DATA-DRIVEN FRAMEWORK FOR AN ONLINE 3D IMMERSIVE ENVIRONMENT FOR EDUCATIONAL APPLICATIONS

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Abstract

This paper addresses the issue of online education through 3D avatar-based virtual environments, with focus on features such as telemetrics, immersiveness, content presentation tools, and web integration. We provide the outline of a joint project by Carleton University and Algonquin College in Ottawa, Canada, aimed at providing an immersive online learning solution to enable emergency workers from different disciplines to learn the necessary skills to handle domestic violence emergency scenarios effectively. To accomplish this task, a tool was used to enable online real-time immersive learning via simulated 3D avatar based collaboration in real-time via a web-browser. In addition to providing a rich environment for learning, this tool affords us access to significant telemetric data that is presented here and may be used for further research into learning and collaboration research. Our methodology, experience, and early results are captured and presented as well as future possibilities.

Keywords: Immersive Learning, 3D, Online Collaboration, Telemetry, Analytics, Virtual World

1 INTRODUCTION

Advances in computer and communication technologies provide significant potentials for improving educational systems that heavily depend on interaction, communication and visualization. Military training and flight simulation were among the earliest applications of computer-controlled virtual environments. The rapid growth in computer-based interactive entertainment extended such applications to other social and educational areas, due to the possibility of using computer game technology in non-entertainment cases. The concept of serious games also helped combine the digital entertainment technologies with more "serious" topics. Online 3D virtual worlds like Second Life (http://www.secondlife.com) now host a variety of communities that target socialization as well as education and business.

Most educational institutions now use online content management and collaboration systems, and a few have started to use 3D virtual environments as alternative to traditional classrooms and labs [2,3,12]. In particular, educators are using virtual environments to not only offer content but also allow participants to collaborate and interact in realistic training scenarios and virtually "learn to do". Immersive online collaboration research to date has focused predominantly on qualitative analysis of feedback from participants, and quantitative analysis of some objectives. Empirical collaboration and learning studies tend to focus on effectiveness, efficiency, productivity, commitment, and satisfaction as key metrics to evaluate tools and scenarios.

Despite the extensive use of digital media in educational systems, there are still major issues to be addressed in this regard. Some of these issues are:

- Many of these applications do not use the properties of digital media effectively. Simple text-based or even multimedia websites do not utilize the power of digital media to creative dynamic content intelligently, allow full interaction, browse through a virtual world, and access/edit mass distributed content. Tools like Wikis and 3D worlds (based on the success of computer game technology) try to address some of these shortcomings, but an integrated comprehensive customized 3D virtual environment for education is yet to be developed.
- The effectiveness and advantages of virtual worlds have been studied and suggested by some researchers, but a thorough analysis is still missing, particularly for 3D avatar-based systems [9,10,14]. Although some researchers and professionals have used general purpose or somewhat customized virtual worlds and reported on their strengths, it is necessary to study the performance of such systems when designed and customized specifically for education, through properly defined metrics and collected data.

- Realism, immersiveness, and interactivity are major requirement of a 3D virtual world, especially when used for training. Current systems offer limited support for advanced functionality like realistic 3D sound, various content presentation methods, characters with personality and emotion, and intelligent agents.

1.1 Background

The project reported in this paper is an effort to use a virtual environment to offer a course on domestic violence that teaches emergency and healthcare professionals how to react, communicate, and collaborate when responding to an emergency call. The course is part of a program by Algonquin College, Ottawa, Canada, and traditionally uses lectures mixed with video screening showing domestic violence scenarios. Some of the difficulties faced by instructors and students are:

1. The need to be physically present at sessions which can be a problem fr professionals with full-time jobs
2. The limited number of videos due to the need for actors and settings
3. Non-interactive nature of recorded scenarios
4. Difficulty and cost of setting up real-time live scenarios even if students are present
5. Limited access to resources such as presentations and synchronized web access
6. The lack of inter-personal interaction, in distance learning cases

The project team has a history of collaboration with Algonquin College and also some companies developing tools for virtual environments. So it was decided that creating a virtual educational experience would benefit the course and also provide a framework for evaluating virtual environments and their effectiveness as educational experiences. We decided to use web.alive technology from Avaya (http://avayalive.com) which combines the tools for creating virtual worlds with many other features such as 3D sound, multiple content presentation methods, web integration, and a wealth of measurement tools that are essential in our research. The team had the advantage of working closely with the product developers to customize the system for the most effective experience, as reported in the following sections.

