005). Similarly, using virtual worlds for simulating scientific reasoning, Chen et al. (2016) identified three pathways for cultivating self-interest that could potentially apply to immersive settings: enhancing student autonomy, fostering a sense of relatedness, and supporting the growth of students' competencies.

VR presents opportunities to hone interest and motivation by addressing the factors of autonomy, relatedness, and competence. For one, practitioners can foster autonomy by facilitating collaborative activities where learners interact with virtual agents and unknown environments (Novick et al., 2019). The concept of relatedness, described as “the need to feel belongingness and connectedness with others” (Ryan & Deci, 2000), can be further developed through immersive social activities. These activities can enable students who may be physically apart to feel connected with one another in a manner resembling face-to-face interactions. Relatedly, another set of benefits to gathering virtually with others is what Smith (1992) referred to as “collective goods”, which include increased social network capital, knowledge capital, and communion. Lastly, personalized learning experiences, potentially aided by VR systems that can track users' real-time motion and physiological data, can help bolster individual learner’s sense of competence by tailoring experiences to their specific needs.

Prior research has examined the role of interest and motivation in VR learning scenarios, noting the medium’s efficacy and best practices. For example, in the work of Makransky et al. (2020), VR-based learning significantly increased students’ self-efficacy as well as interest in learning about laboratory safety as well as their self-efficacy, which was shown to be greater than when learning through a video. In a more recent study, Lin and Wang (2021) showed that VR is effective in eliciting intrinsic motivation, which refers to the willingness to take action given one’s interest in the topic. Cheng et al. (2023) later proposed an affection-oriented model for studying interests and curiosity and found that students’ sense of novelty, a construct closely linked to situational interest, mediated the relationship between curiosity and cognitive attitudinal learning. The authors further outlined practical implications for educators, for instance leveraging novel cognitive experiences to trigger situational interests and adopting self-regulation approaches to enhance epistemic curiosity. Despite the empirical evidence presented, there remains a need to develop theories that situate an individual's motivational processes in VR learning within the context of one’s cognitive, social, and affective processes (Mayer & Bailenson, 2024).

Crucially, individuals may also exhibit different social behaviors and levels of interest and motivation towards the learning experiences. For example, changes in student interests after immersive learning experiences can differ across gender (Makransky et al., 2020). Shy people may speak out more and well-mannered people are more likely to exhibit verbal aggression, a phenomena Dede (1995) credited to disinhibition in virtual settings. Additionally, since VR provides a venue to escape from reality, it is also possible for some individuals to perceive the technology not as a vehicle to learn and interact with others, but rather one where they can seek refuge in an oversimplified virtual world (Dede, 1995; Siricharoen, 2019). In such situations, individuals will not be as motivated or driven to learn and collaborate with others in the virtual spaces. It is also possible for users to become addicted to the medium (Barreda-Ángeles & Hartmann, 2022; Bojic et al., 2024), which may lead them to obsessively control their virtual environments and self-representations. This excessive focus on control can in turn also hinder their learning experiences. As such, it is necessary to design learning experiences that consider individual differences when fostering interest and motivation, while also mitigating the risks of escapism, negative disinhibition, and addiction.

3.2 Virtual Agents as Social Actors

A large body of work on VR learning involves virtual agents. These machine-based virtual agents are effective in part because individuals perceive and react to them similar to how they would to human beings. This phenomenon of humans anthropomorphizing information technologies is well-documented in both non-immersive and immersive settings (Nowak, 2017; Nowak & Biocca, 2003). In virtual environments, virtual agents can take on embodiments similar to virtual avatars that are controlled by other users, making them more difficult to distinguish from their human counterparts. Additionally, virtual agents' growing capabilities to produce human-like responses and display realistic nonverbal behaviors further diminishes the perceptual differences between machine- and human- controlled avatars. It is therefore not surprising that virtual agents have shown success in facilitating learning processes in VR.

One such use case lies in instantiating virtual agents as teachers. In the early work of Rickel and Johnson (1998), the authors introduced STEVE, a VR pedagogical agent for assisting students through task demonstrations, action explaining, and performance monitoring. Later works have built systems for other scenarios, for example deploying virtual instructors for delivering lectures using preset responses (Tsaramirsis et al., 2016) and using recorded motion from experts for task guidance (Huang et al., 2021; Thanyadit et al., 2022). Others have studied the benefits of guiding students through individual learning activities by simulating social interactions (Ravindran et al., 2019; Wang et al., 2023) and building virtual robots for guiding children with high-functioning autism through music lessons (Shahab et al., 2022).

