A Networked Social Virtual Reality Learning Environment Platform for Special Education

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Abstract—Delivering curriculum using desktop-based virtual learning environment (VLE) technologies in a collaborative group setting has been shown to reduce the social skill limitations of students with learning disabilities. However, the lack of the immersiveness and effective generalization of acquiring knowledge and skills among students remains a critical challenge in the interactive tools used in current VLEs. In this paper, we present a networked social virtual reality learning environment (VRLE) system viz., vSocial that has been redesigned based on iterative user feedback and developed in order to leverage the latest advances in integration of smart devices such as VR headsets for virtual content delivery. We describe a comparative study to evaluate technology trade-offs in the development process of transitioning from a VLE to a VRLE, from both technological and user (e.g., student/instructor) perspectives. Lastly, we outline open issues in using VRLEs which include: system complexity, emotion recognition, cybersickness and system sustainability.

Index Terms—Networked Virtual Reality, Multimedia and Real-time Communication, Learning Environment, IoT

I. INTRODUCTION

There are many challenges in the development of special education programs for youth with Autism Spectrum Disorder (ASD) to help them understand the basic rules of the social engagement. Students on the autism spectrum often have trouble in this area of social competence as they lack the knowledge of identifying the social cues among their peers. Delivering a robust and effective curriculum relies on the type of learning environment that promotes transferrable skills in real-world scenarios [1]. Hence, there is a need to deliver a curriculum using interactive learning environments that can help in reducing students’ social skills limitations.

Prior studies have sought to train ASD students through a social skills enhancing curriculum using desktop-based virtual learning environment (VLE) technologies. Authors in [2] aim to improve the social reciprocal learning in students with autism through a collaborative VLE which includes a 3D expressive avatar representing the students, animated social situation pictures and a text-to-text communication feature. Specific VLE technologies such as Face3D [3] have been developed to promote empathy as well as to demonstrate the relation between the emotional and social behaviors of youth with ASD.

Specifically, in our prior work from [1] we designed a Social Competence Intervention (SCI) [4] Curriculum to enhance the social competence needs in adolescents in the high-functioning autism spectrum. Our aim was to provide a desktop-based content delivery medium viz., iSocial that can render an interactive virtual environment for the students with learning impediments to improve their social competency. The iSocial VLE supports a practice of social competence for individuals with ASD through an online virtual learning environment in a face-to-face small-group setting. Students advance through learning modules and activities provided by the SCI curriculum with the intent to build up their social skills and apply them in a real-world setting. This interactive technology is a viable way to show the potential in which a student can increase in areas of their social competence. Despite its upside, such technological capabilities only allow insubstantial evidence of acquiring knowledge and social skills for youth students with ASD. Current VLE technologies such as iSocial are limited i.e., they lack the immersiveness of a real-world environment during user interactions and reduce the overall user experience [1]. In addition, personalized avatars inadequately represent a student’s movement, which leads to a decrease in user engagement.

In this paper, we address these limitations of the iSocial VLE by developing a novel networked social virtual reality learning environment (VRLE), viz. vSocial. The main innovation in vSocial is the fact that it integrates immersive virtual reality (VR) and smart devices (e.g., wearable sensors, head-up displays) technologies that offer promising opportunities for SCI curriculum delivery in special education. In our exemplar VRLE system i.e., vSocial, the core underlying technology is the High Fidelity [5] “social VR” platform, which is an open source environment tool capable of running 3D applications in the “Desktop” and “VR” modes. The desktop mode is similar to a VLE experience and involves manipulation of personalized avatars and navigation control through a keyboard and mouse. Conversely, the VR mode supports the use of head-mounted displays (HMDs) and hand-held controllers such as HTC Vive [6] and Oculus Rift [7] for easy navigation control.

VR technologies within a high-speed, low-latency cloud platform for improved system integration and wide-connectivity to geographically distributed students and instructors, such setup could deliver advanced features such as immersive rendering, flexible curriculum control, and session progress tracking of students as detailed in [8]. Moreover, vSocial supports rigorous training modules for students to
learn and apply recognizing facial expressions, sharing ideas, and practicing their conversational skills to ensure viable growth in their cognitive and communicative abilities. The immersive environments created by VRLEs have been shown to have the potential to better engage users than a typical desktop-based VLE system [9]. Despite the previous works on immersive VR-based application development for students with autism such as vSocial, there is a lack of prior works that provide an in-depth comparison of the developmental trade-offs when transferring from a VLE (iSocial) to a VRLE (vSocial) to integrate the learning components in the SCI curriculum.

