EPiC Series in Built Environment
Volume 2, 2021, Pages 469–477
ASC 2021. 57th Annual Associated Schools of Construction International Conference

Potentials of Virtual Social Spaces for Construction Education

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The reality of COVID-19 public health concerns and increasing demand for distance education have forced educators to move to online delivery of their courses. Particularly in construction education, the majority of physical location-based educational activities (e.g., labs, site visits, or field trips) have been canceled during the pandemic that results in reducing students' engagement, learning motivation, and cognitive achievement. Virtual Social Spaces (VSS) with innovative interaction affordances and immersive experience are well poised to supplement current online construction education. This paper discusses the potentials of VSS for construction education while focusing on the common applications of VSS, the communication and collaboration affordances of VSS, and design principles of this technology based on 15 popular VSS platforms. Overall, VSS applications are mainly found in education, entertainment, and socializing. The main communication and collaboration affordances of VSS include avatars, multi-user support, asynchronous commenting, synchronous chat, and visual-sharing affordances. These technical features illustrate the potentials of VSS for improving online construction education quality, eliminating the challenges associated with geographical dispersion of students, and decreasing the students' lack of engagement.

Keywords: Virtual Social Space, Construction Education, Communication, Collaboration, Immersive Experience.

Introduction

In academic learning, communication and collaboration are essential components to transmit required information and knowledge between students-students, students-instructors. Generally, the majority of information delivery methods of learning communities include face-to-face instruction and online computer-media communication tools such as video conferencing (via Zoom, Skype), E-mail, and voice mail (Denis McQuail 2010). As the reality of COVID-19 public health concerns have forced that the majority of face-to-face interactive communication was moved to online computer-media communication. The traditional video conferencing platforms lack eye contact, less sense of co-presence, and inflexible communication types resulting in a lack of emotional engagement of students with the learning content, a greater feeling of isolation, and less learning motivation cognitive achievement (Pellas et al. 2017). For example, despite that students can participate in synchronous online classes via Zoom, multiple discussion groups in one room cannot be accomplished. Instructors have to create a break-out room for each group that causes the deficiency of synchronous group-group communication. Moreover, although Zoom allows users to use camera-sharing, most students are reluctant to turn on the camera because of privacy concerns. The lack of facial expression and eye contact during online courses means instructors cannot obtain real-time feedback from students and fail to improve their engagement with students.

Virtual Social Spaces (VSS) is a digital world where multiple people can interact in real-time with network-based simulated environments (Girvan 2018). VSS provides embodied spatial interaction through customized avatars and customized virtual spaces, and multiple communication tools to solve the communication and collaboration deficiency of traditional learning systems. Communication is typically defined as the transmission of resources through shared media and symbols among different parties (Cheng et al. 2001). Collaboration enables multiple parties to complete a set of tasks by using available resources wisely, sharing the multiple project risk factors across multiple domains, and eliminating fragmentation, duplication, and distrust. (Shelbourn et al. 2007). According to the recent survey, there are more than 500 active virtual worlds in the current marketing, such as the open-source virtual worlds (e.g., Open Simulator), and the combination with virtual reality simulation and compatible and immersion devices (e.g., Second Life, VRChat, Mozilla Hubs) (Griol et al. 2019).

Aim and Methods

This paper aims to explore the potentials of VSS for construction education. It leads to the following objectives: providing a comprehensive overview of VSS application areas in the literature, reviewing the popular VSS platforms currently available on the market, and finally discussing the potentials of VSS for construction education. The study applies a content analysis-based literature review to analyze the VSS-related publications in the last 20 years. To identify the related literature, several keywords were used for searching various research databases. “Virtual Social Space” or “Virtual Learning Space” were used to ensure the publications were applying the VSS technology in their studies. Several strings of other keywords were also used to better identify the related publications, including “construction education”, “collaboration”, “immersive experience”, “multi-user”, and “avatar”. In addition to the literature review, this paper reviews multiple VSS platforms based on their application purposes. This paper reviews 15 popular VSS platforms with high active users that have been previously used in at least two or more general application areas identified in the literature. Finally, some discussions will be provided on the potentials of VSS construction education applications. The outcome of this review would be a practical resource to guide educators and researchers to recognize the potentials of VSS for construction education.

