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Promoting Collaborative Learning through VR Technologies in the Era of COVID-19

Mengxi Zhou
dept. of Counseling and Educational Psychology
Indiana University Bloomington
Bloomington, USA
mz13@iu.edu

Faisal Kalota
dept. of Educational Technology, Research, and Assessment
Northern Illinois University
Dekalb, USA
fkalota1@niu.edu

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***Abstract*—Most governments have temporarily implemented school closures and urge individuals to remain in their homes as parts of practicing social distancing to contain the spread of coronavirus disease 2019 (COVID-19) infections. However, collaborative learning experiences are crucial to help students develop knowledge and social skills. Being informed by existing research and theories, this paper aims to explore the applications of virtual reality (VR) to promote collaborative learning and to share perspectives on the affordances and challenges of applying VR technologies in this pandemic.**

Keywords—virtual reality, COVID-19, social distancing, collaboration

I. Introduction

In response to coronavirus disease 2019 (COVID-19), most governments have temporarily closed educational institutions and have started to offer classes online. In online learning environments, students watch and learn through pre-recorded videos, games, and other online materials. Their interaction with their teachers and peers occurs through discussion boards, chats, audio-, video- conferencing as well as other synchronous and asynchronous communication technologies. Unfortunately, online education systems cannot fully replicate the classroom experience in certain instances. Students might miss opportunities to develop social skills, such as collaboration and communication, due to the lack of interaction with peers and instructors, caused by suspended social groups and disrupted daily routines [1]. Hence, strict social distancing and prolonged school closures may affect students' development of knowledge and social skills.

Social skills, such as collaboration and communication, are highlighted in all walks of life. For example, a study on United States ships found that people must work collaboratively and build on each other's expertise to pilot a ship [2]. Members of a medical team distributed decision making in hospital emergency rooms, as cited in [2]. A report from Oxford Economics [3] listed team and collaboration as the most desired human qualities by employers in future employees. Other top priorities, including relationship building, cultural sensitivity, and managing diverse employees, are also associated with collaboration and communication to some extent. Previous research has demonstrated an association between collaborative learning with collaboration and communication skills [4], [5]. As a result, collaborative learning has been an essential component of educational research and school reform [6], [7]. The advancement of technology has changed how students interact with peers and teachers. There are different tools that may be utilized for collaborative learning such as video conferencing tools, online games, Virtual Reality (VR), etc. Among these technologies, VR is one of the technologies that educators can utilize.

VR, a computer-generated virtual world or immersive multimedia, can simulate real physical experience or an imaginary world. VR technologies have been gaining attention in the education field because research results reported increased motivation, better learning outcomes, and long-term retention of students participating in VR simulation [8] - [10]. VR technologies provide a collaborative and multi-user virtual learning environment that allow students to interact with one another [11].

VR technologies allow students to achieve an interactive learning experience with the environments that may be challenging otherwise due to safety concerns and physical distance [12]. Therefore, VR can introduce many potential benefits for students in the era of social distancing. This would also include the promotion of collaborative learning skills. However, if VR isn't implemented properly, it can be counterproductive as well. As such, this paper aims to provide a survey on the integration of collaborative learning and VR as well as to share perspectives on the affordances and challenges of applying VR in this pandemic.

II. Collaborative Learning

Collaborative learning is defined as a joint effort of two or more students working together to achieve a shared learning goal [4], [6]. Jeong and Hmelo-Silver [6] differentiated collaborative learning from cooperative learning: the former involves participants' "joint and symmetrical engagement" towards a shared goal. In contrast, in cooperative learning, students usually work separately on a smaller portion of the ultimate shared task. However, there is a general agreement that there is a substantial overlap between the two terms, and it is

difficult to separate them in a real situation [4], [6], [13]. Although there is a distinction between collaborative learning and cooperative learning [6], in this paper, we view collaborative learning in VR activities as a group of students participating towards a shared goal.

The application of VR in education to promote collaboration is driven by the belief that learning happens when sharing meanings in social contexts [14]. Collaborative learning, wherein learners co-construct knowledge and develop understanding by building on each other's ideas, requires interdependency in which group members work together to make plans, organize activities, and solve problems [15]. In collaborative learning, learners are forced to articulate their positions and interpretations. Conflicts may arise when they are holding different opinions while working collaboratively. To resolve these conflicts, learners have to defend and justify their stances, which often requires reflection on their understandings [16], [17]. They must also think from multiple perspectives before deciding the most convincing interpretations. Therefore, peer interaction is essential an essential element to learning, particularly in learning ambiguous and complex concepts [11].

