Computer-Supported Expert-Guided Experiential Learning Tool for Advanced Healthcare Skills

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Abstract

Healthcare professionals, just like any other community, can exhibit implicit biases. These biases adversely impact patients' health outcomes. Promoting awareness of both social determinants of health (SDH) and the impact of implicit/explicit biases assists healthcare professionals to understand their patients well and improve care experiences. In addition, it helps to augment the long-lasting empathy and compassion in healthcare professionals towards patients for care treatments while maintaining better healthcare professional-patient relationships. Thus, this research provides Computer-Supported Expert-Guided Experiential Learning (CSEGEL) tools or mobile applications that facilitate healthcare professionals with a first-person learning experience to augment advanced healthcare skills (e.g., professional communication, cultural humility, awareness of both SDH and impact of biases on health outcomes). The CSEGEL tools in the form of mobile applications incorporate virtual reality-based serious role-playing scenarios along with a novel Life Course module to deliver first-person experiential learning capability to augment the advanced healthcare skills of healthcare professionals and public awareness. Finally, a preliminary data analysis is provided to demonstrate the positive influence of CSEGEL tools and measure the required number of sample sizes for concrete evidence to show effective results.

Introduction

Health care plays an important role in improving the quality of life of an individual. Genetics and lifestyle have a significant influence in determining health outcomes, but the conditions in which people are born, grow, work, live, learn, play, and work are known as social determinants of health (SDH) [1] [2] and have a significant impact. According to World Health Organization (WHO) [1], several studies indicate that SDH accounts for between 30-55% of health outcomes. Skewed opinions about other individuals, especially those who do not belong to one's in-groups, develop over time and are frequently unfavorable [3]. The negative effects of implicit and explicit biases on marginalized populations in healthcare need ongoing attention and improvement [4][5] because healthcare professionals are no less prone to have biases than other people [6]. Moreover, physicians who are aware of their prejudices and practice perspective-taking and individuation skills may be able to minimize the effect of implicit bias on health care disparities [7] [8] [9] [10] [11]. Owing to that, it is essential to promote awareness about advanced healthcare skills (e.g., professional communication, cultural humility, awareness of both SDH and impact of biases on health outcomes), especially among healthcare professionals.

Furthermore, inadequate learning experience or lack of professional training may result in unpleasant care experiences and lessen the relationship between healthcare professionals and patients. Though "Experiential Learning" (EL) [12] or "learning by doing" is an important concept for improving education, it is not appropriate or ethical to utilize it directly in real life wherever high-risk care is essential [13]. Thus, it is favorable to develop learning tools that support digital experiential learning for a better educational experience for healthcare professionals. Research [14] has demonstrated that computer-supported experiential learning tool is an effective learning platform to improve cultural sensitivity in health care. Additionally, as shown in Figure 1, research [15] [16] has introduced the idea of integration of the virtual expert guide or instructor along with a role-playing game design for instant evaluation, better user learning experiences, and knowledge enhancement. Thus, inspired by previous research [14] [15] [16], we have designed and developed the Computer-Supported Expert-Guided Experiential Learning (CSEGEL) tools in the form of mobile applications to deliver the hands-on learning experience for improving advanced healthcare skills (e.g., professional communication, cultural humility, awareness of both SDH and impact of biases on health outcomes) for healthcare professionals and public awareness. The CSEGEL tools help to achieve objectives such as (1) overcoming the challenges of limited self-driven learning platforms to enhance advanced healthcare skills, (2) delivering learning mediums in the form of mobile applications that are affordable and easily available, and (3) providing effective training modules with the integration of virtual expert evaluation mechanism for knowledge enhancement.

(a) (b)

Figure 1. *Utilization of virtual expert guide in computer-supported experiential and cognitive learning tool. (a) Direct/Action-based communication module (b) Non-verbal behavioral communication module (Images courtesy of Dixit Bharatkumar Patel et al. [15] and [16]).*

In addition, CSEGEL tools or mobile applications contain virtual reality-based serious role-playing scenarios featuring two main virtual characters or patients (i.e., 1. Charles, a 60-year-old African American gay man; and 2. Ashley, an 18-year-old female with autism spectrum disorder) and their clinical visit experience along with the effective learning module called life course to enhance learners' (specifically healthcare professionals') understanding and awareness of advanced healthcare skills. In

CSEGEL tools, various role-playing scenarios with first-person viewing experience are included such as patient introduction, patient's preparation for the clinical visit, transportation to the clinic, and patient's clinical visit experience at the community health center, an encounter with a healthcare professional. Moreover, some assessment questionnaires are also included at various points in the game design to measure the effectiveness of our CSEGEL tools and observe the learning behavior of an application user.

Furthermore, we have collected preliminary experiential learning data from 6 physicians who have completed one of the two CSEGEL tools or mobile applications. IRB approval was obtained for this study. The participants' experiential learning data expresses the positive influence of our CSEGEL tools. Additionally, the T-Test Power Analysis is performed on the participants' experiential learning data to calculate the required sample sizes to demonstrate the statistically significant improvement through our CSEGEL tools.

Overall, our CSEGEL tools deliver an opportunity for learners to enhance their advanced healthcare skills (e.g., professional communication, cultural humility, awareness of both SDH and impact of biases on health outcomes) via going through the first-person virtual patients' clinical visit experiences on the mobile device (i.e., iPhone, iPad, Android Phone, or Tablet) at anytime and anywhere with the only requirement of Wi-Fi access. This paper further provides the technical summary of the design and development of our CSEGEL tools, the virtual reality-based serious role-playing games to deliver advanced healthcare skills for healthcare professionals and public awareness.

