https://doi.org/10.2352/EI.2023.35.1.VDA-399

Computer-Supported Expert-Guided Experiential Learning-Based Tools for 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 social determinants of health (SDH) and the impact of implicit/explicit biases assists healthcare professionals in understanding their patients well and improving 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) approach-based tools or mobile applications that facilitate healthcare professionals with a first-person learning experience to augment healthcare skills (e.g., awareness of the importance of cultural humility, inclusive communication proficiencies, awareness of the enduring impact of social determinants of health and impact of implicit/explicit biases on health outcomes, and compassionate and empathetic attitude). The CSEGEL approach-based mobile applications incorporate virtual reality-based serious role-playing scenarios along with a novel Life Course module to deliver digital experiential learning capability to augment the healthcare skills of healthcare professionals and for public awareness. Finally, a preliminary data analysis is provided to demonstrate the positive influence of CSEGEL approach-based mobile applications for improving healthcare skills and measure the required sample sizes (i.e., the number of participants' data samples) 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 healthcare skills (e.g., awareness of the importance of cultural humility, inclusive communication proficiencies, awareness of the enduring impact of social determinants of health and impact of implicit/explicit biases on health outcomes, and compassionate and empathetic attitude), especially among healthcare professionals.

Furthermore, deficient learning experience or lack of professional training of healthcare professionals 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 approach for improving education, it is less 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 a digital experiential learning approach for delivering a better educational experience to 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 illustrated in Figure 1, Dixit Bharatkumar Patel et al. [15] [16] have introduced the computer-supported expert-guided experiential learning (hereinafter referred to as CSEGEL) approach in their digital experiential learning tool which has introduced the idea of integrating the virtual expert guide or instructor and instant/real-time evaluation mechanism along with a serious role-playing game design that facilitates the learners for the better user learning experience and knowledge enhancement. Thus, inspired by and utilizing the concepts from the previous research [14] [15] [16], this research provides Computer-Supported Expert-Guided Experiential Learning (CSEGEL) approach-based tools (or mobile applications or serious role-playing games) to deliver hands-on learning experience and improve healthcare skills (e.g., awareness of the importance of cultural humility, inclusive communication proficiencies, awareness of the enduring impact of social determinants of health and impact of implicit/explicit biases on health outcomes, and compassionate and empathetic attitude) of healthcare professionals and for public awareness. Our CSEGEL approach-based mobile applications help to achieve objectives such as but are not limited to (1) overcoming the challenges of limited self-driven learning platforms to enhance the healthcare skills of healthcare professionals, (2) delivering learning mediums in the form of mobile applications that are easily available, affordable, and accessible, and (3) providing effective training modules with the integration of virtual expert guided evaluation mechanism for the learners' knowledge enhancement.

In addition, CSEGEL approach-based mobile applications comprise 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 an effective learning module called Life Course to enhance learners' (specifically healthcare professionals') understanding and awareness of healthcare skills. In our CSEGEL approach-based mobile applications, various role-playing scenarios with first-person viewing experience are included as but not limited to the patient introduction, patient's preparation for the clinic visit, transportation to the clinic, and patient's clinic visit experience at the community health center, and an encounter with healthcare professionals or workers (e.g., health care provider, medical assistant, and medical receptionist). Moreover, a few surveys or assessment questionnaires are included at various stages in our mobile applications to measure the effectiveness of our CSEGEL approach-based tools and observe the learning experience of our application users.

(a) (b)

Figure 1. *Integration of virtual expert guide and real-time evaluation mechanism in the computer-supported expert-guided 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]).*

Furthermore, we have collected preliminary experiential learning data from 6 physicians who have participated in one of our two CSEGEL approach-based tools or mobile applications and completed the learning modules. The Institutional Review Board (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 (i.e., the number of participants' data samples) to demonstrate the statistically significant improvement through our CSEGEL approach-based tools.

