



The Development of Immersive Interactive 3D Learning Materials Using Virtual Reality Technology to Enhance the Skills of SIEVE, SORT, and START Triage (VR-SSST) in Mass Casualty Situations

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Abstract

Triage training is an essential component of emergency medical services and disaster response, where healthcare professionals are trained to assess and prioritize patients quickly and efficiently. This study aimed to develop immersive, interactive 3D learning materials using virtual reality technology to enhance the skills of sieve, sort, and start triage (VR-SSST) in mass casualty situations, and to test its feasibility. This study employs a research and development design composed of three phases: (1) content development and scenario design; (2) technical development and platform selection; and (3) pilot testing to gather feedback on feasibility. Thirty 2nd-year emergency medical technician students in academic year 2024 from the Naval Operational Medicine School, Naval Medical Department, Royal Thai Navy were recruited for testing VR-SSST. Data were collected using a questionnaire. Data analysis included calculating the content validity index, mean, and standard deviation.

The results show that the VR-SSST is a triage program that includes sieve, sort, and start triages, leveraging virtual reality technology to create a highly immersive and engaging learning experience. It involves the use of 3D simulations and environments to facilitate learning, allowing users to interact with and explore triage content. The content validity index was highly acceptable (CVI = 1). The feasibility of VR-SSST was rated at a high level (M = 4.49, SD = 0.88). The VR-SSST is a valuable tool with good content validity and high feasibility. Trainers can use VR-SSST as a tool for the triage training.

Keywords: immersive interactive 3D learning materials, triage, virtual reality

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Background and Significance of the Study

Emergency medical services and disaster response require triage training, which particularly instructs medical personnel on how to rapidly and effectively assess and prioritize patients. Triage methods are designed to prioritize patients that require immediate medical attention in order to lower the rates of mortality and morbidity¹. Traditionally, this training has relied on classroom instruction, table-top exercising, and simulations. These methods aim to provide fundamental understanding and experience for handling mass casualty situations². Significant advances in technology in the field of medical education have resulted in the introduction of digital resources and simulations, which have begun to supplement or even replace traditional conventional instruction methods. The complexity and unpredictability of real-life medical situations have made it clear that more realistic, and captivating training materials are needed. Since it directly affects patient outcomes, unexpected mortality rates, and the overall effectiveness of medical responses, effective triage training is crucial.

Despite the advancements in medical training technology, the triage training methods that are currently in existence encounter various major challenges. First, comprehensive and dynamic training methods are not enough to imitate the complex and volatile conditions of real-world emergency situations. The inadequacy of training realism impedes learners' capacity

to utilize their abilities in practical scenarios⁶. Individualized learning experiences and immediate feedback are also frequently absent from current methods, regardless of having been demonstrated, both of which are essential for the efficient development of skills and learning. The accessibility and scalability of these training approaches are a further major issue. Traditional approaches are difficult to scale, particularly when dealing with a large number of students or those spread across several geographic locations. This situation highlights the obvious need for a creative training method that can get beyond these limitations and provide a more effective, fascinating, and adaptable approach to triage training. By providing a realistic, immersive, and interactive learning environment that is appropriate to the evolving needs of contemporary medical training, the recommended VR platform attempts to address these issues.

Thai Intermediate Emergency Medical Technicians (EMT-I), who are essential healthcare professionals trained over a two-year period, play a crucial role in providing emergency medical services to patients both pre-hospital and during transport to medical facilities. These professionals are skilled in assessing patients' conditions, administering emergency care, and ensuring safe access to medical facilities. They often serve as the first responders in medical emergencies such as catastrophes, severe injuries, and serious medical conditions to provide effective and efficient medical

evaluation and deliver intervention. In the setting of mass casualty incidents, triage, the process of classifying patients based on the severity of their conditions, must be performed by those with the minimum of an EMT level of training^{3,4}.

Personnel with at least an EMT level of training should be preferred to triage in mass casualty incidents (MCI). Because of their training, EMTs have the capacity to evaluate the level of injury and prioritize the requirements of patients quickly, which is crucial if there are numerous victims and limited resource availability⁵.

Objectives

1. To develop immersive interactive 3D learning materials using VR technology to enhance the skill of sieve, sort, and start triages (VR-SSST) in mass casualty situations.
2. To test the feasibility of VR-SSST.