Approach

The primary goals and contribution of this research are to utilize concepts of recent breakthroughs in virtual reality, serious games, role-playing games, digital experiential learning, human-computer interaction (HCI), and mobile computing. By specifically utilizing the multi-modal capabilities of affordable and widely available Android and iOS smart devices (e.g., iPads, iPhones, Android phones, and tablets), our approach facilitates the virtual reality-based serious role-playing games that promote digital experiential learning and maximize the delivery of advanced healthcare skills and awareness. For healthcare professionals, offering the first-person viewing experience by utilizing the virtual clinical environment enhances learning and creates a lasting knowledge practice. Furthermore, by effectively using virtual reality-based hypothetical case scenarios with a variety of virtual characters, learning experiments can be carried out in a secure environment or without endangering real people, such as patients in healthcare settings.

Additionally, utilizing the digital experiential learning concept along with the expert-guided mechanism facilitates instant evaluation and improves the users' long-lasting learning experience. Further, by integrating concealed learning objectives with a fascinating structure of gameplay, the virtual reality-based serious role-playing game approach aids to convey self-driven and self-motivational learning which enables cognitive learning and behavioral change for learners. Moreover, using visual cues while playing minimizes the intricacy of the learning approach because it makes use of fewer explanation resources while still providing a successful learning practice. Lastly, combining intermediate assessment questionnaires into the game design also makes it easier to evaluate how well users are learning new material and how well CSEGEL tools work in the healthcare industry.

Designs

This study aims to design and develop Computer-Supported Expert-Guided Experiential Learning (CSEGEL) tools in the form of mobile applications that facilitate virtual reality-based serious role-playing scenarios to encourage and motivate healthcare professionals to acquire advanced healthcare skills (e.g., professional communication, cultural humility, awareness of both SDH and impact of biases on health outcomes) through iOS and Android mobile devices like iPads, iPhones, tablets, and Android phones. For this research, our design and development are inspired by the previous research [14] [15] [16] to produce an enhanced version of computer-supported experiential learning to deliver the advanced healthcare skills called Computer-Supported Expert-Guided Experiential Learning (CSEGEL). Importantly, our CSEGEL tools are in the form of two distinct mobile applications. Each mobile application or CSEGEL tool represents a virtual case scenario featuring either Charles or Ashley, a virtual character, and his/her clinical visit experience. A virtual case scenario featuring Charles, a 60-year-old African American gay man is hereinafter referred to as an "LGBTQIA+ case", whereas, a virtual case scenario featuring Ashley, an 18-year-old female with autism spectrum disorder and mild intellectual disability is hereinafter referred to as an "ASD case".

Skill Acquisition Goals

In addition to the earlier mentioned objectives, our CSEGEL mobile applications (i.e., LGBTQIA+ and ASD cases) facilitate learners to acquire learning skills such as (1) gaining an appreciation of the challenges faced by both persons identifying as LGBTQIA+ and autistic persons as they transition into adulthood (2) Recognize how social determinants of health can exacerbate challenges faced by persons identifying as LGBTQIA+ and autistic persons (3) Recognize how implicit biases can affect the experience of persons identifying as LBGTQIA+ and autistic persons in the healthcare setting (4) Recognize that understanding an individual's unique life experiences can decrease vulnerability to the impact of implicit biases and increase compassion for the individual.

High-Level Block Diagram of Application Workflow

Both virtual case scenarios (i.e., LGBTQIA+ and ASD cases) have similar high-level design workflow as shown in Figure 2. On application start, the web server is requested to provide a session number (token) in the back end and application users', or learners' demographic data is collected. Following that, Dr. Erika Parker, a virtual expert guide, or instructor, introduces herself to the learner or application user and instructs them to proceed with the role-playing scenarios. A brief introduction of the patient (i.e., Charles in the LGBTQIA+ case or Ashley in the ASD case) is given in the first role-playing scene or section of the game flow to make aware or alert the application user about the patient's reason for a clinical visit to the community health center. During the patient introduction scene, the learner will get a first-person viewing experience from the perspective of the healthcare provider. After that, the first assessment questionnaire is given to determine how the learner (specifically healthcare professionals) feels about accepting this individual as their next patient and how they feel about the patient as introduced.

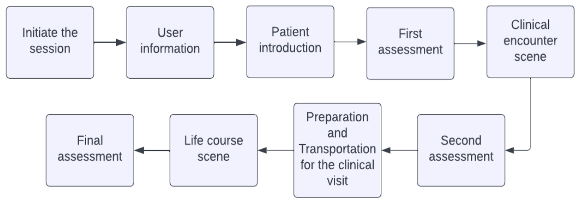


Figure 2. *High-level block diagram of application design workflow for both virtual case scenarios* (i.e., LGBTQIA+ and ASD cases)*.*

Subsequently, in the clinical encounter scene, a learner gets an opportunity to interact with the virtual patient in the virtual clinical setting as a serious role-playing module. Furthermore, the learner is given a second assessment questionnaire to identify any improvement in the learning experience. Later, the learner is facilitated with multiple first-person viewing role-playing scenes from the perspective of the patient including (1) the patient's preparation for clinical appointment and transportation to the health center and (2) the patient's check-in experience at the health center. Next, the Life Course scene is provided in the game design to highlight the important social determinants of the health of the patient. Lastly, the final assessment questionnaire is given to observe the knowledge enhancement of the learner. Importantly, between each scene transition, Dr. Erika Parker educates learners about outcomes of barriers, biases, discrimination, assumptions, microaggression, etc. to improve the learning skills of healthcare professionals.