Common Application Areas of Virtual Social Spaces

The Virtual Social Space (VSS) is a persistent 3D environment where users co-exist through their avatars to explore, build, interact, and communicate in the shared virtual space. A variety of other terms are used in the literature to label a virtual social space (VSS), such as virtual world (Girvan 2018) (Koutsabasis et al. 2012), collaborative virtual environment (Koutsabasis et al. 2012), multi-user environment (Pellas et al. 2017), virtual learning environment (Dillenbourg et al. 2002), 3D virtual environment(Dalgarno and Lee 2010). The two critical components of VSS are virtual and space. The virtual element for VSS is also represented as Virtual Reality (VR). VR illustrates a simulation-related characteristic that provides a semi-real experience of reality. In such a simulated experience, the virtual objects are perceived to exist but lack physical properties beyond the user interface (Girvan 2018). The space component in VSS has three key characteristics: (1) it is a shared environment where users can move around, (2) user experience in such a shared environment are mediated through psychological responses and physical bodies, and (3) user can construct a world with shared understanding through interaction with others (Girvan 2018). In order to satisfy these virtual and space requirements of the VSS, the following technical features are required: (1) sense of co-presence, (2) user embodiment/representations, (3) multiple communication methods, and (4) real-time simulation of interactive artifacts. With the advancement of computers' graphics processing capabilities and network bandwidth (Patel and Sakadasariya 2018), VSS is becoming widely popular in education, entertainment, and socialization.

An early design and structure of VSS are proposed to support distance education in the IT Management program(Nunes et al. 2002). The essential components of the early VSS included 'a personal portraits gallery', 'a chat room', 'a social calendar', 'a course news section', 'a useful contacts section', and 'an alumni section'(Nunes et al. 2002). The platform allowed students to obtain practical and administrative information relating to their studies and supported students with social networks. However, the early VSS failed in education since the limited popularity and insufficient integration of learning content (Mcpherson and Nunes 2004). To improve VSS usability in education, researchers pointed out education-related VSS should mainly concentrate on how people learn within VSS and how features relate to effective learning (Choi and Baek 2011). VictoryXR built the most extensive digital twin virtual reality campus on the Engage platform (Grubbs 2020). The digital twin campus allows for live instructors and real-time interacting in classes as if they are learning in the physical classroom and provides effective teaching methods impossible to accomplish in the real world for a specific major. For instance, the virtual class can dissect virtual animals without incurring the cost of real frogs or mice in the biology class (Grubbs 2020). The virtual biological class reduces the financial burden and use of animals during the primary practice process.

VSS also supports entertainment, such as gaming and music. In the virtual gaming world, users can communicate with other players by voice and message and present as a character. A virtual collaborative game was proposed as social skill training to enhance the social interaction practice of high-functioning autistic children (Ke and Moon 2018). Researchers implemented OpenSimulator to construct 3D virtual environments related to competition-themed social gaming, role-play gaming, and design-themed architectural gaming (Ke and Moon 2018). In addition to gaming applications, VSS also are used in the music field. For example, Sansar is currently one of the most popular 3D virtual music spaces. Users in Sansar can see their favorite artists without traveling to their shows and create their own virtual spaces to meet their friends or play parties.