1.2 Objectives

The first objective of our research has been to design an avatar-based 3D virtual environment for students to attend lectures, have real time conversations, access multimedia content and practice their learned skills by acting in simulated situations. We used the web.alive technology as the base framework, and through collaboration with educators, designed and developed the virtual environment, animated characters, customized multimedia content, interactive training scenarios, and other parts of the educational experience. In the virtual environment, the participants have access to a series of different lecture and simulation arrangements. The environment is designed and tested within the framework of the course on domestic violence for students coming from different backgrounds (nurses, police officers, emergency response professionals, child aid and other public healthcare workers, etc). In the simulation environments they are to be presented with situations very similar to real life (including user-controlled avatars and if necessary AI-based non-player characters) and are expected to respond. The role playing will be recorded and provided to the lecturer to evaluate and provide feedback.

Our second objective was to provide a series of detailed and quantitative analytical tools and metrics in order to study and compare different pedagogical methods. We have equipped our immersive environment with significant telemetry allowing us to, for example, determine what a given participant is looking at, what they might be paying attention to, who they are talking to, at what distance they are standing from other participants, etc. and more importantly how these might change over time. Using this data, we create different collaborative spaces in our 3D environment to test the effectiveness of alternative modalities for classroom training. For example the effect of screen arrangement in a lecture hall on the students' attention can be analysed by re-organizing the environment and gathering telemetry. Some of the logged data fields are Date, Time, IP Address, Username, 3D Coordinates and Orientation, Event Triggers, and Conversations. Measurements will be on-going in nature and sampled before, during and after each of the learning scenarios. We will use the measurements to determine the participants' levels of cognitive and social presence. Other collected data will include pre and post lecture collaboration such as students getting together in groups to discuss content.

The preliminary results show that our virtual environment is effective and provides the following major contributions:

1. A realistic and powerful educational experience through a variety of interaction and presentation methods
2. Collecting a variety of data elements otherwise not available that help understand the effectiveness of the course and methods used.

The following sections will briefly provide a review of the related work, our methodology and preliminary results, and some concluding remarks.

2 RELATED WORK

Many researchers have studied virtual communities in general [18,20,21] and particularly for learning [1,3,4,12,19,22] and health care [6,9,10,23]. Davis et al. [8] proposed a community building approach for cancer patients, while Curran et al. [6] describe the Town of Mirror Lake, a virtual community for educating nurses and medical staff. Most of these researchers have noticed that virtual communities have become more and more popular thanks to familiarity of users, particularly younger generations, with digital online media.

Second Life (http://www.secondlife.com) is a 3D virtual world that has been widely used for social, educational, and commercial purposes. Active Worlds (http://www.activeworlds.com), Twinity (http://www.twinity.com) and IMVU (http://www.imvu.com) are other examples of virtual world that target chat in 3D, reconstruction of real cities and creating social meeting places, respectively. Boulos et al. [2] have provided a good review of potential uses of Second Life and other 3D virtual worlds for health and medical education. They argue that 3D worlds provide an immersive realistic experience that can combine communication, entertainment, training, and access to a variety of data types. On the other hand, serious and educational games, and the effect of story-based learning and empathic virtual characters have been studied by different researchers such as McQuiggan et al. [17] and Kenny et al. [16], while some researchers [5] have tried to focus on the issue of community members and how they can differ based on gender, age, and race, and require different treatments.

Callaghan et al. [3] also report the use of Second Life for technology education. They notice the need for some simplifications (for example in teaching engineering equipments) which can be a problem but also mention partial integration with a content management system (Moodle) which is a considerable advantage. Danilicheva et al. [7] explore the educational values of 3D virtual worlds but from a storytelling point of view. Their work points to the value of artificial intelligence and also uses stereoscopic 3D to increase immersiveness.