Features

This research carries the virtual reality-based Computer-Supported Expert-Guided Experiential Learning (CSEGEL) tools or mobile applications in the form of mobile serious role-playing games that integrate a variety of important technology enabling features (e.g., virtual environment, virtual characters, interactive virtual reality-based serious role-playing scenarios, visual cues, virtual expert guide, life course module, and easy accessibility and availability) to facilitate an easy but effective learning experience for learners as described below.

Implementation Of Virtual Environment

For a variety of objectives, including healthcare, using the virtual environment in digital learning platforms is advantageous. These include evaluation and treatment, educating the public about various ailments, and training medical professionals. Learners can remain enthusiastic and involved throughout the gameplay by using a virtual environment in a serious role-playing game. The virtual world helps to deliver a better learning experience and relate to real-world circumstances while simultaneously understanding and improving their academic and professional skills. Using lifelike virtual objects in the virtual environment, players can experiment with and test out a variety of healthcare treatments. Additionally, it facilitates the incorporation of complex real-world objects into virtual form, enhancing the development of a variety of case studies based on realism for serious role-playing games. Our mobile applications or CSEGEL tools utilize the above-mentioned features and advantages of virtual environments to engage learners in virtual case scenarios and provide an advanced learning experience through mobile devices. To illustrate, Figure 3 demonstrates distinct examples (e.g., clinic reception desk, clinic hallway, drawing room, Kitchen) of the utilization of virtual environments in our mobile applications.

Implementation Of Virtual Characters

The CSEGEL tools utilize virtual realistic characters, such as patients and peers, which enable the efficient delivery of clinical practices and education in healthcare. Virtual personas help players maintain engagement and focus while learning new skills through gameplay. Additionally, virtual characters and a virtual world combinedly improve serious role-playing game design, learners can revisit the application to advance their learning experience and gain knowledge enrichment wherever they like. Furthermore, virtual characters can interact and have meaningful conversations with players during the hands-on experience of the game. Thus, our CSEGEL mobile applications utilize the benefits of the integration of virtual characters in the game design to provide an enhanced learning experience for application users. To illustrate, Figure 3 demonstrates distinct examples of the utilization of virtual characters (e.g., receptionist, medical assistant, peers of Charles and Ashley) in our mobile applications.

Figure 3. *Illustrations of the virtual environment and virtual characters utilized in the game design.*

Deployment of Visual Cues

The assimilation of visual cues in the digital experiential learning mechanism plays a vital role in an educational purpose. Especially for healthcare-related learning tools, visual cues are a critical and challenging aspect to deliver learning objectives. In CSEGEL tools, visual cues are indications that help a learner comprehend the various effects of their actions, interactions, and choices. To illustrate, visual cues can be anything that appears on screen, such as virtual objects, symbols, graphics, subtitles, thought bubbles, changes in character behavior, facial/body emotions, etc. that facilitate learners as a better explanation medium about the ongoing situation in the virtual case scenario. Furthermore, since visual cues are easier to decipher than actual text, they encourage participation and engagement with the learning platform, which enhances knowledge enrichment. However, visual cues may need specialized skills or knowledge to interpret the hidden message in the gameplay. Figure 4 shows the distinctive visual signals that we used in our CSEGEL tools or mobile applications to help learners educate more effectively.

One of the valuable visual cues is the "Psychological Safety Meter" used in the serious role-playing segment or clinical encounter with the virtual patient (i.e., Charles or Ashley). The purpose of the psychological safety meter in the game design is to indicate the level of psychological safety a virtual patient is feeling. A psychologically safe environment is one in which an individual feels like they belong, that they are valued and understood and that they will not be judged for their thoughts or opinions. In the health care setting, the presence or absence of psychological safety affects the extent to which patients feel that they matter or are cared about, an important component of the clinician-patient relationship. This can affect the patient's willingness to be honest and forthright and may subsequently impact adherence to a treatment plan. Evidence of biases toward minority or marginalized groups functions as threat cues, contributing to a psychologically unsafe environment. Thus, the choices made by the learner throughout the clinical encounter will affect the psychological safety of the virtual patient and will be reflected by the psychological safety meter.

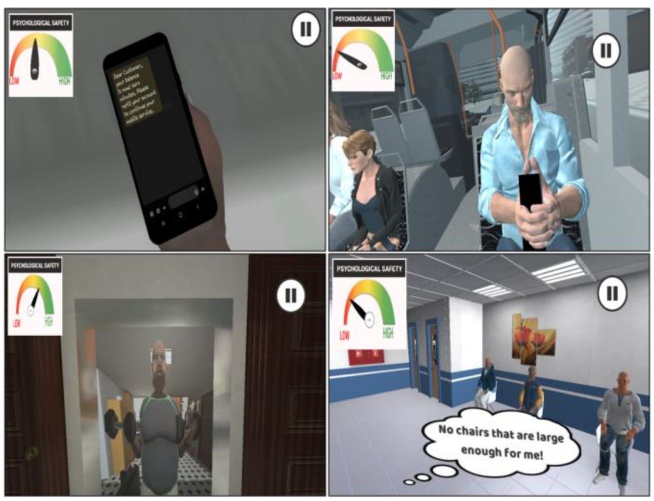
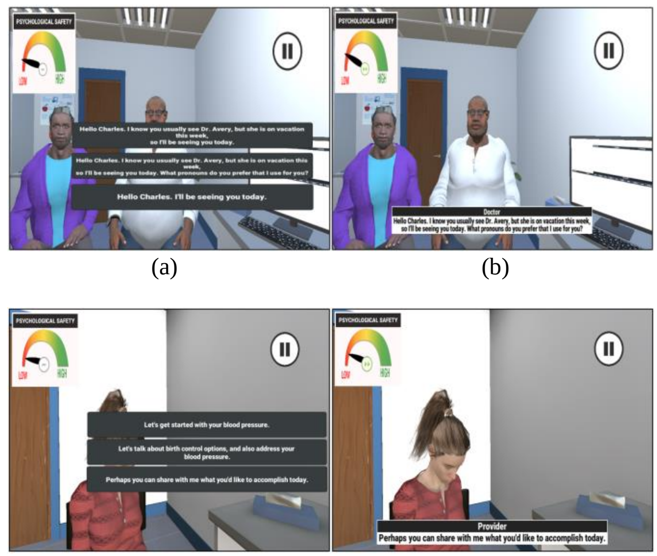