Virtual agents can also simulate students for training teachers. Compared to non-interactive teaching where individuals explain concepts to non-present students, research has suggested that doing so towards an actual person can improve learning of the teacher (Hoogerheide et al., 2016). In Chiquet et al.' work (2023), the authors studied learning outcomes of individuals describing content of a studied text to virtual agents in VR. Results showed that for high-absorption individuals (i.e., those who can easily focus on sensory experiences and ignore external distractions), compared to teaching a virtual agent on a desktop screen, doing so in VR facilitates better learning. For low-absorption individuals, the authors found that instructing the individuals to imagine the virtual agent as a student can further improve learning outcomes. Teaching scenarios can also extend beyond dyadic interactions. Through a VR simulation of an experimental classroom, Dai et al. (2024) instantiated six conversational agents as virtual students using generative AI and evaluated how participants acting as teachers perceived and interacted with the system. Notably, the authors observed that the AI-powered agents were well received on dimensions of engagement, realism and humanlike, leveraged humor during social interactions, and prompted reflective teaching.

Beyond using virtual agents for enacting student-teacher interactions, agents are also used in social training scenarios. For one, virtual agents have been used to enact doctor-patient interactions (Lee et al., 2020). Evidence showed that VR simulations of a general practitioner's consultation room resulted in high place illusion and plausibility and can be used to simulate interactions for engaging with insistent patients (Pan et al., 2016). In a system developed by Ochs et al. (2017), doctors interacted with virtual patients and also replayed past interactions to improve communicative skills. Another body of literature concerns social skills training for children with conditions such as autism (Ke et al., 2022; Parsons & Mitchell, 2002) and schizophrenia (Park et al., 2011), and demonstrated that VR role-playing and social games can enhance social skills. That said, authors noted concerns on the generalization of learned skills to novel scenarios (Parsons & Mitchell, 2002), long-term impact (Ke et al., 2022), and greater benefits to conversational skills but not vocal and nonverbal skills when compared to non-VR interventions (Park et al., 2011).

Researchers have also studied the benefits of virtual agents in social skills training beyond the medical field. For example, Guimarães et al. (2020) studied the benefits of social skills training using a police interview scenario. In their task, participants interacted with a virtual suspect powered by modules responsible for dialogue generation, decision making, emotion modeling, and enactment of the avatar's verbal and nonverbal behaviors. Compared to participants who completed the training through a computer screen, those who used VR reported higher levels of social presence but no significant difference in the believability of the virtual agent.

When designing learning experiences, it is also important to consider how the representation of the avatar may influence the learning outcome (Chang et al., 2019; Makransky et al., 2019; Petersen et al., 2021). Notably, in a study of middle school students during a laboratory safety simulation guided by pedagogical agents, Makransky et al. (2019) found that girls exhibited better performance, retention, and transfer when guided by a female avatar. Male students, conversely, performed better on these three dimensions when guided by a character resembling a mechanical drone. Petersen et al. (2021) further examined how the appearance and behavior of pedagogical agents influence learning. In their work, the authors manipulated the behavioral and visual realism of a virtual museum guide and measured learning performance using a knowledge test based on the content of the exhibition. Results showed that the effects of the virtual agent on learning was dependent on the type of knowledge being queried: though a virtual agent might impede factual learning, they could enhance learning of conceptual information.

3.3 Learning in the Presence of Others

Moving away from interactions with virtual agents, one framework useful in categorizing virtual social interactions is the A3C framework, which was introduced by Jeong et al. (2017) to describe online knowledge communities. In it, the authors detail four categories of joint interactions: attendance, coordination, cooperation, and collaboration. The categories are distinguished along three dimensions: goals, processes, and outcomes. Together, the dimensions capture the level of shared responsibility within a social group. At one end of the spectrum, attendance describes the lowest degree of collective responsibilities. Individuals act independently but sometimes concurrently with others in the same virtual space, do not share goals, and output distinct outcomes that are accredited to specific individuals. Falling on the other end of the spectrum, collaboration emphasizes the shared aspect across the dimensions, where processes are shared to an extent such that identification of individual contributions is no longer possible. When collaborating, groups share a collective responsibility and a mutual understanding of their goals and outcomes. Groups form a shared identity (Anthony et al., 2009), which shapes individual behaviors in a way that overpowers individual interests.