As part of a comparative study contribution of this work, we detail the limitations and describe the challenges as well as opportunities in the technical transition from the existing VLE i.e., iSocial setup to our proposed VRLE i.e., vSocial setup for ultimately enhancing special education for youth with ASD. Specifically, we describe, in depth, the technical transition process that we experienced in developing a VRLE, starting from an existing VLE application. Table I summarizes the transition process and lists the trade-off aspects from both a technical as well as a user (e.g., student/instructor) perspective. As part of this study, we consider our target audience to be students with high functioning autism between the ages of 11-14 as considered in [1]. The goal of this comparative study is to reflect on the technology trade-offs while utilizing immersive virtual reality technology for delivery of the SCI curriculum by instructors, and for students to engage and enjoy their learning experiences. While VRLEs improve create a tangible learning environment to provide users with a near-realistic experience, providing a near-realistic experience within a VRLE creates a trade-off in equipment in terms of VR hardware, strong graphics processing unit (GPU) and enough physical space to allow end-users to navigate within the VR space accordingly. Hence, we demonstrate these trade-offs through three essential aspects: the curriculum, functionality, and system requirements needed to operate a fully-functional VRLE.

The rest of the paper is organized as follows: In Section II, we present a literature review and discuss existing virtual applications for education, as well as methods for evaluating the usefulness of these applications. Section III details the design considerations and limitations of the iSocial VLE and methodologies used for vSocial development. Section IV describes the technological trade-offs in transferring from a VLE to the VRLE using the SCI curriculum. In Lastly, Section V concludes the paper.

II. RELATED WORK

A. Existing Virtual Learning Environments

Previous studies have sought to resolve the issues on the lack of progressive learning for people with high-functioning autism and other disabilities by using highly functional Virtual Learning Environments (VLEs) as an interactive training tool. The work in [10] describes the background and rationale for developing iSocial as well as displaying the overview of the system. A similar virtual environment platform [11] integrates three-dimensional interactive systems aimed to improve the skills of children with dyslexia. This platform combines visual and auditory messages that complement each other, in order to provide an immersive experience and to train more than one of the five senses at a time. These two applications are not immersive in terms of the navigational controls owing to use of a desktop keyboard, which affects user engagement with the system.

Another related work in [12] used adaptive 3D-Virtual Learning Environments (3D-VLEs) to dynamically change its contents according to the learning goals of each student that can result in improved learning. This platform used customized teaching materials to individual students and minimized the change of astray navigation within the virtual world. However, these systems lacks the evidence of enhancing a student’s learning ability through their performance within the application. Our proposed work in vSocial, a virtual reality learning environment (VRLE), overcomes the aforementioned limitations that can deliver curriculum content through a VR medium. The vSocial system includes navigational controls through VR hardware of HMDs and hand-held controllers that help immerse the users in a near-realistic experience. Providing a social curriculum through an immersive environment naturally boosts students’ excitement and engagement towards their surroundings.

B. Design Considerations for VR Learning Platforms

The work in [13] presents a design of a fully operational VR-based system to improve the competence of social skills among ASD students. It develops an interactive scenario-based system for role-playing and turn-taking to evaluate and verify the effectiveness of immersive environments on the social performance of ASD students. Relevant studies such as [14] similar to the aforementioned VR-based system aim to reduce the gap experienced by students due to their struggles to communicate. They use joint attention (JA) skill training in an immersive platform environment to improve the social communication between students with ASD. The requirement of developing a system based on these works can create a suitable environment for the struggling students on the autism spectrum. Authors in [15] conduct a usability study for children with high function autism (HFA), i.e., ages 7+ and reveal that completing 10 sessions/hours of Virtual Reality Social Cognition Training (VR-SCT) shows an improvement of their cognitive learning ability. The VR-SCT application shows how training youth with HFA can cause an increase of important social skills within a short period of time. [16] used an immersive virtual reality environment (VRE) to perform Cognitive Behavior Therapy (CBT) training students with autism experiencing specific phobias. After six months of training, the study reported the improvement in less than half (38%) of the participants who were treated through the VRE. These results indicate the brief VR exposure with CBT is acceptable to deliver through child clinical service and is effective for some participants.
The purpose of social orthotics is to enable learners to engage in effective social practice through the convergence of networked technologies and computer hardware (e.g., desktop, keyboard, central processing unit). Social orthotics enable individuals with ASD to interact socially oriented environments and uses instruction techniques to build the attention of students lacking proper social competence skills. The SCI curriculum delivered through an immersive medium allows for effective generalization, which constitutes the ability to apply one’s skills in real-world environments [17].