Figure 4. *Illustrations of visual cues (e.g., captions, facial or body expressions, thought bubbles, psychological safety meter) that are utilized in the game design.*

Adaptation Of Interactive Serious Role-Playing Segment

Both the virtual realistic case (i.e., LGBTQIA+ and ASD case) scenarios demonstrated in our mobile applications or CSEGEL tools include the serious role-playing segment (i.e., the clinical encounter with the virtual patient) and facilitate the first-person viewing experience from the perspective of healthcare provider during the clinical visit of the virtual patient (i.e., Charles or Ashley). In the serious role-playing segment, the learner plays the role of a healthcare provider and gets an opportunity to provide health care to the virtual patient via scripted interaction. To interact with a virtual patient, the user is provided with multiple conversational choices. Thus, this segment helps learners to achieve virtual care practice in a safe environment as it does not harm a real-life patient for obtaining advanced healthcare skills or improving healthcare practices.

An important visual cue, a psychological safety meter, is added during the serious role-playing segment or clinical encounter with a virtual patient. As explained earlier, psychological safety helps learners to understand whether the selected choice during the interaction made by them delivers a positive or negative impact on the virtual patient's health. Thus, virtual clinical encounter practice assists improve the learner's awareness and understanding of the difficulties and severity of the patients. It also aids in educating learners about the advancement of professional skills. For instance, students can research how the professional communication gap affects patient care and lifestyle choices, the implications of implicit and explicit biases on health outcomes, and the influence of social determinants of health (SDH). Moreover, this serious role-playing segment benefits learners to understand the importance of empathetic communication while interacting with the real-life patient. Figures 5(a) and 5(b) demonstrate the instances of the clinical encounter between the learner (who plays the role of healthcare provider) and the patient in the LGBTQIA+ case, whereas figures 5(c) and 5(d) demonstrate the ASD case.



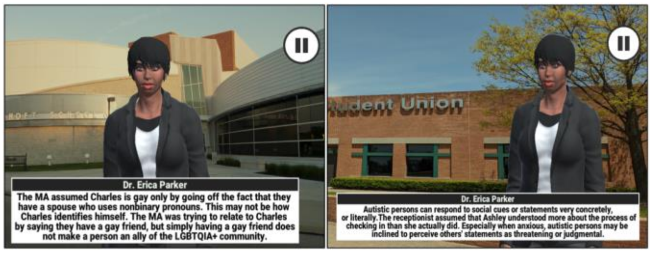
(a) (b)

(c) (d)

Figure 5. *Illustrations of interactive virtual reality-based serious role-playing scenarios utilized in the game design. (a) and (b) represent LGBTQIA+ case, whereas (c) and (d) represent ASD case.*

Deployment of Virtual Expert Guide or Instructor

The CSEGEL tools or mobile applications (i.e., LGBTQIA+ and ASD cases) described in this research integrate the idea of a virtual expert guide or instructor (motivated by [15] [16]) to deliver a better learning experience to healthcare professionals or learners. In addition, owing to the limitations of availability of real-life professional or expert trainers at anytime and anywhere, our CSEGEL tools deploy the virtual expert guide (hereinafter referred to as Dr. Erica Parker) to instruct the learner throughout the hands-on learning experience through our mobile applications. Specifically, Dr. Erica Parker assists in further delivering important awareness and understanding of various aspects of advanced healthcare skills such as the influence of social determinants of health and the impact of implicit/explicit biases on health outcomes. Moreover, Dr. Erica Parker educates learners about outcomes of barriers, discrimination, assumptions, and microaggression to improve the learning skills of learners or healthcare professionals. Thus, virtual expert trainer facilitates learners with additional opportunity to improve their knowledge and awareness along with the virtual reality-based role-playing segments in our CSEGEL tools. To illustrate, Figures 6(a) and 6(b) demonstrate the instances where Dr. Erica Parker educates learners or application users in LGBTQIA+ and ASD cases respectively.



(a) (b)

Figure 6. *Illustrations of an expert guide (i.e., Dr. Erica Parker) educates learners in (a) LGBTQIA+ case and (b) ASD case.*

Implementation of Life course Module

It is critical to comprehend the impact of social determinants of health to improve care experiences. No matter the patient's demographic background, including modules that raise awareness about their past experiences can serve to highlight the social determinants of health and increase empathy and compassion for them. A Life Course module describes the patient's life experience in more detail. The primary purpose of the Life Course module in the application game design is to immerse the learner (specifically healthcare professional) into the past life experiences or events at distinct age instances of the main virtual character. Thus, the Life Course module acts as an effective tool for conveying the learning experience from the game to the end-user.