Given these distinctions, we organize the remainder of section 3 as follows. In the rest of section 3.3, we review evidence on joint interactions involving lower levels of shared responsibilities (i.e., attendance, coordination, cooperation). In section 3.4, we present evidence on collaborative learning scenarios, with a particular emphasis on constructivist learning.

3.3.1 Learning at scale with joint interactions

One benefit to organizing learning experiences with largely independent interactions is the ability to facilitate individual learning processes at scale. In contrast to monitoring individual experiences one at a time which can be time-consuming and impractical in classroom settings, the assumption that individuals are acting independently and are not influenced by others allows researchers and practitioners to organize learning activities in groups of greater sizes.

For example, in the VR classroom study organized by Han et al. (2023), 137 university students participated in individual design activities across eight weeks in discussion sections with 2 to 11 members. During these activities, students gathered in their pre-assigned groups in a virtual environment and completed individual design tasks concurrently under the supervision of a teaching assistant. From a pedagogical perspective, supervising multiple students simultaneously through the same activity reduced the effort required of the teaching staff to monitor multiple individual VR sessions. Given the minimal interactions between the students, researchers were able to evaluate the designs created by students as separate responses (Study 1, Wang et al., 2024a). That said, as we discuss next, the presence of other users and limited resources in immersive environments can influence learning outcomes even during individual activities. It will be critical to develop effective individual learning activities at scale while mitigating unwanted influences from the presence of others, especially in light of logistical constraints on time, hardware, and teaching staff.

3.3.2 Individual learning in the presences of others

The mere presence of peers and instructors can influence individual learning experiences. When individuals perform better in the presence of others, it is referred to as social facilitation. The phenomenon of individuals performing worst in the presence of others is known as social inhibition. These concepts are well-studied both within and beyond the domain of VR (Bond & Titus, 1983; Hoyt et al., 2003; Study 1, Miller et al., 2019). In practice, VR literatures have predominantly studied these phenomena using virtual agents (for a review, see Sterna et al., 2019). In these studies, virtual agents enacted pre-programmed animations such as walking and idling (Study 1, Miller et al., 2019) and carried out subtle head motion and eye movement to simulate human-like behaviors (Hoyt et al., 2003). Researchers found that performance on simple tasks improves in the presence of a virtual human, and conversely that performance on difficult tasks worsens in the presence of a virtual human (Study 1, Miller et al., 2019; Park & Catrambone, 2007). Later scholars have suggested that the effect of social facilitation and inhibition is context-dependent, and that practitioners should consider factors such as the social realism of virtual agents (Strojny et al., 2020) and user arousal (Sterna et al., 2024).

Another line of work called for comparing virtual agents (i.e., computer-controlled characters) to virtual avatars (i.e., human-controlled characters) (Hoyt et al., 2003; Sterna et al., 2019). The early work by Hoyt et al. (2003) showed that compared to performing tasks alone or in the presence of a virtual agent, the effect of social inhibition is more salient when a user is in the presence of a virtual avatar. A possible explanation given by the authors is that virtual agents may be perceived as non-evaluative, particularly when compared to virtual avatars. The perception of virtual agents mattered, as the mere belief that a virtual agent is controlled by a human can influence learning performances (Okita et al., 2007). In a meta-analysis done by Fox et al. (2015), perceived avatars yield stronger social influence than perceived agents. While this may be the case, in line with Blascovich's (2002) model of social influence, the effects of virtual agents on learning outcomes can still be salient, particularly when they exhibit behaviors similar to those of a human.

For instance, in an evaluation of safety training using VR (Shi et al., 2018), participants who saw a virtual agent engaging in unsafe behaviors (i.e., falling from a plank) exhibited more mistakes and unsafe behaviors, subsequently impeding learning outcomes. In another example, Bailenson et al. (Experiment 4, 2008) found that populating a virtual classroom with virtual agents exemplifying ideal student behaviors, compared with those exemplifying distracting ones, improved individual recall of lecture materials. In the same experiment, results indicated a greater improvement when the virtual classroom was emptied, leaving only the student and the teacher. Recently, Hasenbein et al. (2022) evaluated how visualization style and performance-related behaviors for virtual avatars instantiated as peer learners influenced learning in a VR classroom. In their study, six-graders exhibited greater visual attention towards virtual peer learners with cartoonish appearances, compared to realistic ones. Students seeing cartoonish peer learners also reported greater levels of engagement. The study also found that the hand-raising ratio of virtual peer learners significantly influenced student's visual attention: "extreme" hand-raising conditions (i.e., 20% and 80%) yielded higher gaze centrality from students to their peers, while moderate hand-raising conditions (i.e., 35% and 65%) led to higher gaze centrality from students to the virtual teacher and screen.