III. DESIGN CONSIDERATIONS OF VIRTUAL LEARNING TECHNOLOGIES

A. Virtual Learning Environment Design and Limitations

Three dimensional virtual learning environment (3D-VLE) technologies such as iSocial [1] are computer-generated, simulated environments that emulate real-world settings. They promote face-to-face small group settings by creating virtual representations of users, known as avatars. These distributed computer-based virtual space (or a set of spaces) [18] are designed to support the socialization and communication among peers, particularly students with high-functioning autism, based on social competence curriculum modules. The creators of iSocial designed a collaborative 3D-VLE [19] to train youth with ASD by implementing the SCI curriculum to adapt to individuals’ needs in achieving specific social skills.

One of the critical features included in the iSocial implementation is ‘social orthotics’, which focuses on building an environment and uses instruction techniques to build the attention of students lacking proper social competence skills. The purpose of social orthotics is to enable learners to engage in effective social practice through the convergence of networked technologies and computer hardware (e.g., desktop, keyboard, central processing unit). iSocial utilizes the SCI curriculum to integrate four key constructs: individual presence, social presence, behavior management and adaptivity. The individual presence gives students a sense of immersion while allowing them to sustain a coherent and positive self image inside and outside of the VLE. Students are immersed into the VLE using a desktop-based medium, where they collaborate in a multi-user environment using their personalized avatars. The social presence enables mechanisms for interaction (e.g., social orthotics) within the collaborative VLE. Behavior management allows additional support staff to stand beside the students for assistance while trained instructors deliver the learning content and monitor the students’ progression. Implementing social orthotics which enable individuals with ASD to interact socially creates an adaptive and flexible environment that meet learners’ individual developmental needs.

While designing 3D VLEs can help deliver social competence training to youth with ASD, the usability studies evaluating human performance can be a challenge for such virtual desktop applications. The VLEs limit students with ASD from fully engaging themselves, providing inadequate interactions among their peers. These barriers yield sub optimal performances and hinder the performance while engaging the user with the learning modules. Performance testing on these management systems are critical in the development of improving young students with high-functioning autism. Students must improve in areas of their incompetence that are most significant to properly identify social cues.

The emergence of immersive VR technology, however, creates new and bold opportunities to engage students in an even more impactful manner. Unlike virtual desktop applications (e.g., iSocial VLEs), virtual reality learning environment (VRLE) technologies are capable of heightening the levels of focus and creating more authentic interactions among users [13]. This in turn benefits in delivering curriculum content that maximize youths’ abilities to understand and interpret social gestures. In the following, we apply our understanding of social VRLE management systems to a realistic VRLE use case viz., vSocial, and intuitively compare its effectiveness to its VLE counterpart.

<table>
<thead>
<tr>
<th>Perspectives - Technical</th>
<th>Virtual Learning Environment (VLE)</th>
<th>Virtual Reality Learning Environment (VRLE)</th>
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<tr>
<td>Equipment</td>
<td>Desktop Computer</td>
<td>VR Hardware</td>
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<td>Ease of Usage</td>
<td>High Ease</td>
<td>Medium Ease</td>
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<td>Cost Effective</td>
<td>Medium Cost</td>
<td>High Cost</td>
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<td>System Requirements</td>
<td>Standard</td>
<td>NVIDIA GTX 970 or higher</td>
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<td>Accessibility to Other Systems</td>
<td>Easy</td>
<td>Medium</td>
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<tr>
<td>Perspectives - Users</td>
<td>Virtual Learning Environment (VLE)</td>
<td>Virtual Reality Learning Environment (VRLE)</td>
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<tr>
<td>Cognitive EEG</td>
<td>N/A</td>
<td>Muse Headset</td>
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<td>User Safety</td>
<td>High</td>
<td>Low - Cybersickness</td>
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<td>Ease of Physical Movement</td>
<td>Very Low</td>
<td>Low - Needs Physical Space</td>
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<td>Networking</td>
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<td>User Immersiveness</td>
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Although the aforementioned works have promising directions on the intervention of pedagogical methodologies through a VR environment, there are inadequate comparisons when transferring between two networked mediums (i.e., VLE to VRLE). Motivated by this, we uniquely describe the fundamental transitions between a VLE and VRLE from both a user and technical perspective. We demonstrate this design through our networked-based vSocial VRLE that utilizes SCI through training modules aimed to improve the social-cognitive ability in students. The SCI curriculum delivered through an immersive medium allows for effective generalization, which constitutes the ability to apply one’s skills in real-world environments [17].