Each virtual realistic case (i.e., LGBTQIA+ or ASD case) scenario in our CSEGEL tools or mobile applications has a Life Couse module that demonstrates the past life experiences at distinct age instances of a main virtual character (i.e., Charles in the LGBTQIA+ or Ashley in the ASD case) along with the past life experiences or events at the same age of another privileged companion character (i.e., Christopher in LGBTQIA+ case and Sarah in ASD case). The main virtual characters (i.e., Charles and Ashley) are overall underprivileged compared to the companion characters (Christopher and Sarah).

The events presented in the Life Course are chosen to be striking and memorable. They intend to evoke emotions that will act as a supplement to the simulation's learning experience. Our Life Course module is designed as a booklet that features a series of illustrations in the form of images and video clips that represent certain events that happened to the main virtual characters throughout their life. The events shown in the images usually have some location in the background (e.g., house, school, apartment, playground) with the character(s) or object(s) in the foreground. Utilized characters in the events are represented in a mood (e.g., happy, sad, excited) by the event type. Our design of the Life Course module allows learners to visit previous and next events at any time during the life span of the Life Course scene in the application.

Life Course module offers learners an opportunity to experience the past journey of the patients to better comprehend them as an individual and address other crucial factors like the impact of social determinants of health. As a result, the life course module is essential in forging a bond between the learner (specifically healthcare professional) and patient, which fosters the augmentation of compassion, empathy, and care experiences. Moreover, it eventually helps to reduce prejudice and health disparities.

Figure 7 shows the illustration of an event of the Life Course module in the LGBTQIA+ case scenario. It depicts that at age 11, Charles is underprivileged compared to Christopher. Figure 8 shows the illustration of an event of the Life Course module in the ASD case scenario. It depicts that at age 8, Ashley is underprivileged compared to Sarah.

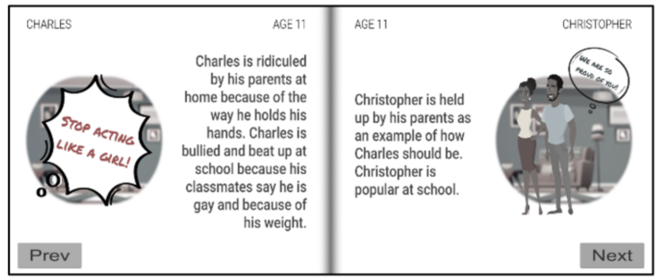


Figure 7. *Illustration of a Life Course module in the LGBTQIA+ case.*

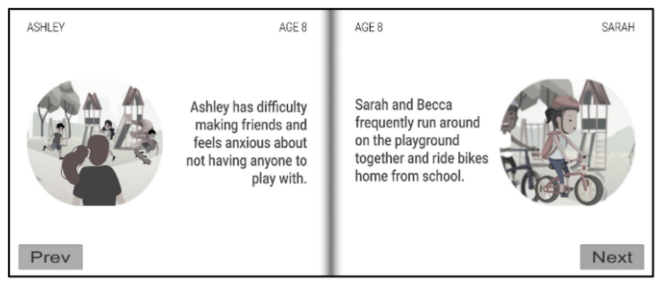


Figure 8. *Illustration of a Life Course module in the ASD case.*

Easy Accessibility and Availability

Ease of accessibility and availability is the next valuable component of this research. Learning is more efficient when users can do it at their own pace. Learners may need or want to examine their learning experiences at any time, it is essential that computer-supported expert-guided experiential learning tools are easily accessible and available. As a result, this research disseminates the mobile application that enables users of iOS and Android devices (such as iPhones, iPads, tablets, and Android phones) to receive advanced healthcare skills training at any time and from any location with an internet connection.

Challenges and Optimization

For the development of this research, we have utilized different software tools such as Unity Game Engine [17] for the development of virtual reality-based role-playing scenarios and Reallusion products (e.g., iClone and Character Creator) [18] for the development of virtual characters and their animations. Along the design and development path, we have encountered various challenges and utilized various optimization techniques to effectively work on mobile devices (i.e., iPhones, iPads, Android phones, and tablets) and improved the application interface for a better learning experience.

Eliminate Server Dependencies for Life Course Module

Our Life Course module is an advanced version of the Life Course module developed in [12] with a new design, well descriptive, and an easy-to-use approach. Moreover, our CSEGEL approach integrates the Life Course module inside the application itself instead of depending on the webserver for running the Life Course module utilized in previous research [12]. So, our Life Course module is not dependent on additional server availability to mitigate the challenge of running the application without any interruptions like server crash issues.

Virtual Character Optimization

Virtual characters need to be of high quality and realistic in appearance and behavior for them to have a stronger impact on the players. The application's overall size must be controlled while ensuring the simulation runs properly, therefore minimizing avatar memory utilization is essential. In computer graphics, the mesh is used to generate the framework for the body, clothing, and every other kind of object. Polygons, which are triangles, make up mesh. The quality of the character increases with the number of vertices and polygons. Although the file size will increase if the quality is higher. The performance of the game is further hampered by scenes with many characters. Additionally, high-quality characters frequently have more textures, which raises the number of draw calls and slows down game rendering. As a result, virtual characters' optimization is essential. One of the important ways we utilized to optimize the virtual characters is polygon reduction with the Insta LOD feature facilitated in the Reallusion Character Creator tool.