The main factor of VSS on socializing is a pleasant environment for social interaction and communication. To develop VSS applications in socializing, the researchers pointed out the significant effects on users' continuous use of VSS on socializing are hedonic outcomes and social presence (Mäntymäki and Riemer 2014). Hedonic outcomes' definition on socializing of VSS was "the extent to which using the VSS is perceived enjoyable in its own right" (Deci and Ryan 2000). Social presence is "the degree of human warmth associated with the VSS" (Yoo and Alavi 2001). In order to stimulate users' high hedonic outcomes and social presence, innovative communication tools and virtual reality technology are implemented to attract more users to construct their social network in VSS. For example, VTime is a popular social-orientated VSS. Users can assess VTime to communicate with their friends using avatar in a virtual environment. Participants can choose an appropriate virtual environment to process a simple and effective social activity based on the type of social event, such as classroom, conference room, and lecture.

Communication and Collaboration Affordances of Virtual Social Spaces

Traditional online communication platforms involve less sense of co-presence, inflexible communication tools, and a lack of real-time interaction that results in inefficient collaboration among multiple parties. Compared with traditional online communication platforms, VSS provides a more innovatively interactive experience, such as avatar, multi-user capabilities, asynchronous and synchronous chat, voice chat, and visual-sharing affordances. Participants who work in VSS obtain the sense of co-presence and flexible communication methods that lead to active engagement and high cognitive achievement, and high-efficiency collaboration.

Avatar, as a 3D embodiment of users, represents their identity and position in VSS. From the perspective of self-disclosure and interpersonal socializing, an attractive avatar leads to more intimate and persuasive behavior. For example, a study of the influence of avatars on online consumer shopping behavior shows that an attractive avatar can enhance the effectiveness of a Web-based sales channel and make the avatar more persuasive for specific shoppers (Holzwarth, Janiszewski, and Neumann 2006). Besides, since physical isolation and the anonymity of the VSS users, the avatar may significantly influence users' digital representation and rationalize their behavior consistent with the avatar's identity (Guegan et al. 2016). Thereby, in most VSS, users can choose or customize the avatars that look like them or present certain aspects of their ideal self. Due to the self-representing of avatars, VSS is a friendly virtual platform for the disabled who lack social activities in the physical world because of travel inconvenience and fear of face-to-face communication. Avatars in VSS can also display real-time emotional responses to enhance interaction with others in learning or social activities through various gestures and emotional symbols. During virtual events, users control their avatars to traverse the virtual space through the controller or the keyboard.

VSS allows multi-users to present in the same spatial location and realize synchronous communication and collaboration. To users can be within the VSS in the same way, they need to connect to a central server through a client on their computer. In addition to multi-user capabilities, VSS is social scalability that allows users to create variable group sizes depending on the different scale requirements of virtual activities (Scavarelli, Arya, and Teather 2019b). For instance, the educational researcher pointed out the educational methodologies that focus on integrating collaborative activities and individual accountability to enhance academic achievement (Scavarelli, Arya, and Teather 2019a). Thereby, social scalability is a design consideration for VSS.

Asynchronous commenting function occurs in delayed time and does not require simultaneous participation (Genevieve and Johnson 2004). For instance, Mozilla Hubs allow users to leave offline messages in virtual space, and other users can review them at different times. Nevertheless, asynchronous commenting lacks immediacy. It indicates that asynchronous commenting might not suitable for the projects or activities that need to be completed promptly. Synchronous chat means that participants can immediately send an immediately private or public message to realize efficient communication, which reduces coordination latency and avoids misunderstanding among multiple parties. For instance, Geollery allows users to chat with each other through text bubbles when two participants virtually meet (Du, Li, and Varshney 2019). Voice chat belongs to a type of synchronous communication. The communication method can real-time transfer voice messages to avoid the lack of mutual understanding in telecommunication. For example, Altspace allows users to voice chat in interpersonal meetings or team meetings, and the intensity of the sound varies as it travels, depending on the distance (Patel and Sakadasariya 2018).
To achieve efficient collaboration based on a unit of "team", in addition to text and voice chat, VSS also includes some visual-sharing affordances, such as the upload of media and symbols or the design of shared space. The visual-sharing affordances may occur between groups of people with different

skills, knowledge, and abilities to share their telecommunication work. For example, Mozilla Hubs allow users to share images/videos/webpages and carry out tasks on a whiteboard without meeting up at a physical location.