The emergence of immersive VR technology, however, creates new and bold opportunities to engage students in an even more impactful manner. Unlike virtual desktop applications (e.g., iSocial VLEs), virtual reality learning environment (VRLE) technologies are capable of heightening the levels of focus and creating more authentic interactions among users [13]. This in turn benefits in delivering curriculum content that maximize youths’ abilities to understand and interpret social gestures. In the following, we apply our understanding of social VRLE management systems to a realistic VRLE use case viz., vSocial, and intuitively compare its effectiveness to its VLE counterpart.
B. Virtual Reality Learning Environment System Overview

Social VRLEs are 3-dimensional spaces that mimic the real world within a simulated environment. The purpose of these social 3-D simulations is to enhance a human’s ability to interact with realistic objects and create objects that can be manipulated in the virtual world. They intuitively immerse the end-user to create organic interactions that represent genuine conversations between peers in real life settings. The potential of this cutting-edge technology is vast, as it can be a training tool in various fields that includes medicine, military, construction as well as education [20].

Figure 1 shows how the vSocial VRLE can be used to create a safe and robust learning space for youth students on the autism spectrum. vSocial provides an online version of the existing SCI curriculum in a 3-D virtual learning environment setting through integration of HMDs, hand-held controllers, and base tracking devices. It is important to note that these equipment can be easily adopted and used for more intuitive control within the immersive VR environment. The application is run on High Fidelity [5], an open source, social VR gaming engine that allows users to collaborate within a shared domain. It uses high-end graphics to render real-life models, which include natural foliage, buildings, and themed park areas.

vSocial runs on a cloud server hosted on a cloud infrastructure [21] to allow an administrator to manage sessions running High Fidelity. The cloud server hosts the vSocial portal for instructors to monitor students’ session performance including lesson progress and related emotion states. Instructors monitor student progression through a HumHub portal [22], an open source social network software application used for internal communication and collaboration among users. Real-time data from user input during sessions gets streamed into the portal, making it feasible for instructors to check student progress and provide their immediate feedback. These inputs are recorded into a secure database hosted using the Amazon DynamoDB service. The application also promotes portability, as it is set up on a Docker container [23] that hosts a session management portal. To host our vSocial domain with the relevant content that is accessible to the High Fidelity platform for public use, we use the Google Cloud Platform [21]. Specifically, we have configured a vSocial domain in a cloud instance as shown in Figure 1 that allows the High Fidelity to render our hosted vSocial VRLE content from a publicly routable IP address. The high-speed, low-latency network server provides rendering of the VR environment through the High Fidelity gaming engine for students to remotely access via VR equipment. VR glasses are used to display surreal graphics that require a reasonable amount of GPU power. These devices, HMDs and controllers, are tracked through the HTC Vive [6] base stations, which create a room-scale virtual reality space to keep a user from stepping outside the range of the indicated boundaries.

We adopt above methodologies to deliver a more robust, interconnected platform that ensures a safe and well managed learning environment for our target users. In the following, we explore the successes and disadvantages when transferring from a desktop-based application (VLE) into an immersive application delivery (VRLE). We use constructive feedback given from the creators of iSocal to iteratively design a robust learning environment.

IV. Technical Transition from a VLE to a VRLE

The transition from a VLE to a VRLE entails many technical opportunities as well as difficulties since VR is still an emerging field. Although a traditional VLE system e.g., iSocial [1] provides a virtual learning environment, the vSocial VRLE exemplifies a highly immersive and rapidly developing technology e.g., social virtual reality. We consider these perspectives from both technical and the users themselves (e.g., instructors and students). For example, a shift from a desktop application to a more immersive and networked platform, for example, may have a lower cost efficiency when acquiring advanced equipment, software components,
and network accommodations that are needed to run the system. While this may be an increase in cost, the added feature that the instructor and student gain is a networked-VR experience. The promotion of this collaborative, multi-user feature opens an opportunity for users to remotely interact, which increases the accessibility to deliver special education to remote areas e.g., rural regions. The main difference between using a VLE compared to a VRLE platform, is in the higher user immersiveness. In the following, we reflect on the system trade-off design by highlighting the factors that thrived or became a hindrance from both points of view as follows: the curriculum, functionality, and requirements needed to use the VRLE.