The instructional designers and developers should have a structured approach to guide and engage the learners in the collaborative learning process. Collaboration often may not occur in a vacuum; therefore, educators and instructional designers have to provide opportunities that can foster collaboration. One way to foster collaboration would be to use collaboration scripts [18]. Zhao and colleagues proposed the concept of collaboration scripts that constitute of basic four elements: task, sequence, role, and resources. Collaborative learning scripts allow educators to control the collaborative learning process by systematically guiding learners.

Similarly, Jeong and Hmelo-Silver [6] presented a framework of seven core affordances of technology for collaborative learning: 1) joint tasks, 2) communication, 3) resources sharing, 4) productive and collaborative learning processes, 5) co-construction, 6) monitor & regulate collaborative learning, and 7) build communities and groups. These affordances can also be incorporated in the VR learning environments to promote collaborative learning.

III. Virtual Reality

Virtual Environments (VEs) provide the illusion of presence in a place and time different from one's current physical surroundings and time. The goal of VR is to create an artificial experience that cannot be distinguished from the real experience. Such an experience allows the end-users to immerse within the VEs in real-time [19] and enables them to interact with other users in the distance. Social skills, including collaboration, are promoted through the direct experience and interaction, [20].

As technology improves, a variety of VR applications have emerged, such as immersive, tele-presence, mixed reality, and virtual worlds [21]. Users are completely immersed in the VE through a Head Mounted Display (HMD), which supports auditory and visual display of the virtual environment. Tele-presence uses systems to connect remote sensors to the sense of human operator; examples of tele-presence are teleconferencing and operating vehicles remotely. Mixed reality is a combination of tele-presence and VR systems, where users can experience a virtual world and control it through tele-presence. A virtual world is a digital space in which users can explore surroundings, interact with other objects and users. Users can choose an avatar to represent themselves and interact with other avatars and the environment.

IV. Virtual Reality and Collaborative Learning

Cutting edge advancements in hardware (CPU, GPU, etc.) and software have optimized the development and deployment process for VR and VLEs. These technological innovations have increased the opportunities to improve the quality of teaching and learning. Such technologies include but aren't limited to Learning Management Systems (LMS), virtual meeting tools, multimedia development tools, etc. VR and VLEs are among the many technologies that provide many learning opportunities including but not limited to social and collaborative learning skills. The potential of specific VR techniques to revolutionize education in terms of realizing collaborative learning has been identified in many studies [20], [22] - [26].

In the late 20th century, Churchill and Snowdon [22] published an introduction to a collaborative virtual environment (CVE) and explored how to achieve collaborative and cooperative activities in virtual environments by applying desktop-based systems from third-person perspectives. In the CVE, the participants were able to communicate synchronously, which provided more opportunities for interaction and collaboration.

Jackson and Fagan [20] believe peer collaboration is vital to student engagement in VLEs, particularly causal and comfortable conversations can enhance the learning experience and increase the sense of presence. They designed an immersive, multi-user VLE called Global Change World (GCW). The design and implementation of GCW are built on constructivism, which is summed up in two aspects: knowledge is developed through active construction rather than passive acquisition, and instruction is meant to support the construction process rather than merely delivering knowledge. The design of GCW embodies two design considerations from Jeong and Hmelo-Silver's [6] framework: a) it supports peer communication and b) interaction within the VLE. For example, students can communicate with their peers; instructors can monitor students' activities and guide them through various learning demonstration. Tasks, as one of the basic elements of collaborative script [18], are also embedded within the GCW design. Students have access to a virtual tool kit within GCW, which will be helpful for them to perform required tasks related to environmental research. The researchers found that GCW promoted peer collaboration and supported students abilities to co-construct theories as a result of the intellectual discussion within VLE.

Birchfield and Megowan-Romanowicz [23] designed a mixed-reality learning environment called SMALLab, which supports student interaction through gestures and 3D movements within a digitally mediated space. SMALLab was integrated into high school Geology classes, where students studied geologic evolution by collaboratively monitoring the

earth's movement and identifying patterns over time. The researchers reported significant achievement gains for students and positive impacts of mixed reality on collaborative learning. SMALLab's design had some of the design elements that were proposed in Jeong and Hmelo-Silver 's [6] framework and collaborative scripts by Zhao and colleagues [18]. For example, SMALLab encourages multiple participants to participate in shared educational activities, which resembles the joint task in Jeong and Hmelo-Silver's [6] framework. Additionally, the order of learning activities in SMALLab is consistent with timing arrangement (sequence) in collaborative scripts [18].