Virtual Social Space Platforms

The general design framework for VSS typically includes communication and collaboration affordances and hardware technology. Based on the application's purpose, VSS platforms can be divided into general-purpose (social chat, games), art/media consumption, music performance, education, and business/remote teamwork (Ryan Schultz 2020). Depending on the different application purposes, the design principles of VSS vary slightly. This paper selects 15 popular VSS platforms with high active users and at least two purposes for analyzing the general design principles.

Communication and Collaboration Affordances

VSS's most commonly identified features include avatars, multi-user capability, communication tools, and visual presentations. In the 15 VSS platforms, in addition to iSee VC that is the only platform using a virtual camera as an avatar; most VSS with virtual avatar provide avatar gestures, including eye contact, body movement, and facial expression, to increase users' social presence (Wen and Gheisari 2020). In order to achieve efficient interaction, the involved features consist of multi-user scalability and specific types of communication elements. All 15 VSS allow multi-user capabilities and provide voice chat and the text-based tool to support oral and listening communication. Besides, some VSS enable users to draw and bring their existing media and media streaming platforms into VSS to share with others. Table 1 shows 15 Virtual Social Spaces and their communication and collaboration affordances.

Table 1

Communication and collaboration affordances in Virtual Social Spaces

VSS	Avatars		Multi-user capabilities	Communication tools		Visual-Sharing Affordances	
	User embodiment	User gestures		Voice Chat	Text-based tool	Shared files	Shared drawings
Vtime XR	X	X	X	X	X	X	
AltspaceVR	X	X	X	X	X	X	
Anyland	X	X	X	X	X		X
VRChat	X	X	X	X	X		X
RecRoom	X	X	X	X	X		
Virbela	X	X	X	X	X	X	
Mozilla Hubs	X	X	X	X	X	X	X
Engage	X	X	X	X	X	X	X
Second Life	X	X	X	X	X	X	X
Rumii	X	X	X	X	X	X	X
iSee VC	X		X	X	X	X	
SanSar	X	X	X	X	X		
NeosVR	X	X	X	X	X	X	
JanusVR	X	X	X	X	X	X	

Spatial	X	X	X	X	X	X	X

Hardware Technology

The section introduces the hardware requirements used to support VSS for communication and collaboration purposes. The hardware includes input and output devices that enable users to interact within VSS. Input hardware mainly concentrates on receiving user commands. The standard input hardware consists of the keyboard, mouse, controller, or joystick, whereas more advanced input hardware is sensor gloves and motion sensors that can display more precise users' movement and gestures (Howard 2019). The output hardware displays relevant visual information, for example, the digital environment and the results of users' actions. Promising output technologies can improve fidelity, immersion, and sense-of-presence in VSS (Kihara et al. 2012). The standard output hardware in VSS includes desktop, head-mounted display (HMD), and mobile phone.

Table 2

Hardware Requirements in Virtual Social Spaces

VSS	Hardware				
	Output			Input	
	Computer Screen	HMD	Mobile Phone	Keyboard/Mouse	Game Controller/Joystick
Vtime XR		X	X		X
AltspaceVR	X	X		X	X
Anyland	X	X		X	X
VRChat	X	X		X	X
RecRoom	X	X	X	X	X
Virbela Campus	X	X		X	X
Mozilla Hubs	X	X	X	X	X
Engage	X	X	X	X	X
Second life	X	X		X	X
Rumii	X	X	X	X	X
iSee VC	X			X	
SanSar	X	X	X	X	X
NeosVR	X	X	X	X	X
JanusVR	X	X		X	X
Spatial	X	X	X	X	X