A. Summary of System Requirements

As discussed previously, VRLEs extend the functionalities of iSocial by providing a more immersive user experience in a VR environment. However, there are some differences between iSocial and vSocial regarding space, architecture and requirements which affects the overall cost. VRLE environments require a VR platform for development and accessing the contents remotely. From a technical perspective, the requirements for running iSocial and vSocial involve needing network bandwidth, space, system configuration, and alike. Comparatively, running vSocial requires a strong and robust GPU that renders the immersive environment on the social VR platform. Recent studies in VR show that such immersive experience can help improve response and learning of youth with autism [10]. Also, to access the VR contents and curriculum, users in vSocial require considerable space to move, specifically at least 6.5 x 5 feet, as compared to iSocial, where users can sit at one place to access the curriculum.

The previous iSocial VLE integrated an application to manage student behavior and provide immediate feedback through the SCI Token Behavior System (TBS). The TBS application is synchronized across all clients and has two views: one from the instructor’s side and another from the students’ perspective in the VLE. The purpose of this feature is to: (a) allow instructors to add tokens, passes, and strikes based on students’ behavior, and (b) allow students to view passes and strikes of other students as well as tokens. While instructors were capable of monitoring the social behavior of ASD students, they lacked mechanisms to objectively measure their emotional behavior and performance.

To alleviate this concern, we allow the instructors in vSocial to gain information about the user’s emotions through the use of an electroencephalogram (EEG) device called Muse [24]. This Muse brain sensing headband gives instructors the capability to identify as well as interpret the students’ emotions throughout a learning session. From a user’s perspective, the cognitive tool ensures precise results to understand the fluctuations of emotions (e.g., happiness, calm, excitement, frustration) a person might have at any given moment [25].

By following the same SCI curriculum guidelines as iSocial, we extend the vSocial functionally to allow session management control of students based on their behavior and tokens they were awarded. The vSocial Portal has been developed to integrate a VRLE session, session management and session monitoring into one web-accessible location. The portal has been built using HumHub [22], an open source social networking software, and can be set up on a container using Docker [23] images on any cloud infrastructure. The image is a light-weight, stand-alone, and includes an executable package of vSocial application with: code, runtime, system tools, system libraries, and settings. The instructor uses this portal to start and manage VRLE sessions as well as to monitor students progress in various units, and their emotions states (e.g., engagement, excitement, frustration) in every session. Herein, the web portal provides administrators and instructors with access to the fluctuations of emotions through the EEG headband device.

The vSocial portal can access data from an external cloud for data import (e.g., Fitbit Cloud). Via role-based access control, the portal is configurable to allow secure access to the necessary data and tools for instructors or administrators to e.g., perform user management, create and set up VRLE sessions, and visualize/analyze the students’ performance to provide instructors with real-time feedback in the VRLE sessions. As shown in vSocial portal screenshot in Figure 2, instructors can evaluate students’ performances and assign grades or rewards based on the performance of the student in a VRLE session. We specifically develop a “Strike System” based on the implementation of the iSocial TBS, where instructors can provide the strikes and warnings to students via the portal in case they e.g., misbehave during a learning session. The vSocial Portal has open-source code available at [26].

iSocial used the strike system feature to real-time monitor both the individual student and group’s progress and behavior throughout each lesson. The benefit of this feature is not apparent in a VRLE setting such as vSocial, specifically for the student, as being in the VR mode creates limitations of the data being seen in one’s peripherals continuously. As an instructor, this lack of support technology presents a challenge for monitoring students behavior and providing immediate feedback. This in turn increases the difficulty for an instructor to effectively manage inappropriate behaviour of the students in VRLE sessions.
B. Functional Transitions

The functionalities of the two configurations allows developers to design many useful modules for students with ASD. Both are learning environments that provide an open-source documentation tailored to their respective content delivery. Additionally, an opportunity of the functionalities that are provided for using a VLE and a VRLE is the use of a marketplace that allows creators to publicly share their ideas for others to use. From both a technical and user perspective, the transition to vSocial has created a more rich set of opportunities to utilize several useful functionalities.