Overall, our CSEGEL approach-based tools or mobile applications deliver an opportunity for learners to enhance their healthcare skills (e.g., awareness of the importance of cultural humility, inclusive communication proficiencies, awareness of the enduring impact of social determinants of health and impact of implicit/explicit biases on health outcomes, and compassionate and empathetic attitude) 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 mobile applications, the virtual reality-based serious role-playing games to deliver 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 healthcare skills and awareness. For healthcare professionals, offering the first-person viewing experience by utilizing the virtual realistic clinical environment enhances learning outcomes 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 safe/risk-free 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 (inspired by [15] [16]) 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 aids to convey self-driven and self-motivational learning which enables cognitive learning and behavioral change for learners. Moreover, integrating the visual cues in the mobile application or serious role-playing game design 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 approach-based mobile application or serious role-playing game work in the healthcare industry.

Designs

This study aims to design and develop Computer-Supported Expert-Guided Experiential Learning (CSEGEL) approach-based tools in the form of mobile applications that facilitate virtual reality-based serious role-playing scenarios for delivering healthcare skills (e.g., awareness of the importance of cultural humility, inclusive communication proficiencies, awareness of the enduring impact of social determinants of health and impact of implicit/explicit biases on health outcomes, and compassionate and empathetic attitude) to healthcare professionals through iOS and Android platform supported mobile devices like iPads, iPhones, tablets, and Android phones. For this research, our mobile applications' design is inspired by and utilizes the concepts of the previous research [14] [15] [16] to produce a digital experiential learning tool based on the Computer-Supported Expert-Guided Experiential Learning (CSEGEL) approach to deliver healthcare skills. Importantly, our CSEGEL approach-based tools are in the form of two distinct mobile applications. Each mobile application represents a hypothetical virtual case scenario featuring either Charles or Ashley, a (hypothetical) virtual character or patient, and demonstrates his/her clinic visit experience. A virtual case scenario featuring Charles, a 60-year-old African American gay man is hereinafter referred to as "Charles's case" (or "LGBTQIA+ case"), whereas, a virtual case scenario featuring Ashley, an 18-year-old female with autism spectrum disorder is hereinafter referred to as an "Ashley's case" (or "ASD case").

Skill Acquisition Goals

In addition to the earlier mentioned objectives, our CSEGEL approach-based tools or mobile applications (i.e., Charles's case and Ashley's case) facilitate learners to acquire learning skills such as (1) gaining an appreciation of the challenges faced by both persons identifying as LGBTQIA+ and autistic individuals (or individuals with an autism spectrum disorder) as they transition into adulthood (2) Recognize how social determinants of health can exacerbate challenges faced by persons identifying as LGBTQIA+ and autistic individuals (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 that individual.

High-Level Block Diagram of Application Workflow

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

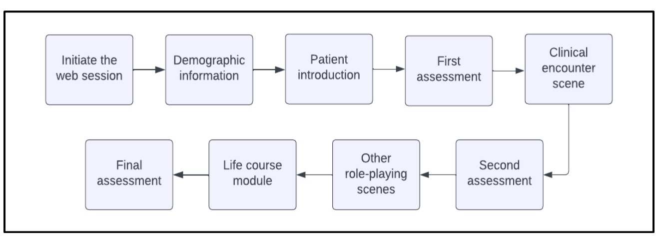


Figure 2. *High-level block diagram of application design workflow for both hypothetical virtual case scenarios (i.e., 1. Charles's case or LGBTQIA+ case, and 2. Ashley's case or ASD case).*

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-based role-playing scenes from the perspective of the virtual 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 module or scene is provided in the mobile application or 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 some critical elements such as but not limited to barriers, biases, discrimination, assumptions, and microaggression to improve the learning skills of healthcare professionals and for public awareness.

Features

This research carries the virtual reality-based Computer-Supported Expert-Guided Experiential Learning (CSEGEL) approach-based tools integrate a variety of important technology-enabling features (e.g., virtual environment, virtual characters, interactive serious role-playing scenarios, visual cues, virtual expert guide, Life Course module, and some additional features such as easy accessibility, availability, affordability, and scalability) to facilitate effective learning experience for learners as described below.