(a) (b)

Figure 9. *Illustrations of utilized Insta LOD polygon reduction approach for optimization of virtual characters. (a) 62,967 triangles Initially on a virtual character without polygon reduction with Insta LOD feature applied and (b) 37,085 triangles Initially on a virtual character without polygon reduction with Insta LOD feature applied.*

Virtual Role-Playing Scenes Optimization

To further optimize our application, we have utilized other optimization techniques, such as scene segmentation and occlusion culling, in the Unity Game Engine. Scene segmentation helps to divide the scenes so that only a portion of the whole virtual case scenario can be played individually in the device memory and hence, reduces the memory utilization at any instance of time during the application playing session.

In addition, occlusion culling is another optimization technique facilitated by Unity Game Engine that we have used to improve the application performance. Occlusion culling aids in eliminating unnecessary rendering operations for game objects that are concealed from view by the camera for the relevant scene running in the device memory. Also, it enables CPU and GPU time savings by avoiding unnecessary rendering operations. To exemplify, Figures 10 and 11 depict a specific situation from our LGBTQIA+ case application where Charles enters the community health facility and walks toward the reception desk. As demonstrated in Figure 10, without the deployment of the occlusion culling technique, 671.6k vertices and 759.3k triangles are generated. Additionally, the number of rendering passes (i.e., Setpass calls) is 517 and the time spent on the CPU along with its rendering thread is 23.5ms.

Figure 10. *Illustration of a game instance (i.e., clinic visit scene in LGBTQIA+ case) without the utilization of occlusion culling optimization technique.*

As demonstrated in Figure 11, with the deployment of the occlusion culling technique, 593.3k vertices and 704.1k triangles are generated. Additionally, the number of rendering passes (i.e., Setpass calls) is 344 and the time spent on the CPU along with its rendering thread is 11.1ms. Hence, occlusion culling improves application performance. It is significant to note that performance may vary for various scenes depending on how the game objects are used for the scenes that are active in the device memory at any one time at a particular time.

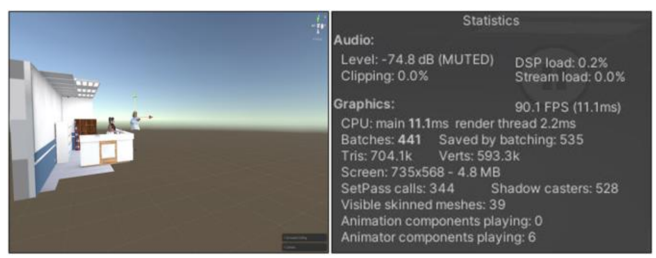


Figure 11. *Illustration of a game instance (i.e., clinic visit scene in LGBTQIA+ case) with the utilization of occlusion culling optimization technique.*

Data Acquisition and Analysis

To analyze the efficiency of our Computer-Supported Expert-Guided Experiential Learning approach (or mobile applications) and the participants' learning experience, we have developed and incorporated three (i.e., First, Second, and Final) surveys or assessment questionnaires in both applications (i.e., LGBTQIA+ and ASD cases) where the first assessment questionnaire is given to the participant on the start of the application (right after providing the introduction of the virtual patient), the second assessment is given to the participant after the clinical encounter with a virtual patient, and the final assessment questionnaire is provided after the successful completion of all the role-playing scenarios. Sample portions of the first and final assessment questionnaires are shown in Figure 12. In each application, the first, second, and final assessment questionnaires contain many similar and other additional questions. The responses that will be collected through these assessment questionnaires help to observe the behavior change and learning experience of a learner before, in middle (or during), and after going through our serious role-playing case scenarios (i.e., LGBTQIA+ and ASD cases).

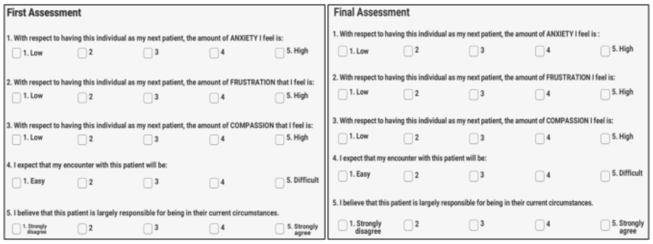


Figure 12. *Illustration of a portion of assessment questionnaires integrated into one of our CSEGEL tools (e.g., LGBTQIA+ or ASD case).*

As a part of the initial survey or data collection, we have temporarily utilized Apple's TestFlight [19] feature to distribute both of our applications to certain participants. There are 6 physicians who took part in the initial survey and have completed one of the two case scenarios or applications. This research provides the T-Test Power Analysis performed on these 6 samples as preliminary results collected in the initial survey. The T-Test Power Analysis suggests that our CSEGEL approach or mobile applications may deliver significant positive or improved influence on users and help to achieve the learning objectives of our application as described below.

T-Test Power Analysis

Our initial survey or data collection shows the positive result of our CSEGEL approach. However, with the help of these initial survey results or data points, we have determined the total number of sample sizes or data points that would be required to provide concrete evidence for the positive effect of our applications. Thus, we have performed the T-Test Power Analysis on the collected samples from all three (i.e., First, Second, and Third) assessment questionnaires or surveys. To achieve the T-Test Power Analysis, we have chosen the Significance Level (alpha) as 5% or 0.05 and Statistical Power as 80% or 0.08 for the entire analysis. Also, to get the effect size values, the Cohen's D values are generated for the respected analysis.

Furthermore, in this analysis, we focus on the most relevant questions listed in Table 1. The sequence of these questions is not synced as existed in the applications. Thus, all the discussions related to the question numbers represent question indices given in Table 1.

