Circles: Exploring Multi-Platform Accessible, Socially Scalable VR in the Classroom

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***Abstract*— In this paper, we describe a work-in-progress VR platform for education called Circles, as well as its associated background motivations, and relevant related work. We highlight the platform's experiential learning opportunities, but also its contributions towards developing socially scalable interactions to enhance collaborative learning and increased VR accessibility by supporting multiple virtual reality platforms (desktop, mobile, and HMD). We also briefly discuss some pilot studies around the development of three virtual environments highlighting the story of Canadian civil rights pioneer Viola Desmond through explorative narrative.**

Keywords*— *virtual reality, learning, collaboration, multi-user, multi-platform, accessibility

I. Introduction

The use of Virtual Reality (VR) to enhance learning is not new, due to its many learning affordances via embodied cognition (the interaction between the body and the mind) and situated cognition (the interaction between the environment and the mind); but most contemporary VR educational efforts focus exclusively on the use of non-accessible Head-Mounted Display (HMD) devices and rarely consider collaborative interactions. The costs and maintenance of high-end VR systems, VR cybersickness, and the social embarrassment [1] associated with using technology in social contexts reduce VR accessibility in social learning spaces such as museums and classrooms. Additionally, when educational VR efforts focus on single-user or non-collaborative experiences, social cognitive (interactions between others) learning opportunities are lost. How can we better create VR learning opportunities that are more collaborative and accessible?

Educational researchers have suggested that educational methodologies such as "Learning Together and Alone", which focus on collaborative activities and group processing in addition to individual accountability and reflection, enhance academic achievement [2]. Creating these learning activities (e.g. explorative "walking simulator" or "narrative" games such as Gone Home [3]) can be difficult for instructors though, as collaboration involves social interdependence between group members (e.g. the game Keep Talking and Nobody Explodes [4]) and "is much more than physical proximity to others" [2]. Multi-user Virtual Environments (MUVEs) are well poised to address these issues, but there are few examples of truly collaborative and accessible Computer-Supported Collaborative Learning (CSCL) VR activities within the literature [5]. This paper poses the following questions:

- Can VR learning be more accessible by supporting immersive *and* non-immersive VR platforms?
- How can we lower the costs and maintenance (e.g. wires, application installs) of supporting high-end VR systems?
- Can VR learning, within social learning spaces, be further enhanced by exploring the concept of collaborative social scalability [1], where multi-user forms responsively adapt from one to many users?
- What type of technology can support learners, instructors wishing to create VR learning activities, and developers wishing to create new content?

Fig.1. View of 3 users accessing Circles from 3 different platforms (PC, Mobile, and HMD). Icons, below the nametag, denote which platform the user is accessing Circles with. From left to right, 3DOF HMD, PC, Mobile.

We are building a learning VR framework, Circles, that proposes the following solutions:

- Circles is created using WebVR, via custom A-Frame [6] interaction and display components that responsively adapt to various VR platforms (e.g. HMD, mobile, PC).
- Circles focuses on non-immersive VR support on platforms most learners have access to (e.g. mobile and PC), and immersive VR as low-cost standalone VR HMDs such as the Oculus GO [7]. Additionally, by using WebVR, content can be accessed via existing web-based Learning Management Systems (LMSs) and supporting web browsers (e.g. Firefox).
- Circles' has been developed to include multi-user capabilities, with current development focusing on joint-task socially scalable (supporting one to many users) [1] interactions in the near future.

- With familiar web technologies providing components for locomotion techniques (e.g. checkpoint navigation), interaction methods (e.g. objects that can be picked up to display information), and hardware detection (e.g. the platform accessing the platform) Circles can lower the barrier for socio-educational VR development.

In this paper, we will describe Circle's design, the narrative worlds of Canadian civil rights pioneer Viola Desmond [8] and basic pilot studies on their development and use.

Fig.2. Campfire hub – learner turned fire on. Also note that the 3 connected world portals now appear in the background allowing users to click and traverse to other VEs or "worlds".

Fig.3. Campfire hub – leraner turned fire off.

II. Related Work

Within the classrooms, we are seeing VR technologies being used to aid learning, and other social VR projects allowing a glimpse into how they could be repurposed for learning.

Google Expeditions [9] helps the instructor provide more immersive experiences via mobile HMDs and 360 images/videos. Additionally, there is much experimentation into the use of VR in science learning such as experiments into increasing student knowledge retention using virtual 3D models [10] and virtual chemistry labs [11], We can also note Greenwald et al.'s "Cocoverse" that explores a multi-user "3D Whitespace" VR learning environment [12].