Implementation Of Virtual Environment

For a variety of objectives, including health care, utilization of the virtual environment in digital experiential learning platforms is advantageous. These include but are not limited to the evaluation and treatment, educating the public about various ailments, and training medical professionals. Learners can remain enthusiastic and involved in the learning process by experiencing a sense of realism through accessing the virtual environment in serious role-playing games. 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 CSEGEL approach-based 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 a few examples (e.g., clinic reception desk, clinic hallway, drawing room, and house kitchen) of the utilization of virtual environments in our mobile applications.

Implementation Of Virtual Characters

The CSEGEL approach-based tools integrate virtual realistic characters, such as patients and peers, who enable the efficient delivery of virtual clinical practices and education on health care. Virtual personas help learners or 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 experiential learning process. Thus, our CSEGEL approach-based 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 a few examples of the utilization of virtual characters (e.g., receptionist, medical assistant, virtual expert guide, and other virtual peers) in our mobile applications.

Figure 3. *Illustrations of the virtual world or environment and virtual characters utilized in our mobile applications or serious role-playing games.*

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.*

Deployment of Visual Cues

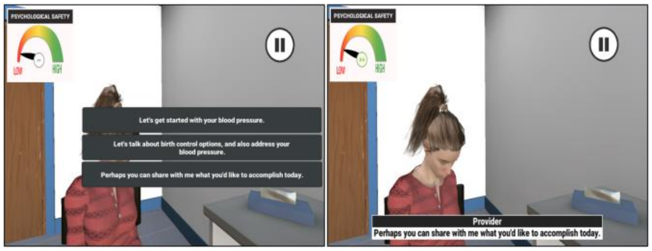
The assimilation of visual cues in the digital experiential learning mechanism plays a vital role in educational purposes. Especially for healthcare-related learning tools, visual cues are a critical and challenging aspect to deliver learning objectives. In our CSEGEL approach-based tools, visual cues 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 virtual patient's behavior, and facial/body emotions that facilitate learners as a better explanatory 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 mobile applications to help learners educate more effectively.

One of the valuable visual cues is the "Psychological Safety Meter" integrated into our mobile applications' role-playing sessions (e.g., a clinical encounter with the virtual patient). 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 or 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.

Adaptation Of Interactive Serious Role-Playing Segment

Both the virtual realistic case scenarios demonstrated in our mobile applications 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 virtual healthcare provider during the clinic visit of the virtual patient. In the clinic encounter segment, the learner plays the role of a virtual healthcare provider and gets an opportunity to provide health care to the virtual patient via a scripted interactive mechanism. To interact with a virtual patient, the user is provided with multiple conversation choices or options. Each conversation choice or option has a score value attached to it which helps to reflect the virtual patient's health outcome on the psychological safety meter. Thus, this segment helps learners to achieve virtual care practice in a safe clinical environment as it does not harm a real-life patient in obtaining healthcare skills or improving healthcare practices.

An important visual cue, a psychological safety meter, is available 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 outcomes. Thus, virtual clinical encounter practice assists in improving the learner's awareness and understanding of the difficulties or severity of the patients. It also aids in educating learners about the advancement of professional skills. For instance, learners can identify 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. Moreover, this serious role-playing segment benefits learners to understand the importance of empathetic communication which eventually helps them to serve real-life patients in a better way. Figures 5(a) and 5(b) demonstrate the instances of the clinical encounter between the learner or application user (who plays the role of virtual healthcare provider) and the patient in Ashley's case.



(a) (b)

Figure 5. *Illustrations of interactive virtual reality-based serious role-playing scenarios utilized in Ashley's case or ASD case.*

Deployment of Virtual Expert Guide or Instructor

The CSEGEL approach-based tools 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 anytime and anywhere, this research deploys the virtual expert guide (hereinafter referred to as Dr. Erica Parker) to instruct and educate the learners 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 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, a virtual expert trainer facilitates learners with an additional opportunity to improve their knowledge and awareness along with the virtual reality-based role-playing segments in our CSEGEL approach-based mobile applications. To illustrate, Figures 6 demonstrate the instance of our mobile application (i.e., Ashley's case) where Dr. Erica Parker educates learners or application users.