Table 1: Assessment questions utilized in the analysis

Index	Question	User Response Options or Levels
1	With respect to having this individual as my next patient, the amount of FRUSTRATION I feel is:	1 (Low) To 5 (High)
2	With respect to having this individual as my next patient, the amount of COMPASSION I feel is:	1 (Low) To 5 (High)
3	I believe that this patient is largely responsible for being in their current circumstances:	1 (Strongly disagree) To 5 (Strongly agree)
4	I attempt to act in nonprejudiced ways toward patients like this because it is personally important to me.	1 (Never) To 5 (Always)
5	I consider discrimination to be a serious social problem.	1 (Strongly disagree) To 5 (Strongly agree)
6	I believe that I have biases toward certain types of people/patients.	1 (Strongly disagree) To 5 (Strongly agree)
7	As a result of this simulation experience, I would be comfortable interacting with a patient/client similar to the one in the simulation scenario in my clinical or non-clinical role in the future.	1 (Strongly agree) To 5 (Strongly disagree)
8	This simulation experience equipped me with new knowledge and resources to apply in my clinical/non-clinical practice to improve the care experience and reduce health disparities for my patients/clients.	1 (Strongly agree) To 5 (Strongly disagree)
9	I will apply at least one new thing that I learned from this simulation experience in my clinical/non-clinical practice.	1 (Strongly agree) To 5 (Strongly disagree)
10	I feel that this simulation met all of the learning objectives listed above.	1 (Strongly agree) To 5 (Strongly disagree)

Questions 7 to 10 are only available in the Final Survey questionnaires and hence, these questions are not included in the T-Test Power Analysis explained below. However, the analysis of questions 7 to 10 is separately described in Figure 15. The following three subsections explain the T-Test Power Analysis performed on the initial survey responses collected for questions 1 to 6.

T-Test Power Analysis between First and Second Assessment Questionnaires

The observations with T-Test Power Analysis between the first and second assessment questionnaires can be seen in Figure 13. This analysis is generated from the initial survey responses for questions 1 to 4. The effect size or Cohen's D values obtained for the responses to questions 5 and 6 are 0 and hence, they are not included in Figure 13. The calculated Cohen's D values and required sample size are given in Table 2 with respect to questions 1 to 4.

Table 2: Cohen's D values and required sample size obtained from the first and second assessment questionnaires' responses

Question Index	Cohen's D value or Effect Size	Required Sample Size

1	0.83	23.79
2	0.92	19.55
3	0.24	273.49
4	0.39	104.18

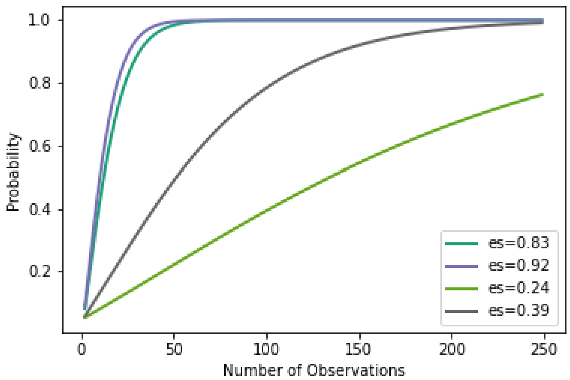


Figure 13. *T-Test Power analysis results were obtained from the first and second assessment questionnaires.*

Table 2 and Figure 13 depict that with the required number of sample size or data points we may observe a significant improvement in users' learning experience (that includes reduction of frustration while dealing with patients like Charles or Ashley in real-life, increasing compassion towards them, acquire understanding about their circumstances, and awareness to act in nonprejudiced ways towards them) in the application flow between the first and second assessment questionnaires.

T-Test Power Analysis between Second and Final Assessment Questionnaires

The observations with T-Test Power Analysis between the second and final assessment questionnaires can be seen in Figure 14. This analysis is generated from the initial survey responses for questions 2 to 6. The effect size or Cohen's D values obtained for the responses to question 1 is 0 and hence, it is not shown in Figure 14. The calculated Cohen's D values and required sample size are given in Table 3 with respect to questions 2 to 6.

Table 3: Cohen's D values and required sample size obtained from the second and final assessment questionnaires' responses

Question Index	Cohen's D value or Effect Size	Required Sample Size
2	0.76	28.17
3	0.22	325.3
4	0.63	40.53
5	0.39	104.18
6	0.55	52.87

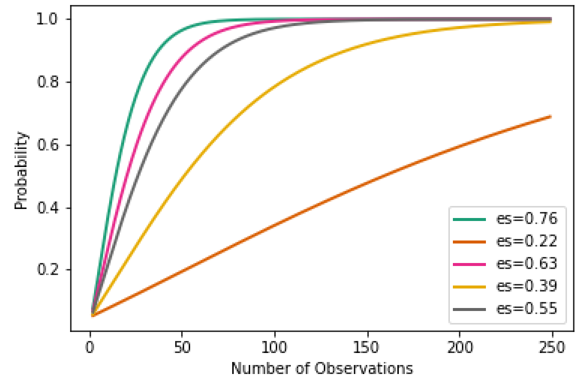


Figure 14. *T-Test Power analysis results were obtained from the second and final assessment questionnaires.*

Table 3 and Figure 14 illustrate that with the required number of sample sizes or data points we may observe a statistically significant improvement in the participants' learning experience (that includes increasing compassion towards patients like Charles or Ashley in real-life, elevating understanding of their circumstances, consciousness to act in nonprejudiced ways towards them, awareness on discrimination, and identify own biases) in the application flow between the second and final assessment questionnaires.