Within a discussion of VR examples in education, we can also look towards other VR frameworks that, though may not be directly related to education, may hold interesting lessons and system structures that can be relevant. For example, recent examples of commercial multi-user VR platforms such as VRChat, AltSpaceVR, High Fidelity, and Mozilla HUBs [13] share several characteristics such as customizable avatar representations, chat systems, shared 3D environments, and multiple types of navigation and interaction methods.

Additionally, Collaborative Virtual Environments (CVEs) [14] could have significant relevance to Virtual Learning Environments (VLEs) within a socio-cultural context. Interestingly, some of these collaborative dynamics can be framed within a social interdependence model where "the accomplishment of each individual's goals is affected by the actions of others" [2]. This type of "closely-coupled collaboration" is clearly evident in the virtual gazebo building project by Roberts et al. that broke down tasks into sub-tasks that required multiple users to complete concurrently in both "*distinct attribute*" (e.g. one holds a wooden beam and the other screws a hole) and "*same attribute*" (e.g. both users need to pick up an object that is too heavy for one) forms [14]. Inspirations for specific collaborative objectives could come from educational "escape" rooms [15] and narrative games [16].

Due to the networked nature of multi-user experiences, it is often beneficial to consider other distributed models of computation where the device, user, and physical station/environment data can be shared between one another [17] allowing for interesting mixed-platform and mixed-environment possibilities.

There are many social VR efforts available; but there are few that are learning focused, support more than one type of VR platform, and are truly collaborative [2]. There are, however, many important lessons from existing social VR efforts such as the importance of avatar customization and user agency in the form of communication and interactions to socialize with other users and the environment. Additionally, considering the past work of other non-VR distributed computing platforms will be essential to framing a networked system that can fluidly share data about abilities, users, and environment. This could help extend a VR framework to include Augmented Reality (AR) where the physical environments become an integral part of the virtual experience (e.g. connecting classrooms and museums).

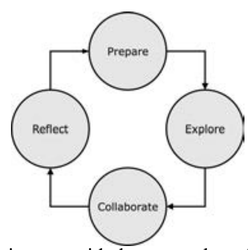

Fig.4. How Circles aims to guide learners - based on Kolb's learning cycle. *Prepare* and start the campfire (Figures 2,3), *Explore* worlds (Figure 5), *Collaborate* with others within and between worlds, and *Reflect* on the experiences at the campfire.

III. PLATFORM DESIGN

In this section, we will describe the Circles platform's current and future features, guided by pedagogical theory.

A. Pedagogical Foundations

It is important that we define the learning theory foundations of the Circles platform explicitly so that it has a clear pedagogy that can shape the platform's creation and development [18]. The two main learning theories we focus on are constructivism and social cognition theory.

Fig.5. Circles' "Worlds" from left to right: Recreation of one of Viola Desmond's beauty salons in the 1930's, The Roseland Theatre where Viola refused to get out of her seat in 1946, and The Nova Scotia Province house where Viola Desmond was posthumously free-pardoned in 2010.

- **Constructivism:** "how people make sense of their experience - learning is the construction of meaning from experience" [19]. This theory focuses on the importance of learners actively constructing their own knowledge via a more experiential model [20]. Kolb's Learning Cycles define experiential learning as concrete experience, reflective observation, abstract conceptualization, and active experimentation [21].
- **Social Cognitive Theory:** "that much human learning occurs in a social environment. By observing others, people acquire knowledge, rules, skills, strategies, beliefs, and attitudes." [22]. Social cognitive theory frames the Learning Together and Alone framework [2] as a significant part of effective classroom learning.

Constructivism is often used by researchers to validate VLE efforts, focusing on user immersion and interaction. However, we must also consider social cognition and collaborative interactions in spaces that include multiple learners.

B. Elements

The following are some terms used to describe various aspects of the Circles platform:

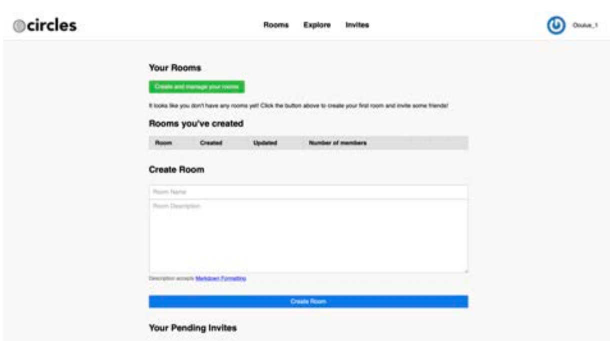

Fig.6. Our prototypical UI for managing rooms and invites to other user's rooms.