Hall and Buckley [15] propose three basic categories of metrics for evaluating collaboration systems: (1) usage statistics, (2) business process and outcome metrics, and (3) system usability metrics. Duivenvoorde et al. [13] have proposed a model to measure success of collaboration along six dimensions; efficiency, effectiveness, productivity, satisfaction with the process, satisfaction with results and commitment. Deokar et al. [11], investigated how cognitive and social presence can be related to measures of collaboration success such as commitment, efficiency and productivity.

The common conclusion seems to be that virtual communities may provide a more flexible and accessible learning experience, empower users (students, professionals, patients, etc) and enhance coordination of education/care services. Eysenbach et al. [14] on the other hand have argued that the advantages and disadvantages of using virtual communities for health and education still needs to be studied. This point is also raised by some other researchers such as Demiris [9,10]. It should be noted that although very interesting and relatively successful in achieving their targets, none of the above mentioned approaches take advantage of all properties of digital media and provide an immersive virtual world with data collection features required for a quantitative analysis. Full audio/visual immersion and quantitative analysis are major missing parts in most of the existing approaches. Some other shortcomings are integration with web applications and real-time content update and web access from within the environment.

3 METHODOLOGY

The proposed project is multi-disciplinary in nature and uses a variety of different methods. Our methodology is based on the following steps:

1. Detailed study of existing systems to understand their strengths and weaknesses
2. User study in order to collect user requirements for typical health and education applications
3. Consulting with professionals in dealing with ethical and legal issues
4. Prototyping and constant community testing
5. Designing a versatile and flexible framework
6. Using the state-of-the-art research results in the areas of advanced functionality
7. Involving community members in application development
8. Building a user/developer community by inviting community members and researchers to actively work with the framework and sample applications to provide constant feedback

In order to create a solution that would enable emergency workers and students to effectively learn by doing whilst not being physically co-located with each other or environments representative of those they are training for, a realistic simulation was required, in addition to more traditional educational settings, i.e. lecture halls. The tool chosen for online collaboration and simulation allows for the creation and import of 3D assets created using a myriad of different content creation technologies. As such, the team looked to university researchers and students to work on the project in conjunction with the technology provider to create a rich simulation environment with included space intended for lectures and group collaboration.

3.1 System Overview

Fig. 1 shows the general structure of our virtual environment, including spaces for lectures, simulations, and social interaction. Fig. 2 and Fig. 3 capture some views of the environment that was created. Fig. 2 shows the lecture hall while Fig. 3 is an outdoor view showing three item types: Item 1 in the figure is one of five instances of a bungalow used by students for situation simulation in context. Item 2 in the figure is one of a suite of offices placed throughout the environment to represent the different organizations represented (nursing, policing, paramedics, fire and rescue, etc.) and contains virtual office and collaboration space. The final item is an open concept collaboration space with tools such as slide and document sharing surface as well as a synchronized web collaboration surface.

Lecture Hall	Simulation Area	Social Space

Web.Alive (server and client sides)