T-Test Power Analysis between First and Final Assessment Questionnaires

The observations with T-Test Power Analysis between the first and final assessment questionnaires can be seen in Figure 15. This analysis is generated from the initial survey responses for questions 1 to 6. The calculated Cohen's D values and required sample size are given in Table 4 with respect to questions 1 to 6. This part of the analysis is precisely important as it delivers the overall learning outcomes of our CSEGEL approach or mobile applications.

Table 4: Cohen's D values and required sample size obtained from the first and final assessment questionnaires' responses

Question Index	Cohen's D value or Effect Size	Required Sample Size
1	0.83	23.79
2	1.46	8.44
3	0.45	78.49
4	1.00	16.71
5	0.39	104.18
6	0.55	52.87

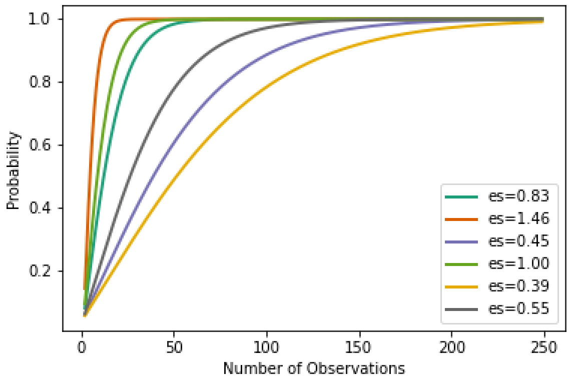


Figure 15. *T-Test Power analysis results were obtained from the first and final assessment questionnaires.*

Table 4 and Figure 15 demonstrate that with the required number of sample sizes or data points we may observe a statistically significant improvement in the participants' learning experience (that includes reduction of frustration while dealing with patients like Charles or Ashley in real life, increasing compassion towards them, acquire understanding about their circumstances, consciousness to act in nonprejudiced ways towards them, awareness on discrimination, and identify own biases) in the overall application flow.

Additional Statistical Analysis

The preliminary collected participant data has shown that the CSEGEL approach or mobile applications help to deliver a positive learning experience to learners or users. This section provides the statistical summary analysis performed on the preliminary users' data as shown in Figure 16.

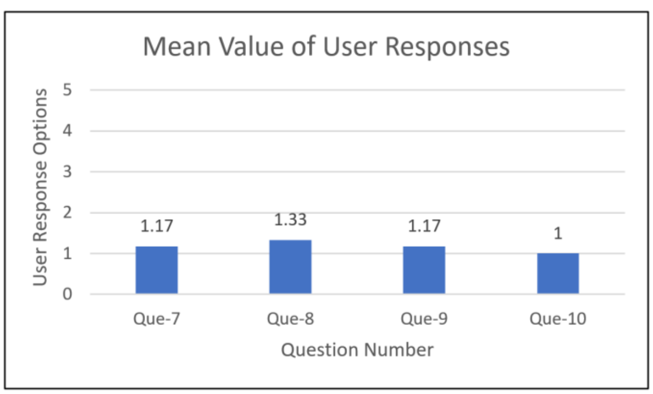


Figure 16. *Statistical analysis for questions 7 to 10.*

Figure 16 illustrates the mean values of users' responses to questions 7 to 10. This result demonstrates that preliminary data shows positive outcomes for the participants' learning experience as a result of our CSEGEL approach.

Application Distribution

As our mobile applications are supported on different iOS and Android-supported devices (i.e., iPhones, iPads, Android phones, and tablets), we are in the process of making our mobile applications publicly available on App Store and Google Play Store platforms so that we can be able to reach out to many users and contribute to achieving the objectives of our learning tools and CSEGEL approach.

Future work

Future work includes further applying optimization strategies to advance the learning experience and reduce the computer memory utilization of our applications. Additionally, the implementation of concepts like natural language processing technology, augmented reality, and immersive virtual reality in the CSEGEL game design can lead the user to achieve the next level of the learning experience. Once the application is utilized by a greater number of people and the survey is completed, we will be able to analyze the resulting data to demonstrate the further efficiency of our CSEGEL approach or mobile applications.

Conclusion

This research provides the Computer-Supported Expert-Guided Experiential Learning (CSEGEL) tools, the virtual reality-based serious role-playing games in the form of mobile applications to facilitate advanced healthcare skills (e.g., cultural humility, professional communication, awareness of social determinants of health and impact of implicit/explicit biases on health outcomes, etc.) to healthcare professionals and public awareness. Additionally, integrated realistic virtual case scenarios (i.e., LGBTQIA+ and ASD cases) with first-person viewing experience increase the understanding of patients' perspectives and helps to augment the compassion and empathy in learners (specifically healthcare professionals) toward real-life patients which eventually benefit promoting health equity. Furthermore, utilization of the virtual expert guide or instructor in the game design facilitates learners to augment the long-lasting knowledge and skills to implement further in real-life. Finally, the preliminary statistical data analysis demonstrates that our CSEGEL tools are delivering a positive influence on users' advanced healthcare skills development. The T-Test Power analysis provides the number of sample sizes required to show statistically significant improvement in the participants' advanced healthcare skills through our CSEGEL tools.

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Mark Allow is a Software Developer and User Interface / User Experience Designer. Previously receiving a bachelor's degree in Marketing at Wright State University, Mark is now finishing a Computer Science Master's Degree in his alma mater. Mark created designs for numerous web platforms and participated in their front- and back-end development cycles. Mark is always trying to explore new horizons, whether it's a new technology or a new part of the world.

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