How the presence of others influences learning outcomes holds implications for learning scenarios in immersive environments. Educators should consider these effects when evaluating performance in learning experiences, for example by controlling for the quantity, level of realism, and representation of other avatars and agents. When incorporating virtual agents and avatars into immersive learning environments, it is also important to consider how their social behaviors may influence the learning outcomes of individual users (Experiment 4, Bailenson et al., 2008; Hasenbein et al., 2022). As VR can be used to partition students into different virtual environments and hide other avatars, another opportunity lies in reducing the number of avatars in virtual spaces to mitigate the effects of social inhibition.

3.3.3 Leveraging VR to address limited resources

Beyond social scenarios with minimal joint interactions, examples of more complicated joint interactions are often characterized by their limited resources. When access to the limited resources differ between individuals, so can their experiences (Jeong et al., 2017). For instance, in discussions, turn-taking and speaking turns are regarded as a limited resource as not all students may be able to speak at the same time. Evidently, conversational patterns in immersive educational settings vary across groups and can be dominated by individual students (DeVeaux et al., 2023). For less vocal students, this imbalance can lead to poorer learning outcomes if they are evaluated solely based on their levels of participation.

Nonverbal behaviors such as eye contact can also be regarded as a limited resource. As eye contact is related to students' perceived levels of attention from instructors (Tan et al., 2019) and their level of compliance (Hamlet et al., 1984), differences in the amount of eye contact between students and instructors can be related to students' learning experiences. Research also showed that the limited resources of space, in particular the location in which students sit in virtual classrooms, can also influence individual learning outcomes (Experiments 2 and 3, Bailenson et al., 2008; McCall et al., 2009). Students sitting farther and in the periphery of the teacher's viewing perspective exhibited poorer learning outcomes (Experiments 2 and 3, Bailenson et al., 2008), and those sitting towards the front of the virtual classroom reported more positive impressions of the speaker (McCall et al., 2009).

As this research suggests, limited resources in virtual learning environments can lead to disparities in individual learning experiences. To this point, researchers have tapped into the medium itself for creative solutions. For example, prior work has addressed the issue of imbalances in gaze by prompting warning messages when students are not receiving enough gaze (Experiment 1, Bailenson et al., 2008) and encouraging self-reflections of gaze distributions through visualizing real-time gaze distributions (Yoo et al., 2024). Virtual interactions do not need to be constrained by the limitations imposed by face-to-face interactions, meaning that a teacher can look at multiple students at the same time (Beall et al., 2003), and all students can be seated at the front and center of virtual classrooms (Experiments 2 and 3, Bailenson et al., 2008). When students partake in immersive experiences individually, VR systems can further instantiate virtual agents as learning companions or co-learners (Experiment 4, Bailenson et al., 2008; Novick et al., 2019) and render past recorded interactions from students and teachers (Brůža et al., 2021; Yuan & Gao, 2023) to keep the students company.

3.4 Constructivist Perspective of Collaboration

Constructivism in the context of learning refers to the idea that knowledge is built through experiences, and that learners are actively forming understandings of the world, as opposed to passively acquiring them (Bada & Olusegun, 2015). Under this paradigm, the focus shifts away from teachers delivering learning materials, with constructivist classrooms featuring more interactive group work and students spending more time negotiating and collaborating with their peers. Through these processes, students are likely to derive frameworks for learning that are easily transferable to comparable scenarios.