Web Infrastructure

Fig. 1. General Structure of the Virtual Educational Environment

Fig. 2. Lecture Hall with Different Presentation Screens

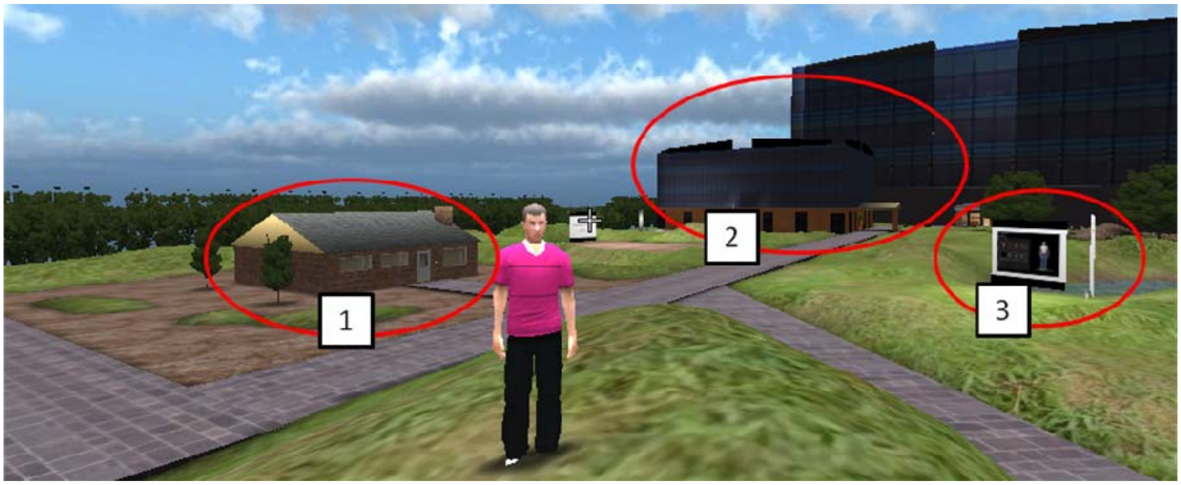


Fig. 3. Outdoor View of the Simulation (items 1 and 2) and Social Areas (item 3)

The content presentation is done through surfaces (screens) that can show videos, images, presentation files (supporting Powerpoint and PDF), and real-time web pages. This will allow instructors and other participants to easily access content and update it in real time while in the environment.

The system allows 3D spatial audio. The sound level can be independent of distance (e.g. for speakers in the lecture hall) or change based on avatars distance (for local talks). At any time, users can know who can hear them, and also can control different audio features such as temporary mute.

Different "areas" can be defined to simplify environmental control (e.g. private meetings) and behavioural monitoring (e.g. who goes where, etc).

Simulation areas use specially designed avatars that represent the characters involved in the training scenarios, with required clothing, animations, etc. The system supports Non-Player Characters controlled by scripts and events, although this particular course did not require them.

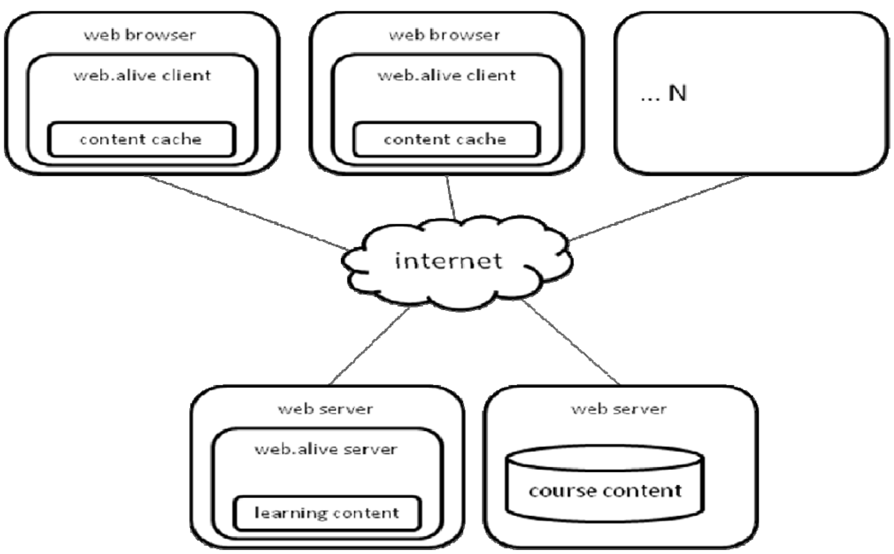


Fig. 4. System Architecture

3.2 Implementation

The implementation of this solution is broken down into three parts: (1) content, (2) telemetrics, (3) integration and deployment. The content is a set of 3D assets generated using standard software tools and environmental controls such as events, triggers, scripts, and volumes, defined using web.alive editor (which also serves as the tool to put together all the assets). Web.alive is based on the Unreal Engine by Epic Games (http://www.unrealtechnology.com) and supports a variety of different asset types. An overview of the telemetric instrumentation and data collection methodology is provided in the next sub-section to give insight into current and future potential of the system. Integration and deployment is done through web.alive server side tools in a web-based format. Fig. 5 shows the general deployment structure of our system.