- **Circle:** a collection of worlds chosen by an instructor connected to a hub world. Users can move between these worlds via portals.
- **Room:** an exclusive collection of users (i.e. were invited to a circle by someone else) that can explore worlds together (see Figure 6).
- **Hub:** a special "world" that exists to connect multiple other worlds together, as well as provide a VE for group processing/reflection (see Figures 2,3 "campfire").
- **World:** can be any VE created to share knowledge about a specific person, event, or place (see Figure 5).
- **Visibility:** refers to which users are visible (i.e. if not in your circle a user will be invisible), and which platform they are accessing the system with (see Figure 1).
- **Portal:** WebVR clickable hyperlinks displayed as spheres that allow users to traverse between worlds (see Figure 2 spheres).

C. Target Users

Our target users include:

- **Learner:** the end-user which will explore and interact with others within the worlds as laid out the instructor.
- **Instructor:** will manage the creation of rooms, circles, for learners while also guiding them through the experiences.
- **Developer:** will design and develop new worlds, using the Circles Javascript components, network and user management systems.

D. Technology and Supported Platforms

Circles is built using WebVR, which is browser-based VR built with HTML and JavaScript. We specifically used the A-Frame [6] WebVR library for client-side development, and Networked-Aframe [23] and Mozilla HUBs [13] client-server technologies (using WebSockets and WebRTC) for multi-user capabilities. All account information (for saving avatar customizations and personal preferences) is stored via a Mongo database. The Node.js server running this system is hosted on a single Amazon EC2 instance.

Due to accessibility concerns (i.e. cost and setup/wires within public spaces) and our formal education institution targets Circles targets the following platforms.

- Standalone immersive VR HMDs (e.g. Oculus GO due to low cost and lack of required PC)
- Smartphones / Tablets (e.g. personal mobile devices)
- PCs (e.g. student laptops). Future work also includes supporting distributed PCs to connect physical learning environments (e.g. museums) to the worlds of Circles.

E. Circles Framework Technology

Circles currently has one "hub" – see Figures 2,3 - and three "worlds" that represent the story of Viola Desmond as an example of diverse historical content [8] (See Figure 5). To create greater immersion each world was modelled in 3D to allow multiple frames of reference [24], include environmental sound design for higher immersion and situated cognitive possibilities. Multiple "hero" objects can also be picked up for further information to activate constructivist knowledge gathering and embodied cognition - see Figure 5.

User interactions currently focus on basic symmetric interactions [25] that allow users to click/tap/ray-cast to select, manipulate, and release objects such as portals (see Figure 2), "hero" objects (e.g. the $10 bill in Figure 5), and to activate objects (e.g. the fire in Figures 2,3).

Each user has an account, the ability to customize their avatar, and to invite/uninvite other users by creating a "room" of participants they can explore a "circle" of worlds together with for social learning - see Figure 6.

With the platform developed, we are also building joint-task actions that scale across a variable number of users for our social scalability and "together and alone" objectives.

IV. PILOT STUDIES

Through some informal qualitative pilot studies on the exploration of the Viola Desmond worlds, we have found the novelty of visiting VR across platforms is convenient, even if immersion is lost when not using HMDs. Some features suggested by participants are the ability to more easily interact with objects, greater social communication (e.g. include avatar gestures), and a smoother login process as typing passwords in VR is difficult. We also need to formally evaluate whether symmetric interactions [25] help understanding or hinder immersion in HMD VR.

While creating the Viola Desmond worlds custom components were created to address some issues. This includes simplifying object interaction (reducing the number of buttons for manipulation from 6 to 2). We also found that picking up objects up to reveal more information about the cultural context was engaging so created several objects within each scene that could be picked up and shown to other virtual participants (e.g. the new $10 bill featuring her likeness).

V. CONCLUSION

Circles shows promise in informal studies, but formal real-world studies of the platform in the classroom will be important. There is great potential for VR in education and we hope that Circles will help validate the learning benefits of multi-platform accessible, socially scalable VR.

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