Constructivist learning thrives in environments that foster interaction and collaboration, and virtual environments serve as a great medium for this purpose (Dede, 1995). For one, the technology enables students to work together in immersive spaces and explore new possibilities beyond what is possible in physical classrooms, for example collaboratively navigating through large and imaginative virtual spaces and creating three-dimensional designs. More formally, Makransky and Petersen's (2023) posits in the theory of immersive collaborative learning (TICOL) that four factors differentiate collaboration in immersive settings from those through traditional media: social presence, physical presence, body ownership, and agency. Under this framework, the authors argued that immersive experiences can leverage the four factors to improve social dynamics, and in turn influence learning outcomes within the context of computer-supported collaborative learning (CSCL). In practice, works in collaboration and VR have looked towards brainstorming (Pituxcoosuvarn et al., 2021), summarization (Petersen et al., 2023), and design activities (Wang et al., 2024a). These interactive experiences can also be tailored to specific domains such as construction safety education (Le et al., 2015) and ocean literacy learning (Queiroz et al., 2023).

Importantly, researchers have compared ways to facilitate constructivist learning in immersive settings. For example, Petersen et al. (2023) studied the effects of collaborative and generative learning activities using a VR lesson on the human bloodstream. They compared learning outcomes between participants engaged in either individual or collaborative generative learning tasks (e.g., summarizing lesson segments, creating cell representations) with those in a control group who did not participate in a learning activity. Results showed that participants in collaborative learning activities improved their factual, spatial, and conceptual knowledge compared to the control group. Conversely, those in the individual learning group only exhibited improved learning on spatial knowledge. This finding that collaboration and generative learning improves individual learning outcomes was further supported by the work of Queiroz et al. (2023). In a VR experience designed for ocean literary learning, participants exhibited better learning outcomes when they collaboratively created visual representations of learning materials using 3D objects compared to those who instead engaged in a discussion of the material in VR.

Taken together, this body of research underscores the potential of collaborative group work in enhancing learning outcomes. The unique features of VR, such as the ability to be immersed in rich and interactive spaces and create 3D designs, offer powerful tools to augment these collaborative processes. However, the effectiveness of such activities hinges on their thoughtful designs, as the structure of group tasks can significantly influence individual learning outcomes (Queiroz et al., 2023). Future research should continue to explore these dynamics, paying close attention to both individual- and group- level outcomes and considering the long-term impacts of immersive collaborative learning (Parsons, 2015; Petersen et al., 2023).

4 Research trends, issues, and future directions

One ongoing thread of research is that of asynchronous interactions. While the notion of asynchronous social interactions is not new to online learning (Hiltz & Wellman, 1997; Wegerif, 2019), its application to VR has been increasingly explored. In particular, researchers have studied ways to revisit past social interactions that preserve causality of co-dependent events (Fender & Holz, 2022), perceive social scenes as an added member to a previous group discussion (Wang et al., 2024b), and co-watch past social interactions in VR (Wang et al., 2020). Works have also developed authoring systems that allow practitioners to record and replay demonstrations in immersive learning settings (Huang et al., 2021; Thanyadit et al., 2022). In addition to the benefit of learning with peers and from teachers and experts at a time more convenient for the learner, reliving social interactions in VR can improve social presence, understanding of shared experiences, and instill a greater sense of fulfillment (Wang et al., 2020). Manipulations of recorded interactions have also been shown to improve social presence and perceived attention (Wang et al., 2024b).

Moving forward, scholars have suggested examining ethical considerations and privacy in asynchronous interactions (Fender & Holz, 2022; Wang et al., 2020; Wang et al., 2024b). With research on virtual pedagogical agents making use of generated and recorded behaviors, another avenue of research lies in instantiating virtual agents with different characteristics of behaviors and investigating how these agents influence learning outcomes.

In our discussion on virtual agents in Section 3.2, agents took on different roles in social settings to simulate human-like behaviors in learning companions (Novick et al., 2019), lecturers (Tsaramirsis et al., 2016), and students (Chiquet et al., 2023; Dai et al., 2024). Recent advances in large language models and generative agents (Park et al., 2023) had led to VR works utilizing models such as OpenAI's GPT models to build conversational agents for educational scenarios such as anatomy education (Chheang et al., 2024), teaching practice (Dai et al., 2024), and communication training (Liaw et al., 2023). As these conversational agents are now able to dynamically respond to user inquiry and handle more complicated social scenes (Xi et al., 2023), it is crucial to deepen our understanding of how these agents can facilitate learning and compare their performance to agents instantiated with pre-programmed social behaviors. Additionally, issues with hallucination (i.e., the generation of false or misleading information) and biases in large-language models are well-documented (Schramowski et al., 2022; Zhang et al., 2023). As such, works should also evaluate the impacts of virtual agents powered by large-language models in immersive learning scenarios and develop guidelines for mitigating these risks.