Definition of Terms

1. Virtual Reality (VR) is defined as the three-dimensional digital representation of a real or imagined space with interactive capabilities.

2. Immersive Interactive 3D Learning Materials Using Virtual Reality (VR) Technology refers to educational content and resources that leverage virtual reality technology to create a highly immersive and engaging learning experience. It involves the use of three-dimensional (3D) simulations, environments, or models to facilitate learning, allowing users to interact with and explore educational content in a virtual world.

3. Mass Casualty Incident (MCI) is classified as the incident when the number and severity of casualties exceeds the capacity of local emergency medical services and emergency medical services personnel and equipment. In order to effectively and efficiently manage the surge in demand, specific protocols must be implemented in this situation. The objective is to treat as many victims as possible with the highest quality care feasible in the shortest amount of time possible given the conditions.

4. Triage is the process of establishing treatment and transportation priorities according to severity of injury and medical need. Triage are as follows: (1) SIEVE triage, is a form of primary triage applied in particular parts of Europe, Australia, and the United Kingdom. It then utilizes four tags, notably red, yellow, green, and black, to categorize the injured patients; (2) SORT triage is a form of secondary triage that consists of four steps and includes a numerical system. In this triage procedure, patients are categorized based on the score calculated from the patient's mental status, respiratory rate, and systolic blood pressure. If the score is 10 or below, the injured individuals are assigned to the red category. If the score is 11, they will be sent to the yellow category. A patient who has a score of 12 will be classified as being to the green category; and (3) START triage is a primary triage created by the Newport Beach Fire Department and Hoag Hospital in California in 1980⁷. All injured

adults will be evaluated within 60 seconds (preferably within 30 seconds) under this triage system. The evaluation criteria consist of walking ability, respiratory rate, capillary filling, radial pulse, and compliance with instructions.

Methods

Population: The population consisted of 53 second-year EMT-I students from the Naval Operational Medicine School, Naval Medical Department, Royal Thai Navy.

Sample: Thirty 2nd-year EMT-I students from the Naval Operational Medicine School. Calculating sample size based on guidelines for designing and evaluating feasibility pilot studies by Teresi et al.⁸, 30 participants were appropriate for this study. The inclusion criteria for participation in the study were: (1) EMT-I students who have completed disaster triage training; and (2) EMT-I students who have provided informed consent and were willing to fully participate in the research process. The exclusion criteria were: (1) EMT-I students with a history of severe motion sickness or epilepsy; (2) EMT-I students who wished to withdraw from the study; and (3) EMT-I students who were unable to fully participate throughout the research process. The withdrawal or termination criteria included EMT-I students who experience injuries, motion sickness, seizures during the study, or any other conditions that pose a risk to the participating EMT-I students.

Design: This study employs a research and development design composed of three phases as follows:

Phase R1: Research - Content Development, and Scenario Design. This phase is composed of: (1) Evaluating traditional triage training methods to identify gaps and areas for improvement; (2) Gathering student feedback on confidence and preparedness for real-world scenarios; (3) Developing a new training approach that integrates VR technology to enhance real-world preparedness, while retaining core educational content; and (4) Designing the VR scenarios in six parts:

- 1) Opening scene
- 2) VR orientation or user interface (UI) tutorial containing scene orientation and interface, patient assessment (scene safety, bleeding and tourniquet, airway and breathing, circulation (pulse palpation and capillary refill time), interactive verbal command using generative AI, and triage bag)
- 3) Triage tutorial containing triage introduction, sieve, sort, and start protocol
- 4) Practice mode containing sieve, sort, and start triage in realistic scenarios
- 5) Examination mode, which contains the MCQ exam and skill test, and
- 6) Quit

Content validity testing was done by five experts, including three emergency medicine physicians with expertise in EMS or prehospital emergency medicine and/or those who completed disaster medicine, one

emergency medicine physician specializing in medical education, and one qualified individual with expertise in computer program production and development, or virtual reality. For content validity testing, the results indicated that the CVI was good with CVI score of 1.

Phase D1: Development - Technical Development and Platform Selection. This phase composed of: (1) develop software for interactive scenarios within the VR environment; (2) design a user-friendly interface to facilitate learning; and (3) select and procure the necessary VR hardware to support the training platform.