The immersion of the High Fidelity social VR engine creates the need for use of high-powered GPU cards to render “real-world” environments that students engage in for a near-realistic experience. Compared to a Desktop mode configuration, a student in an immersive VR mode can better engage with his/her surroundings. As a result, students have a rich interaction within the learning environment for attributing to better performance in learning [27]. By transitioning to an immersive VRLE, we utilize the High Fidelity Marketplace for downloading open-sourced scripts/entities provided by the High Fidelity developer community. VRLE developers are capable of downloading these open-source tools and storing them as virtual assets within their local domains. High Fidelity can also include entities other from third-party computer graphics software applications (e.g., Blender [28], Autodesk Maya [29]). The convergence of the networked infrastructure, the graphics toolset, and easy development using the High Fidelity API create rapid and robust VRLEs for a personalized experience.

Despite the extensible features of the High Fidelity social VR engine, it can be difficult to transfer existing VLE models in iSocial to vSocial VRLE related tasks. For example, specific activities that involve playing games can be hard to interpret and transfer the existing code (e.g., Unity’s C# language to High Fidelity’s JavaScript API). This can also pose a concern within the context of delivering the SCI curriculum if there is no feasible solution for integrating a particular iSocial feature into vSocial due to technology limitations. Hence, this setback from a system’s point of reference creates a less intuitive structure when creating an activity that reserves its key features. In addition, the frequent updates to social VR along with the hardware and software components forces developers to constantly refine the VR content. The rapid emergence of VR technologies naturally is problematic and causes SCI-VR curriculum developers to rewrite and omit certain features that were developed in the past.

Finally, we extended the limitations of the VRLE applications through side effects that compromise the physical safety of the user, as well as create issues with data visualization. An example of this limitation is the effect of operating in VR for a long period of time that results in motion-induced sickness or cybersickness. Each unit is divided into several lessons which are taught within a 45-50 minute time frame by the instructors of the SCI curriculum. The VLE sessions require both the instructor and students to be on a desktop computer. Conversely with VRLE, the student is in a VR mode while the instructor may remain on the desktop computer. The result of being in an immersive application for long periods of time can cause the user to become nauseous, dizzy, and experience headaches that are cybersickness symptoms. Apart from that, vSocial consists of distributed modules and requires connectivity between them. Compromise in data visualization of emotion and network data at the instructor and administrator side respectively, can provide wrong data entries and result in incorrect data during visualizations. This can further affect the user experience as the contents and the activities are changed based on how the students feel.

C. Curriculum Transitions

The standards of iSocial using the SCI curriculum provide guidance on important aspects that include personalized avatars to youth students, environments with minimal distractions, as well as clear pathways for easy navigation. The curriculum entails five units along with two orientation days which targets different learning components to boost the interactive involvement among students. The two orientation days serve as an introductory period for the units. In these introductory worlds, students are acquainted with navigation in a designed learning environment. To maintain the relevant and intuitive features of the existing VLE application using SCI curriculum, we gathered prior knowledge including subject matter feedback from the creators of iSocial to iteratively develop an immersive VRLE system using High Fidelity. The creators of iSocial emphasized the need to design an application that aligns with the pedagogical goals of the SCI curriculum while providing a synchronous learning environment suitable for gathering the engagement of students with ASD. The High Fidelity social VR engine serves as an effective development tool for the purpose of creating virtual domains, personalized avatars that mimic user movement via
motion sensing of VR tracking devices, including seamless deployment for real-time collaboration.

vSocial was developed to maintain three applications from the iSocial VLE: iTalk, iFocus and iGroup. The iTalk application in iSocial is an interface provided for students to practice their conversational skills such as turn taking, and appropriate speech and tone. We incorporate this feature in vSocial on a Tablet Interface embedded in High Fidelity that allows students to practice proper gestures via the Emote App [8], and maintain appropriate tone amongst their peers and instructors. The iFocus application aimed to provide visual cues such as a laser pointer/cursor for the instructor to indicate what is being referenced e.g., the important features of a person’s face to properly identify their facial expression. To coordinate with this, we used the built-in High Fidelity functions of the hand-held VR controller so that students can focus on a particular area the instructor points towards or by simply picking up an object. The purpose of the iGroup application provides features of a group-style management by the instructor. In particular, it consists of individual pods in which the instructor congregates the students through their ability to lock and unlock when teaching lesson content. We term this feature as “group spaces”, which provides the same capabilities of the iGroup application. The cylindrical pods toggle between two green and red indicating that the pod is unlocked and locked, respectively. Although the improvements were critical for delivering the SCI curriculum for students with ASD, we found the need to improve multiple features that were not obtainable in the iSocial application for instructors. This includes proper restoration features for instructors after students complete lesson activities. The existing iSocial application did not have a feature that restored objects at the end of every lesson. Either instructors or developers would have to manually reset each entity back its initial position. The absence of this feature caused a delay when transitioning to a different segment of a lesson. Using the High Fidelity API tool to reset entities to its original position became critical for reducing instructors’ transition time. Furthermore, we resolve the concern of providing a centralized control panel for delivering curriculum content such as slides and videos by utilizing the High Fidelity built-in Web Entity feature. This Web Entity feature presents an interactive, 2D web-page that could be rendered in a 3D space. It allows for slides and even videos to be synchronized across all users for real-time content delivery. The synchronization of these web-pages are maintained to allow students to receive live content and even play games cohesively.