Another theme of ongoing research highlights the need for examining individual differences in learning outcomes. Past works have documented differences in learning experiences during joint activities (Roussos et al., 1999; Wang et al., 2017) and showed that the gender of the learners mattered in designing pedagogical agents (Makransky et al., 2019). Beyond learning scenarios, it is well-established that individuals differ in VR-related characteristics such as their sense of presence (Iachini et al., 2019), and propensity for experiencing simulator sickness (Howard & Van Zandt, 2021). As it becomes more convenient and accessible to socialize and learn in immersive settings, it is increasingly important for practitioners to consider how individual differences influence user behaviors and learning outcomes. Such differences can potentially impart greater disparity among learners when immersive systems become more adaptive and personalized to individual users (Cheng, Gebhardt, & Holz., 2023; Huang et al., 2021). Relatedly, another avenue of research lies in understanding learning in casual and spontaneous social settings, where greater variations in user demographics such as age and prior knowledge can also yield differences in learning outcomes.

Scholars have also advocated for research on longitudinal and remote VR usage for learning (Hill & du Preez, 2021; Khojasteh & Won, 2021; Liu et al., 2020; Liu et al., 2022). Weekly VR usage, specifically discussion sections across a 10-week university course, was found by Han et al. (2023) to increase group cohesion, presence, and enjoyment. In a related study on collaboration across five VR sessions between dyads, Khojasteh and Won (2021) reported no significant changes in presence over time, but increasing adaptation to the medium as well as novel forms of communication behaviors. These discrepant findings on the relationship between longitudinal use and presence underscore the need for a better understanding of the factors affecting social behaviors during longitudinal VR use. The physical locations of users is another relevant consideration in this context. Practically, though remote VR studies can offer a high level of control and replicability (Blascovich et al., 2002), the physical context of social groups can still influence social and nonverbal behavior (Han et al., 2024). As such, scholars should explore how interactions in remote VR settings differ from those in the laboratory.

Finally, another opportunity lies in leveraging commercial headsets and social VR platforms to conduct in-the-wild experiments, which could involve examining learning processes within social VR applications (Maloney et al., 2021; Maloney, Freeman, & Robb, 2020). Observed empirically in existing social VR platforms, there remain risks for harassment in these virtual interactions (Freeman et al., 2022), potentially exacerbated by disinhibition, anonymity, and a greater fluidity in identities in virtual environments (Dede, 1995). As argued by Dede (1995), disinhibition and fluidity of user identity may be viewed as an opportunity for facilitating learning processes beyond what is possible in the real world, where users feel empowered to explore and express their identities. At the same time, the same characteristics of virtual environments may also serve as precursors to addiction and escapism.

5. Practical implications and conclusions

In this chapter, we presented research on social processes of learning in VR. Specifically, we reviewed literature related to establishing and sustaining motivation and interest, virtual agents, learning in the presence of others, and learning through collaboration. The evidence overwhelmingly indicates that VR can be an effective tool for facilitating learning through social interactions, whether with virtual agents controlled by computers or avatars controlled by other users. However, the design of these immersive experiences (e.g., avatar behavior, presence of others) was often found to have varying effects on learning outcomes. There was also generally less evidence considering evaluations of group performance, with the majority of research focusing on analyzing learning outcomes from individuals as a unit of analysis. That said, further research on group dynamics and collective performance in immersive social scenarios is crucial, especially given their practical implications in cooperative and collaborative learning domains such as design and engineering contexts.

Our review highlights the need for further research on how different instantiations of social activities may influence learning outcomes. For practitioners and educators organizing learning activities in VR, it is important to understand how varying implementations of virtual characters combined with differences across individuals can both intentionally and unintentionally influence learning outcomes. Prior work has established the possibility of facilitating social interactions beyond what is possible in the physical world, and an ongoing question remains as to how we can continue to innovate to facilitate more effective learning experiences. Moving forward, it will be essential to investigate how existing frameworks and insights can be generalized to other paradigms such as asynchronous VR social interactions, AI-powered virtual agents, as well as personalized and adaptive learning. As social learning becomes more common across diverse immersive platforms including augmented reality systems (Bailenson et al., 2024), it will be crucial to continue advancing theoretical and empirical research and conduct longitudinal and large-scale evaluations to ensure deployment of meaningful, equitable, and effective VR learning experiences.

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