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 or game design is to immerse the learners (specifically healthcare professionals) 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 education module for conveying the learning experience from the game to the end-user.

Each virtual realistic case scenario in our CSEGEL approach-based mobile applications has a Life Couse module that demonstrates the past life experiences at distinct age instances of a main virtual character along with the past life experiences or events at the same age of another privileged companion character. The main virtual characters are overall underprivileged compared to the companion characters.

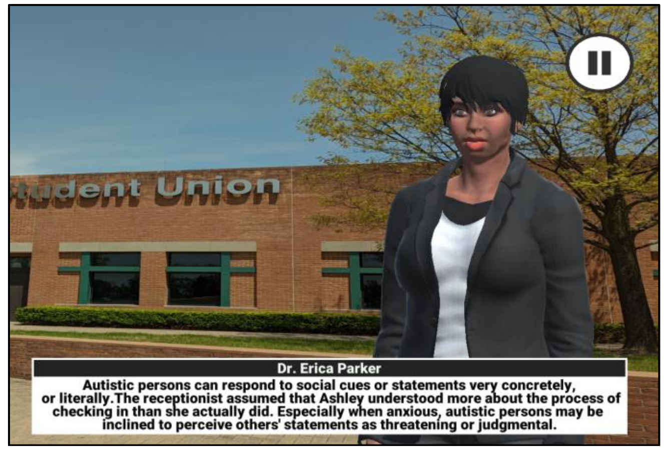


Figure 6. *Illustrations of a virtual expert guide (i.e., Dr. Erica Parker) educates the learners in Ashley's case or ASD case.*

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 that represent certain events that happened to the main virtual characters (i.e., Charles in the LGBTQIA+ case and Ashley in the ASD case) throughout their past 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 mobile application.

The 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 Charles's case. It depicts that at age 6, Charles is underprivileged compared to Christopher. Figure 8 shows the illustration of an event of the Life Course module in Ashley's case. It depicts that at age 8, Ashley is underprivileged compared to Sarah.

Easy Accessibility, Availability, Affordability, and Scalability

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 approach-based mobile applications are easily accessible and available. As a result, these mobile applications were developed so that users of iOS and Android devices (such as iPhones, iPads, tablets, and Android phones) could receive healthcare skills training at any time and from any location with an internet connection but at no additional cost. Thus, it facilitates supplementary features such as affordability and scalability.

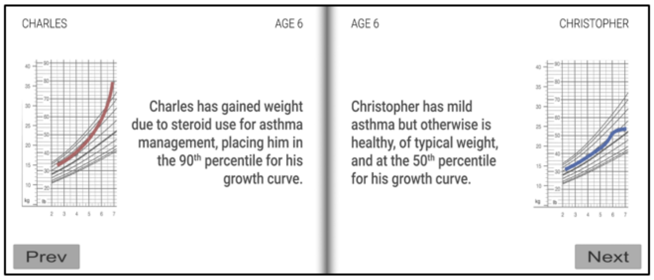


Figure 7. *Illustration of a Life Course module in Charles's case or LGBTQIA+ case.*

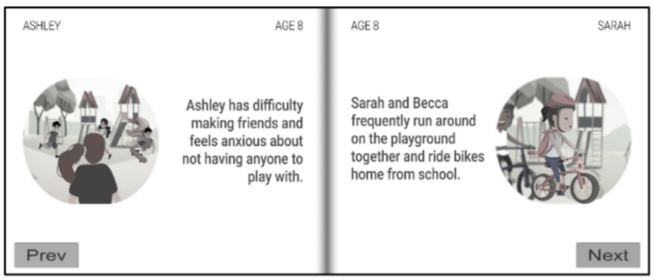


Figure 8. *Illustration of a Life Course module in Ashley's case or ASD case.*

Challenges and Optimization

For the development of this research, we have utilized different software tools and technology such as Unity Game Engine [17] facilitated by Unity Technologies for the development of virtual reality-based role-playing scenarios and Reallusion software products (e.g., iClone7 and Character Creator3) [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. A few of the challenges and utilized optimization strategies are described below.