Other notable improvements in the vSocial VRLE include the pivot between games and lesson activities in curriculum modules. As discussed earlier in Section IV-B, the transferring of existing code from iSocial to vSocial was not always efficient. In Orientation Day 2, for example, students have to learn the fundamentals of the vSocial application and the SCI curriculum by performing games and tuning in to lesson content. One specific activity required students to work together to build a virtual snowman. As we looked into the developing Orientation Day 2, we noticed the models created in iSocial were not attainable in vSocial. By resolving this, we consulted with the SCI experts to build a virtual garden, in which students worked together to create their own version with the set of features that we developed. Thereby, we considered the importance of maintaining the SCI curriculum delivery needs by developing new features in vSocial that aligned with iSocial standards.

Despite the successful curriculum transitions from a student/instructor perspective, the VR and its specialized hardware presents inherent limitations that stifle the development of vSocial using the SCI curriculum from a technical perspective. The curriculum module on Facial Expressions [30] targets the students’ ability to interpret facial cues to identify emotional labels and analyze contextual variables about mental states. Table III shows the differences in capability of the iSocial VLE to use facial expressions data obtained via installed video camera on a computer desktop. Students were able to take pictures that automatically synced onto a web-page in the VLE for instructors to analyze. In a VRLE, however, the VR headset (e.g., HTC Vive) masks the eyes, forehead and eyebrows of the student’s countenance. Thus, the instructor’s ability to analyze facial expressions is blocked and the related information is inaccessible when immediate feedback to students needs to be provided.

**V. CONCLUSION**

In this paper, we presented vSocial, which is an example of a cloud-based VRLE application using social VR and wearable technologies for special education courses. It provides special education students with a near-realistic, immersive VR platform while interacting with an instructor to gain social competence skills learned via virtual spaces. We detailed how vSocial VRLE overcomes limitations in existing VLEs such as iSocial in terms of: (a) the insubstantial evidence for students acquiring knowledge and social skills, (b) the lack of immersiveness in learning i.e., restricting students to roam and interact with their environment for delivering the Social Competence Intervention curriculum over high-speed networks, and (c) the inadequate representation of personalized avatars that mimic student movement, which leads to the decrease in user engagement. We reflected on the technical trade-offs
when transferring from a VLE (e.g., iSocial) to a VRLE (e.g., vSocial) that includes the successful integration of high-speed, low latency cloud platforms in VRLEs and the development of realistic models used from the High Fidelity Marketplace. Nevertheless, the vSocial VRLE application proved to have several advantages over the iSocial VLE counterpart, in terms of user enjoyment and engagement.

The networked social VR platforms have the potential of impacting a larger market of young adults on the autism spectrum, as well becoming vital for other applications in surgical, military, and educational sectors. The capabilities of interconnected cloud-based VRLE systems can foster the target subjects to improve their social and technical skills through interdisciplinary education, research opportunities, as well as hands-on technical experience for employment, particularly in the technology sector. We concluded that the next generation VRLE systems still need improvement in the technical and usability aspects involving: emotional recognition, cloud-based frameworks, system limitations, maintenance and stability of the system, and improved 3D immersive graphics in order to have wide acceptance as an effective distance learning and collaboration technology.

ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under Award Numbers: CNS-1647213 and CNS-1659134. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation. The following students have contributed in various parts of vSocial development and research: Sai Shreya Nuguri, Jaclyn Benigno, Yang Li, Songjie Wang, Nargiza Buranova, and Laura Avery.

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