3.3 Telemetrics

In selecting the web.alive tool, the project gained access to a sophisticated and verbose logging system as well as a preconfigured set of analytic data and tools. In addition, the raw data affords the future potential of immersive learning focused analytics to help increase the overall effectiveness of education both within virtual environments and in real classrooms.

3.3.1 Data Collection

Data is collected by the system on both the server as well as the client. For privacy reasons, the data collected on the server is limited to data which typically collected over the World Wide Web today such as source Internet Protocol (IP) address, user supplied name and action performed. On the client side, detailed logs are collected about encounters that occur within the environment – from individuals walking within listening radius of each other (an encounter) to two or more individuals speaking to each other within listening radius at the same time (a conversation).

The logs are collected in both cases in a format consistent with the standard World Wide Web Consortium (W3C) logging format. In addition, the specific environment or content that was produced for this pilot was outfitted and configured to optimally gather useful data. For example, the environment is sub-divided into volumes or areas where the users can navigate to and from – entering and leaving each volume triggers a log (e.g. user entered classroom 2). Further, specific triggers were placed within the environment using built-in tools from web.alive such as stare triggers which initiate a log when a user places their cursor over an object (such as a slide presentation) for more than three seconds.

3.3.2 Analytics

At this time, data analysis is only just beginning. Based on the tools existing analytics, we are able to browse through encounters of each user, view conversations (who, where and when) that occurred within the environment, observe traffic and conversation patterns based on the interactive heat-map tool and much more.

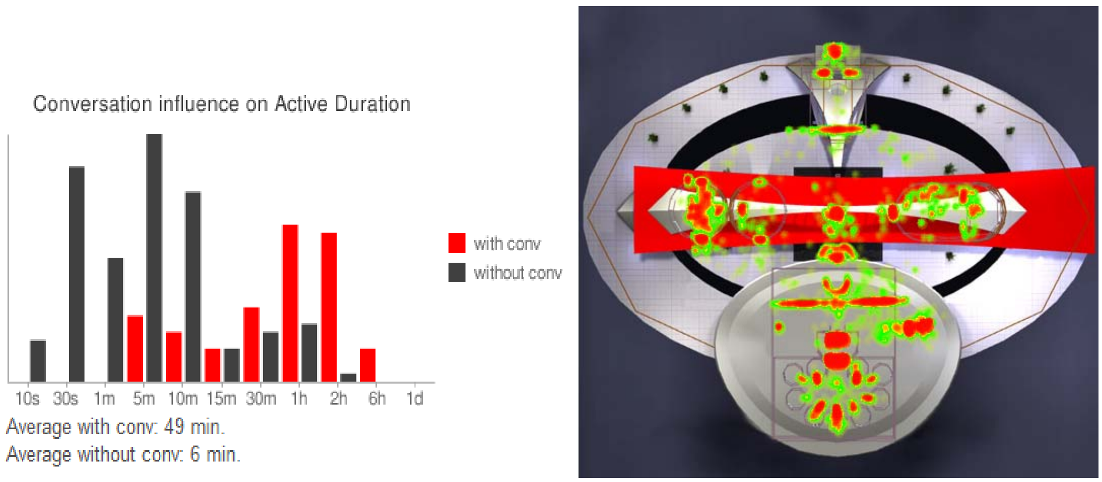


Fig. 5. Example of Conversation Influence on Active Duration (left) and heat-map (right)

For example, using the tool we are able to observe (see Fig. 5) the influence of conversation on active duration within the environment. As indicated by the graph, those users who did not actively participate in conversation within the environment during the pilot window were far more likely to idle or leave the environment. This is an excellent indicator of the importance of encouraging user participation in conversation during learning sessions.