Eliminate Server Dependencies for Life Course Module

Our Life Course module is an advanced version of the Life Course module developed in [14] with a new design, well-descriptive, and an easy-to-use approach. Moreover, our CSEGEL approach-based tools integrate the Life Course module inside the application design itself instead of depending on the webserver for running the Life Course module utilized in previous research [14]. 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 Reallusion's Character Creator3 tool. Figure 9(a) represents that without applying the polygon reduction through the Insta LOD feature, there are 62,967 triangles on a virtual character, whereas Figure 9(b) demonstrates that with applying the polygon reduction through the Insta LOD feature, there are 37085 triangles on a virtual character which eventually helps to reduce the extra memory utilization to render the triangles.

(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 with 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 Charles's 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 instance of time.

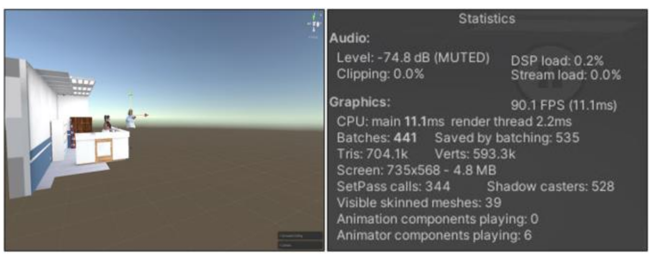


Figure 11. *Illustration of a game instance (i.e., clinic visit scene in Charles's case) with the utilization of occlusion culling optimization technique.*

Data Acquisition and Analysis

To analyze the efficiency of our Computer-Supported Expert-Guided Experiential Learning approach-based tools and the participants' learning experience, we have developed and incorporated three (i.e., First, Second, and Final) surveys or assessment questionnaires in both mobile applications (i.e., Charles's case and Ashley's case) 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 sessions. 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 learners' behavior change and learning experience before, in middle (or during), and after going through our serious role-playing case scenarios.

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 select participants from a local hospital. 6 physicians took part in the survey and have completed one of the two case scenarios or mobile applications. This research provides the T-Test Power Analysis performed on these 6 participants' responses collected in the survey as preliminary results. The T-Test Power Analysis suggests that our CSEGEL approach-based mobile applications may deliver significant positive or improved influence on the learners or application users and help to achieve the learning objectives of our mobile application as described below.

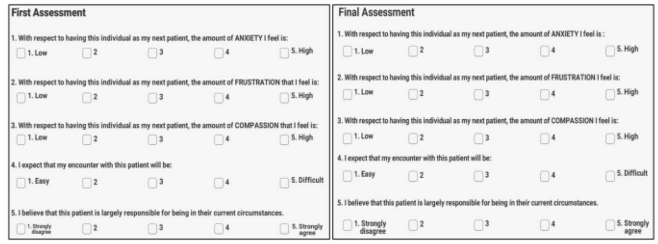


Figure 12. *Illustration of a portion of assessment questionnaires integrated into our CSEGEL approach-based mobile applications.*

T-Test Power Analysis

Our initial survey or data collection shows the positive result of the CSEGEL approach-based mobile applications presented in this research. However, with the help of these initial survey results or data points, we have estimated the total sample sizes or the number of data samples that would be required to provide concrete evidence for the statistically significant positive influence of our mobile 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 0.80 for the entire analysis. Also, to get the effect sizes, Cohen's D values are generated for the respective analysis.

Furthermore, in this analysis, we focus on the most relevant questions from the surveys listed in Table 1. The sequence of the questions presented in Table 1 does not match the original sequence of the same questions that exist in the surveys within the mobile applications. Thus, in this paper, all the discussions related to the questions' indices represent question indices given in Table 1.

Questions 6-9 are only available in the Final Survey questionnaires and hence, these questions are not included in the T-Test Power Analysis explained in the following sections. However, the analysis of questions 6-9 is separately described (in Figure 15). The following three sections explain the T-Test Power Analysis performed on the preliminary survey responses collected for questions 1-5.