VSS Potentials for Construction Education and Training Applications

Students in construction programs learn to analyze the design and plan for construction projects by reviewing 2D/3D drawings, developing cost estimates, and construction safety management; thus, effective communication and safe jobsite visits are crucial for these construction students. However, several limitations appear in traditional construction courses: (1) failure to display physical environment due to the limited spatial capacity and conflicted class schedule; (2) the physical space with a risk of injury for participants; (3) 2D drawings limit students' understanding in building plan and schedule. (Azhar, Kim, and Salman 2018). In order to solve these limitations, previous research applied VR technology to bring students within a simulated environment where students can learn with a 3D/4D full-scale virtual construction model. For example, a VR-based safety game allowed students to learn different hazards in construction jobsite without the need to be on the actual jobsite. Students could walk through the virtual environment and identify the possible hazards (Azhar et al. 2018). Due to the advantages of VR technology, VSS integrates the VR technology to help students gain a sense of being on a construction job site and interact with various objects on the site in a safe and consequence-free environment. Le, Pedro, and Park (2015) developed a collaborative virtual reality-based construction safety education using Second Life 3D virtual world platform. Students in the 3D virtual environment could perform role-playing and collaborative learning to practice hazard inspection and recognize the root causes of construction site accidents. The study's result showed that the social VR environment supports engagement and has great potentials to enhance construction experiential learning.

In addition to the immersive experience and innovative 3D simulation, VSS integrates communication and collaboration affordances to contribute to successful construction education. Effective communication among construction professionals can improve project quality. At many construction schools, communication skills typically are taught and assessed by having students write documents and perform oral presentations to instructors and their classmates. The limitations of providing such communication skills within the regular classroom settings have further broadened recently, as the reality of the COVID-19 public health concerns has forced most natural face-to-face interactive communication opportunities to be stopped. However, the VSS's communication and collaboration affordances help construction educators resolve the limitations. Instructors and students in VSS obtain various communication methods from interpersonal communication to a group or team communication. VSS enables instructors to share knowledge with students by 3D objects, uploads of media, and drawings. For example, Ku and Mahabaleshwarkar (2011) indicated that 3D data-rich models in the construction industry are fragmented and there are limited real-time communication because of geographical dispersion and lack of modeling skills. The study proposed a building interactive modeling in VSS for construction education to enhance student's collaborative skills by role-playing and knowledge-sharing. The study's result showed the potentials of VSS to address the traditional communication issues in the construction industry and effectively complement traditional teaching approaches to enhance construction education.

The majority of VSS platforms provide free versions, which does not imply any cost for the developers or users. For example, Mozilla Hubs offers a unique and flexible environment where simple 3D models can be imported into the VSS, and users can explore it through a web browser. However, the paid version of the VSS platforms should be used for creating large community-scale environments or richer media content. Also, hardware cost and type are another factor that should be considered when selecting a specific VSS platform. VSS platforms might allow users to access their environment only through particular devices, such as HMDs, computers, or smartphones.

Conclusion

This paper presents a comprehensive review of VSS. The uniquely technical advantages of VSS sufficiently support education, entertainment, and online socializing. To explore the design principles of VSS, the paper investigates 15 popular VSS and outlines their communication and collaboration affordances and hardware requirements. The general communication and collaboration affordances include "avatar", multi-user capabilities, asynchronous commenting, synchronous chat, voice chat, and visual-sharing affordances. The research outcome can be a practical resource to guide construction educators and researchers to recognize the potentials of VSS for improving construction educational quality, eliminating geographical dispersion, and decreasing the students' lack of engagement. The main limitation of this research is using a manual search process in literature identification which lead to a relatively subjective selection and analysis of VSS-related papers and platforms. Another limitation is the limited number of investigated VSS platforms. It would be beneficial to explore a larger sample of VSS platforms further to better understand their capabilities and technical features for educational applications. The research found that existing research on VSS in construction education is limited, showing a research gap for further exploration. Additionally, an in-depth analysis of VSS technical implementation and challenges may contribute to a better understanding of VSS capabilities for various educational applications in construction. Further research needs to be conducted to pursue applications of VSS for various construction-related assignments, projects, labs, site visits, competitions, or even regular delivery of courses.

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