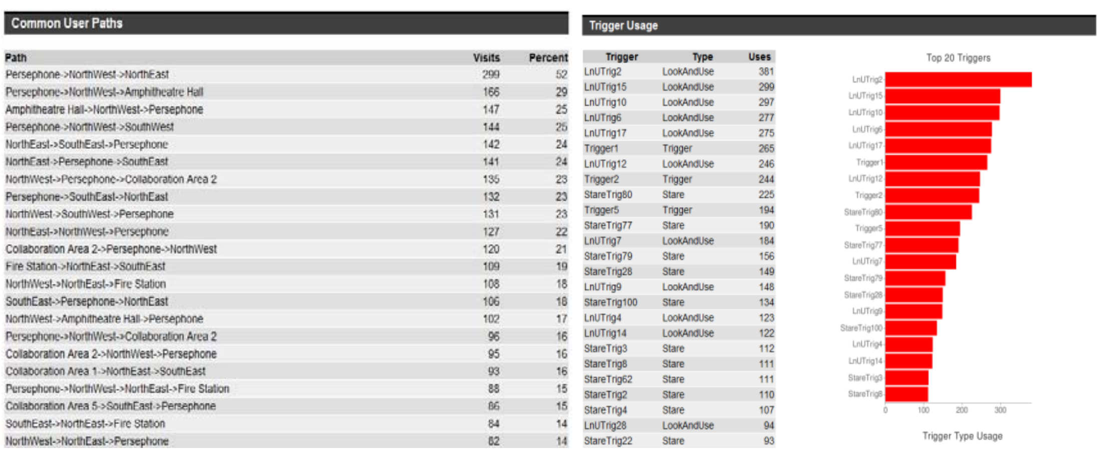
We can also see the distribution of logins to the environment both daily and hourly. What is most important to note from this type of data is that users not only enter the environment for the specific task, but also enter and spend time at other points, likely to collaborate with others and practice their simulations. Other available analyses allow us to identify those that were most active in encouraging participation from others, and the most popular actions and locations within the environment (through heat-map). Further analysis of this data, including more advanced metrics such as calculations of the efficacy of any given media element (slide, video, web site, etc.) within the environment, overall effectiveness of different media types on student participation (are students more likely to become vocal after a slide presentation or a pre-recorded video) are all possible and will be performed as more data is accumulated from the environment.

4 RESULTS

Content creation and environment set-up started in January 2010 and continued till the end of April 2010. The system was deployed and tested for a pilot course with 29 participants and 5 instructors for duration of 4 days (2 sessions each 2 days). Fig. 6 and Fig. 7 show more views of the environment and simulations.

Fig. 6. Views of the Virtual Environment

Fig. 7. Example Scenes from the Simulations



Common User Paths

Path	Visits	Percent
Persephone->NorthWest->NorthEast	299	52
Persephone->NorthWest->Amphitheatre Hall	166	29
Amphitheatre Hall->NorthWest->Persephone	147	25
Persephone->NorthWest->SouthWest	144	25
NorthEast->SouthEast->Persephone	142	24
NorthEast->Persephone->SouthEast	141	24
NorthWest->Persephone->Collaboration Area 2	135	23
Persephone->SouthEast->NorthEast	132	23
NorthWest->SouthWest->Persephone	131	23
NorthEast->NorthWest->Persephone	127	22
Collaboration Area 2->Persephone->NorthWest	120	21
Fire Station->NorthEast->SouthEast	109	19
NorthWest->NorthEast->Fire Station	108	18
SouthEast->Persephone->NorthEast	106	10
NorthWest->Amphitheatre Hall->Persephone	102	17
Persephone->NorthWest->Collaboration Area 2	96	16
Collaboration Area 2->NorthWest->Persephone	95	16
Collaboration Area 1->NorthEast->SouthEast	93	16
Persephone->NorthWest->NorthEast->Fire Station	88	15
Collaboration Area 5->SouthEast->Persephone	86	15
SouthEast->NorthEast->Fire Station	84	14
NorthWest->NorthEast->Persephone	82	14