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	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)
7	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)
8	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)
9	I feel that this simulation met all of the learning objectives listed above.	1 (Strongly agree) To 5 (Strongly disagree)

T-Test Power Analysis Between the First and Second Assessment Questionnaires

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

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

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

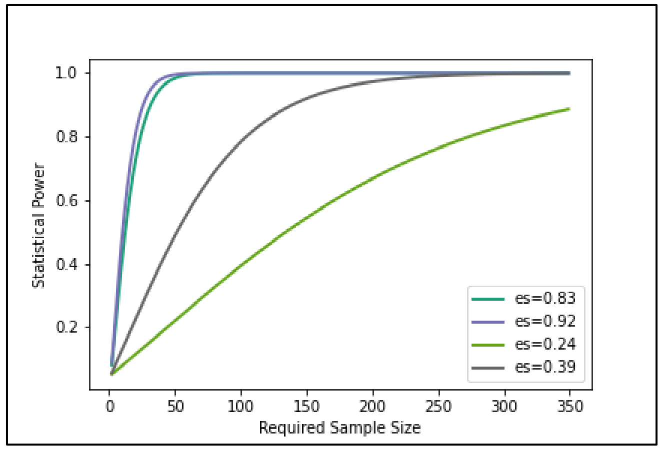


Figure 13. *T-Test Power analysis result from the learners' or participants' responses to the first and second assessment questionnaires.*

Table 2 and Figure 13 depict that with the required sample size or the number of data points, we may observe a significant improvement in application 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 the Second and Final Assessment Questionnaires

The observations with T-Test Power Analysis of the participants' responses for the second and final assessment questionnaires can be seen in Figure 14. This analysis is generated from the preliminary survey responses for questions 2-5. The effect size or Cohen's D value 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 2-5.

Table 3 and Figure 14 illustrate that with the required sample size or the number of 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, and awareness on discrimination) in the application flow between the second and final assessment questionnaires.

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

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

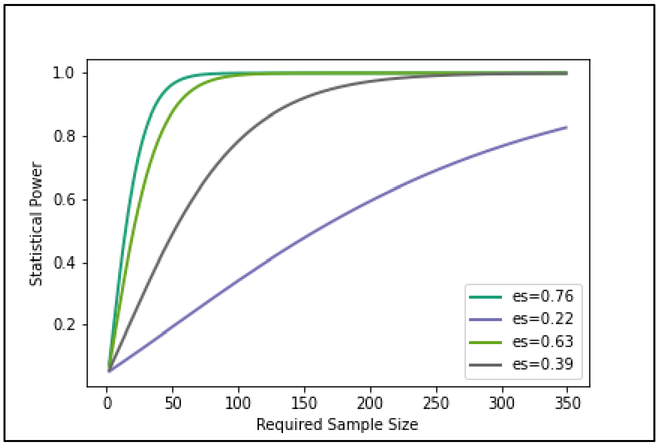


Figure 14. *T-Test Power analysis result from the learners' or participants' responses to the second and final assessment questionnaires.*

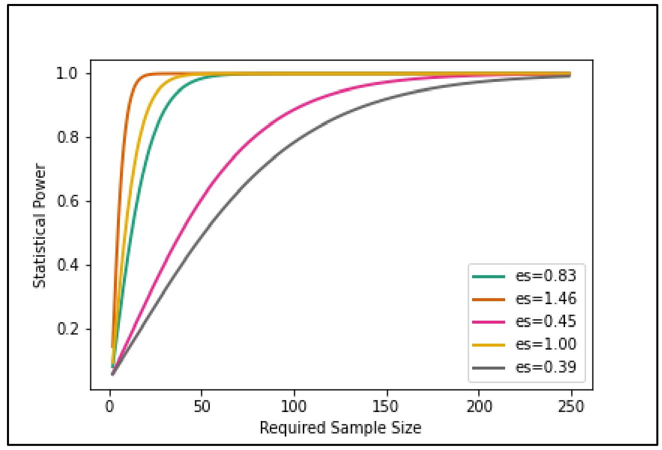


Figure 15. *T-Test Power analysis result from the learners' or participants' responses to the first and final assessment questionnaires.*

T-Test Power Analysis Between the First and Final Assessment Questionnaires

The observations with T-Test Power Analysis of the participants' responses for the first and final assessment questionnaires can be seen in Figure 15. This analysis is generated from the preliminary survey responses for questions 1-5. The calculated Cohen's D values and required sample size are given in Table 4 with respect to questions 1-5. This part of the analysis is precisely important as it delivers the overall learning outcomes of our CSEGEL approach-based tools (or mobile applications or serious role-playing games).