Phase R2: Research - Testing and Feedback (Duration 2 months). This phase composed of: (1) conduct pilot testing of the VR training scenarios to collect data on their effectiveness and user experience; and (2) gather comprehensive feedback on the VR-SSST's feasibility from the test participants.

Instruments

1. A personal data recording form was conducted by researchers, and the instrument comprised information about age, height, weight, disease, triage training experience, and VR experience.

2. The feasibility questionnaire was developed by researchers. It is a self-reported questionnaire consisting of 10 items. The questionnaire has a 5-choice rating scale format, scoring each item from 1 to 5 (Lowest level = 1, Highest level = 5). The mean score was calculated for the scale. The scale score, ranging from 1 to 5, was used to interpret the levels of feasibility:

lowest (1.00 - 1.50), low (1.51 - 2.50), moderate (2.51 - 3.50), high (3.51 - 4.50), and highest (4.51 - 5.00). The content validity index was 1.

3. Oculus Quest 3 VR glasses produced by Meta, which passed the OSHA's Hazard Communication and European Classification Labeling regulation (EC) 1272/2008.

4. Software for developing educational tools, Unity 3D and Blender, which are standard programs for media production.

5. Digital Assets including scene components, characters, and Deep Voice AI generator assets are electronic properties traded in the market.

6. Wit.AI which has a Privacy Policy regulated under the European Commission's law.

Data Collection: The data collection were as follows: (1) obtain Institutional Review Board (IRB) approval before any data collection begins to ensure compliance with ethical research standards; (2) the researcher prepare formal correspondence to the director of the participating institution to seek permission for conducting the research with the identified sample groups; (3) arrange a meeting with the potential participants to explain the research details, including objectives, procedures, potential risks, benefits, and the confidentiality of data; (4) after obtaining informed consent from the participants, initiate the VR instructional sessions as part of the research intervention; and (5) following the VR sessions, distribute a feasibility questionnaire to the participants to gather their feedback on the practicality and applicability of the VR teaching method.

Ethical Considerations: This research was approved by the Ethical Review Committee at Naval Medical Department (Approval No. COA-NMD-REC 010/67).

Data Analysis: The analysis was conducted using established statistical software. The specific data analysis procedures included: (1) participants' demographic and other personal data were summarized using descriptive statistics. This includes the calculation of frequencies and percentages for categorical variables, and means and standard deviations for continuous variables; (2) the validity of the instruments or content used within the research was evaluated using the Index of Content Validity (I-CVI) for individual item analysis and the Scale Content Validity Index (S-CVI) for overall scale assessment; and (3) the feasibility of VR-SSST was assessed using the mean and standard deviation (SD)

users to interact with and explore triage content. The VR-SSST utilizes virtual reality technology to improve real-world preparedness through six-part components: opening scene, VR orientation (scene introduction and general patient assessment, including bleeding, respiratory rate, pulse, capillary refill time, Glasgow coma scale evaluation, and interactive verbal commands using generative AI), triage tutorial (detailed introduction to sieve, sort, and start protocols), practice mode (realistic triage scenarios), examination mode (MCQs and skill tests), and quit. The tool offers highly realistic scenarios such as a classroom, Japanese subway, casualty collecting point with an organized disaster scene, and New York City, together with immersive sound and ambient effects that imitate real-world crisis environments.

Results

Personal Characteristics of the Participants

The majority of sample were aged between 19 and 21 years (mean = 19.63, SD = 0.72) and most of them did not have experience in VR (90%).

Characteristic of the VR-SSST

The VR-SSST is a triage learning program that includes sieve, sort, and start triages, leveraging virtual reality technology to create a highly immersive and engaging learning experience. It involves the use of 3D simulations and environments to facilitate learning, allowing



Figure 1. User Interface



Figure 2. Triage bag



Figure 3. Casualty Collecting Point



Figure 4. SORT score insertion



Figure 5. Hand tracking

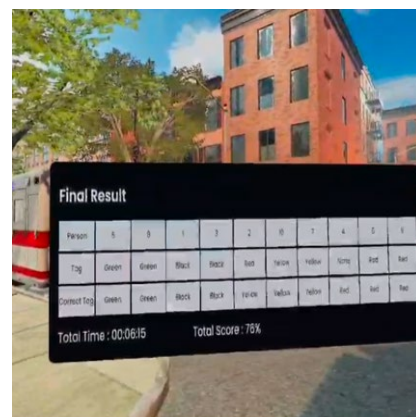


Figure 6. Feedback board



The feasibility of VR-SSST was rated at a high level (Mean = 4.49, SD = 0.88), as shown in Table 1.