Trigger Usage

Trigger	Type	Uses
LnUTrig2	LookAndUse	381
LnUTrig15	LookAndUse	299
LnUTrig10	LookAndUse	297
LnUTrig6	LookAndUse	277
LnUTrig17	LookAndUse	275
Trigger1	Trigger	265
LnUTrig12	LookAndUse	246
Trigger2	Trigger	244
StareTrig80	Stare	225
Trigger5	Trigger	194
StareTrig77	Stare	190
LnUTrig7	LookAndUse	184
StareTrig79	Stare	156
StareTrig28	Stare	149
LnUTrig9	LookAndUse	148
StareTrig100	Stare	134
LnUTrig4	LookAndUse	123
LnUTrig14	LookAndUse	122
StareTrig3	Stare	112
StareTrig8	Stare	111
StareTrig62	Stare	111
StareTrig2	Stare	110
StareTrig4	Stare	107
LnUTrig28	LookAndUse	94
StareTrig22	Stare	93

Fig. 8. Most Common Paths and Event Triggers

Most Valued Influencers (users who influenced other users to speak and explore), most used volumes, most common paths, and most used event triggers were among the noticeable results of telemetrics and related analyses, as shown in Fig 8. Tasks included participating in lecture, reviewing pre-recorded videos in groups, working in groups (~5 students) on discussion points and finally acting out simulations of scenarios discussed. Some of the early results from this pilot project are reported here.

- Comparisons were continually being made between "real-life" vs. "virtual world" simulations and a few pro's and con's were mentioned with each approach:

- Real-life simulation areas are limited, but virtual simulation space seems limitless.
- Students recognized the importance of non-verbal communication. Eye contact, hand gesturing, and facial expressions were missing or not fully supported, but students stated that they were forced to talk more, which was good for verbal training.

- As the research objective was comparing the real life simulation and the virtual simulation, all participants were at the pilot site and using the same computer lab. This was very distracting and was corrected in the second day when participants were distributed over different labs.
- In terms of the technology acceptance, it was obvious that students see their avatar as their representative. Many of them, before immersing in the environment, took the time and changed and customized their avatars. They especially enjoyed improvising on their uniforms while they had the chance. Some participants found being in virtual environment significantly shielded them from the anxiety of role acting. Some mentioned not having a patient to touch and check was a little distracting to them, while other participants mentioned totally opposite, not having patient to examine helped them focus more on the conversation going on during the simulation.
  - In one instance, the instructor asked seven students at the end of their session "to name one thing they would take away from this experience" and not one of the answers mentioned the virtual experience. All answers were related to the course material, not the tool being used. (i.e. the tool was not a distraction)
- Social Interaction was another significant aspect of the experience. Making funny dresses, jumping over the roof, wearing pink police clothes resulted in creating a fun socially engaging atmosphere. Students asked if they could use the virtual environment for their group meetings for other online courses.
- Simulation scenarios played a major role in this course. Lecturers did not use the child avatars within the scenario and participants did not like it. It was clear that simulation environments should be created as detailed as possible - kid's hiding places, all house furniture's , if they play a role - for learning to be the most effective. Students wanted to always have different scenarios and mentioned that it would be nice to be thrown to a totally different set of events to improve their skills.
- It was noticed that the need to transfer teacher's class control and engaging tricks into the virtual environment is also very important. We should observe each teacher while they are lecturing in real life and make sure that we inform them on how to transfer these tricks into the virtual environment.

5 CONCLUSION

In this paper, we reviewed the experience of providing a course on domestic violence to healthcare professionals through a virtual environment. Our experience, although in preliminary phases, demonstrated the advantages of such approach particularly in flexibility of content and interaction methods, data measurement and analysis tools, immersiveness, and web integration without the need for physical presence or settings.

It was noticed that to be successful in simulation-type trainings, the virtual environment should be detailed enough in terms of what the participants do and use. Also ability to express personality and mood, customize the environment, and possibly better use of AI-based characters could improve the experience and so are the objectives of our future research.

The system provides us with a wealth of data. Our next steps are to structure this data more effectively, define and use clear evaluation criteria and metrics, and perform a quantitative analysis of the environment and its success as an educational tool.

Acknowledgements

The authors wish to thank researchers and instructors at Algonquin College, in particular Michelle Morley, Eleanor Riesen, Elizabeth Gilhooly, and John Willman, for their contribution and for providing the opportunity to work on this project. The authors are also grateful for the support they received from Avaya and the content developers, particularly the students at the School of Information Technology.

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