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

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

Table 4 and Figure 15 demonstrate that with the required sample size or the number of data points, we may observe a statistically significant improvement in the participants' learning experience (that includes a 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, and awareness on discrimination) in the overall application flow.

Additional Statistical Analysis

The participants' preliminary experiential learning data has shown that the CSEGEL approach-based mobile applications help to deliver a positive learning experience to learners or application users. This section provides the additional statistical analysis performed on the participants' data samples.

Figure 16 illustrates the mean or average values of participants' responses to questions 6-9. This result from the preliminary data demonstrates that the average value of the user response options or levels chosen by participants for questions 6-9 remains close to 1 which indicates that overall participants agree with questions 6-9 listed in Table 1. In other words, our CSEGEL approach-based mobile applications help learners (or healthcare professionals) in distinct ways including but not limited to being more comfortable interacting with patients (like Charles and Ashley), to enhance new skills or knowledge for implementing in their clinical practice, to reduce the health disparities for patients, and achieve the learning objectives mentioned earlier.

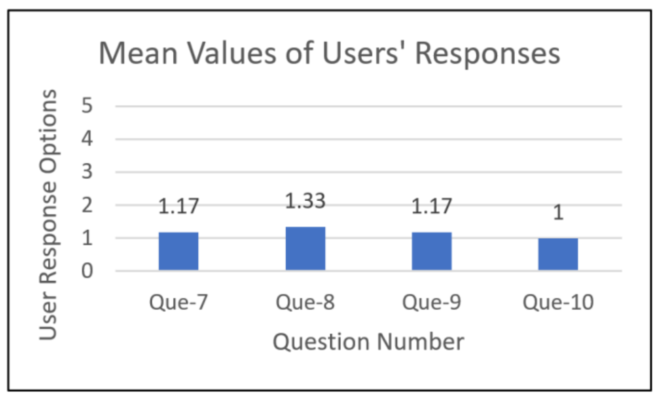


Figure 16. *Mean values of participants' responses for questions 6-9.*

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, and augmented reality in our mobile application or serious role-playing 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 more participants' responses to demonstrate the further effectiveness of our CSEGEL approach-based tools or mobile applications.

Conclusion

This research provides Computer-Supported Expert-Guided Experiential Learning (CSEGEL) approach-based tools (or mobile applications or serious role-playing games) to facilitate healthcare skills (e.g., awareness of the importance of cultural humility, inclusive communication proficiencies, awareness of the enduring impact of social determinants of health and impact of implicit/explicit biases on health outcomes, and compassionate and empathetic attitude) to healthcare professionals and public awareness. Additionally, integrated hypothetical virtual realistic case scenarios (i.e., Charles's case and Ashley's case) with first-person viewing experience helps the learners (specifically healthcare professionals) to increase their understanding of patients' perspectives and augment the compassion/empathy toward real-life patients which eventually benefits promoting health equity and reducing health disparities. Furthermore, the utilization of the virtual expert guide or instructor in game design facilitates learners to augment their proficiency (e.g., healthcare skills) to implement further in real-life. Finally, the preliminary statistical data analysis demonstrates that our CSEGEL approach-based tools deliver a positive influence on learners' or application users' healthcare skills development. The T-Test Power analysis provides the estimation of the required sample size to demonstrate statistically significant improvement of participants' healthcare skills through our CSEGEL approach-based tools.

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Acknowledgments

The Medicaid Care Experience Simulation (MCarES) Project was funded by the Ohio Department of Medicaid and administered by the Ohio Colleges of Medicine Government Resource Center. The views expressed in this publication are solely those of the authors and do not represent the views of the state of Ohio or federal Medicaid programs.

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