Table 1 Feasibility of using the VR-SSST (n = 30)

VR-SSST	Mean	SD	Level of feasibility
1. User-friendliness	3.90	0.94	High
2. Interesting interactive presentation	4.84	0.58	Highest
3. Instructional Flow	4.55	0.68	Highest
4. Content Clarity	4.26	0.73	High
5. Text Legibility	4.58	0.62	Highest
6. Realism of scenarios	4.58	0.62	Highest
7. Visual Quality	4.48	0.62	High
8. Sound Clarity	4.65	0.95	Highest
9. Duration Suitability	4.48	1.23	High
10. Safety in use	4.58	1.18	Highest
Total	4.49	0.88	High

Discussion

The findings from this study showed the VR-SSST program was highly practical for use in triage training, receiving a high score for feasibility. This success can be attributed to several key factors, particularly the advantages of VR technology and the distinctive characteristics of the sample group involved in the study.

Firstly, VR technology brought an immersive, interactive environment that closely mimicked real-life scenarios, which was especially beneficial in triage training. In these scenarios, the ability to practice making quick decisions under pressure is delivered. Through the use of 3D simulations, VR allows learners to experience the urgency and complexity of mass casualty situations in a safe environment without exposing them to real-world risks, which leads to improved confidence and positive satisfaction after training^{7,9}.

It was clear from the study group, who ranged in age from 19 to 21, known as Generation Z, that this demographic was a good fit for VR-based training. This can be explained by the research on trainees who were in generation Z, who have been comfortable in digital and virtual spaces. Their familiarity with technology likely contributed to their positive experience with the VR-SSST program¹⁰. Despite the fact that 90% of the participants had never used virtual reality before, their comfort level with new technology probably helped them interact with and use the VR platform more easily. Their generation has been acknowledged as being adaptable since they have grown up with the quick advancement of technology and were confident experimenting with new digital tools.

The item “Interesting interactive presentation” received the highest score,

reflecting the strong interest and engagement participants felt during the VR-SSST training. This metric is key in evaluating the program's effectiveness, particularly in sustaining learners' attention and enhancing the educational experience. The program's interactive and immersive components made the learning process more engaging, suggesting that participants found the virtual environment both compelling and informative, potentially leading to improved learning outcomes.

Conversely, the "user-friendliness" category scored the lowest. Since 90% of the participants had never used virtual reality before, this could be explained by the fact that, for most of them, the technology was unfamiliar to them. They might have first found it challenging to use the implementation due to their lack of experience with the technology, which resulted in lower user-friendliness ratings. In new technologies in general, there's generally a learning curve, and it takes some time for users to get used to the controls and interface. The reason that user-friendliness received a lower rating than other elements could be attributed to this initial barrier. Early adoption of virtual reality training programs by educational institutions might assist students develop confidence and mastery with technology. Students can make a more seamless transition to more complicated applications by starting with simple sessions, which familiarize them with the

equipment and interface. Tutorials and interactive instructions, among other pre-training orientations, reduce discomfort and improve the intuitiveness of the learning process.

In spite of this, the VR-SSST program's significant level of overall feasibility indicated its potential as an effective tool for triage training. Once virtual reality (VR) became increasingly common in educational settings and students gained more familiarity with the technology, the user-friendliness challenges would decrease. Virtual reality (VR) was expected to enhance medical education programs over time and become an even more effective tool for training medical professionals for emergency situations they would encounter in the real world.

===== Suggestions =====

The results demonstrate that the VR-SSST is a highly feasible and valuable tool for triage training. Phase R1-D1-RD1 has been successfully finished. The subsequent step would need to expand the testing by including paramedics, nurses, doctors, students, existing emergency network professionals, and international participants. Additionally, the VR-SSST should be compared to current training methods to determine differences in effectiveness and knowledge retention, therefore ensuring its potential for widespread use in a variety of healthcare setting.

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