A recent research by Jensen [24] resonates with the emphasis on collaboration in previous studies, which documented the involvement of VR as a communication and collaborative tool to support students' lively discussion and synchronously being in the same space. The rules in the VR system were user-driven because they developed the rules of engagement to promote collaboration. This appears to be consistent with collaborative script [18] on the use of the collaborative scripts to promote active participation and collaboration, which suggested the design of tasks should ensure interdependent relationship among team members because this kind of relationship will promote active participation and productive collaboration. The task design is in the essence of participants' performance in VR activities. Therefore, a more deliberate and mature task can produce more effective performance outcomes.

Piumsomboon and colleagues [25] developed a Collaborative Virtual and Augmented Reality system (CoVAR), to support remote collaboration and interaction. CoVAR supports many interaction methods, such as gestures and eye gaze, and provides virtual cues to enhance the feeling of sharing the same space with a remote collaborator. CoVAR users in two different environments, Augment Reality (AR) and Augmented Virtuality (AV), share the local environment and to collaborate. They recommended that communication and interaction among end-users be aligned more closely with the task. This is also consistent with recommendations related to collaboration tasks in collaborative script [18]. This study further provides supporting evidence of VR as a tool to promote collaboration.

Shibata and colleagues [26] conducted a study to examine how to leverage 3D and VR techniques to improve education quality. They found that displaying educational materials in three-dimensional (3D) methods enabled students to better understand many of the concepts as opposed to learning the same concepts in a 2D space. Additionally, they found that VR promoted collaboration and learning-related discussions.

V. Challenges and Future Directions

With any technology, there are often certain challenges associated with its implementation and adoption. This section discusses some of these challenges and provides some recommendations for future research.

In a physical classroom environment, learners can interact with one another without any boundaries. However, in a virtual environment, the participants don't share the same physical location; hence there is additional consideration required to connect the learners. There is a need for a Networked VE that allows learners to be connected via the Internet. However, such environments also pose certain challenges that must be addressed. These challenges include but aren't limited to network connectivity, network security, and internet availability [19]. Unfortunately, many leaners are unable to access such technologies due to socioeconomic reasons. Sen and Tucker [27] described that there is still a lack of internet connection among poor and non-white children. In the face of school closures because of the COVID-19 pandemic, their empirical insights emphasized how the digital divide might exacerbate and reinforce existing inequalities in educational resources. Additionally, in most cases, a VLE requires VR kits consisting of mobile devices and VR headsets or goggles [28]. However, the purchase of such equipment will burden school and family budgets. Therefore, it is recommended that academic institutions, governments, and organizations should work together to provide appropriate technologies for the leaners.

Health concerns associated with virtual learning are prominent in previous studies. Participants of VLEs reported that they experienced cybersickness [29]-[31], physical discomfort [26], [28], and cognitive loss [28while utilizing HMDs. (HMDs). Cybersickness and physical discomfort can cause passive attitudes towards technology and lower learning outcomes [32], [33]. This indicated that designers and instructors must consider how educational materials can be displayed in VLEs [26] and provide a balance between the frame rate and authenticity of the simulated environment to provide a comfortable experience [34].

Some of the health concerns and usability concerns may be handled by conducting Usability Testing and User Experience (UX) studies. Usability is defined "as the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [35]. Usability testing focuses on the users' ability to carry out a task. Therefore, the designers and developers of VR and VLE must ensure that users, whether teachers or students, can use the environments effectively. Designers should develop VR and VLE by utilizing effective design and interaction principles. It's also essential to conduct UX studies. UX generally takes a "broader view, looking at the individual's entire interaction with the thing, as well as the thoughts, feelings, and perceptions that result from that interaction" [36]. With UX studies, one may also uncover discomfort, health, and other possible issues that may impact the adoption of such environments. Additionally, the usability testing and UX research would provide opportunities for the developers and educators to find alternate solutions, if such environments may not be suitable under given conditions.

COVID-19 has changed the norms of society. However, government bodies, organizations, and people can work collaboratively to minimize the impact of such pandemics. Many skills are critical for children to learn, and collaboration is one of them. Likewise, many tools and technologies can promote the notion of collaborative learning, and VR and VLE are one of them as well. While VR and VLE may not be the optimal solution in certain instances, it may be an excellent technique to improve the teaching and learning process in other instances.

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