SSH
Society for Simulation in Healthcare

STORM

Simulation Technology & Operations Resource Magazine (STORM)

STORM highlights exemplar work contributing to the advancement of healthcare simulation operations. All submissions are peer reviewed before publication in the STORM special edition of the SSH Simulation Spotlight. With articles covering training, policy & procedure, emerging technologies, and professional development, STORM has everything needed to stay current and well-rounded in the pursuit of simulation operations excellence.

CONTENTS

EDITORIAL BOARD

Editor in Chief
David Biffar, MS, CHSOS-A, FSSH
Arizona Simulation Technology & Education Center, University of Arizona

Amy Folmer, CHSOS-A, FSSH
Zamierowski Institute for Experiential Learning, University of Kansas

Jason Konzelmann, EMT
DeSales University

Marissa Lovett, MS, MD
Banner University Medical Center

Pooja Nawathe, MD, FAAP, FCCM, CHSOS, CHSE-A, FSSH
Cedar Sinai Medical Center

Society for Simulation in Healthcare STORM Coordinator
Ashley Grossman
Director of Membership, Society for Simulation in Healthcare

Dinker Pai, MBBS, MS, FRCS, CHSE, FSSH
Mahatma Gandhi Medical College and Research Institute
CAE Healthcare
GSL Medical College Rajamundry

Matthew Pierce, MS, EMT, CHSOS
Texas Tech University Health Sciences Center Simulation Program, Texas Tech University

Sarah Rucker, MA, CHSOS
Zamierowski Institute for Experiential Learning, University of Kansas

Copy Editor
Christina Partica, MLSt
Arizona Simulation Technology & Education Center, University of Arizona

Hently Small, CHSOS
St. Michael's Hospital Allan Waters Family Simulation Centre
Humber College Institute of Technology & Advanced Learning

Dawn Swiderski, MSN, RN, CHSE, FSSH
Atrium Health

Joshua Vognsen, MSHS, CHSOS
Weill Cornell Medicine

Janet Willhaus, PhD, RN, CHSE, CHSOS-A

Novice to Advanced: A Roadmap for Simulation Operations Certification Success

Author

Adrienne D. Wilk, PhD, RN, CHSE, CNE, CHSOS-A[1]

[1]Austin Peay State University, School of Nursing, Clarksville, Tennessee

Conflict of Interest Statement
The author declares no conflict of interest.

Corresponding Author
Adrienne D. Wilk, PhD, RN, CHSE, CNE, CHSOS-A, Austin Peay State University, School of Nursing, Clarksville, Tennessee
Email: wilka@apsu.edu

Brief Description

The Society for Simulation in Healthcare (SSH) grants four certifications for healthcare simulation (SSH Certification, 2023). The Certified Healthcare Simulation Educator® (CHSE) and advanced CHSE (CHSE-A) are intended for simulationists assuming the educator role. The Certified Healthcare Simulation Operations Specialist® (CHSOS) and advanced CHSOS (CHSOS-A) are intended for individuals who assume a simulation operations role. This article will highlight the CHSOS and CHSOS-A credentials and present practical tips and tricks for obtaining the operations certifications.

Introduction

"But you never played with dolls as a kid!" my mother exclaimed when I told her about my new fascination with healthcare simulation. She was correct; I was the child who demonstrated little to no imagination or creativity growing up. So, imagine her surprise when I told her that after working as a nursing professor, I would venture into the new-to-me world of manikins, task trainers, standardized participants, moulage, and audiovisual technology.

Like many of you reading this, I got my start in simulation operations because I found several unopened equipment boxes in the musty basement of my place of employment. The school where I was employed had a phenomenal grant writer who loved purchasing the latest and greatest simulation technology. The problem was that no one knew how to assemble or use the equipment. I knew nothing about simulation then, but decided to take on the challenge of getting the manikins and equipment up and running. Thankfully, I have come a long way since the early days, and I want to encourage others to follow my path of becoming a simulationist. This article aims to provide readers with a general roadmap for simulation operations-specific professional development and growth, ultimately leading to attaining the CHSOS-A credential.

Getting Started in Simulation Operations

Mentorship

When I started in simulation, I lacked a simulation mentor at my place of employment. Thankfully, there were several options for external sources of reliable information and eager encouragement. I cannot overstate how important reaching out to others will be when getting started. Thankfully, I had old ties to one of the ten study sites participating in the landmark simulation study for the National Council of State Boards of Nursing (Hayden, Smiley, Alexander, Kardong-Edgren, & Jeffries, 2014). My past faculty welcomed me with open arms and mentored me as a simulationist. If you do not have connections with another facility utilizing simulation, I would urge you to pick up a phone or write an email and ask for a tour at the closest simulation center. The sim world is smaller than it may appear, and building relationships with other simulationists is vital to your success.

Resource-Sharing

Much of what I learned in the early days came from old-fashioned trial and error. I would contact the various help desks and scour the forums and online social networks provided by the manikin vendors. Later, I discovered that simulation pioneers were sharing their knowledge for free on YouTube and other social media outlets. I relied heavily on YouTube channels like Simulation Tek (Simulation Tek, n.d.) and Healthy Simulation (Healthy Simulation, n.d.). Another invaluable resource is podcasts. A quick search of your favorite podcast platform will provide a robust list of options. Facebook, Instagram, LinkedIn, and Twitter also house multiple simulation operations-specific pages.

Professional Development

Attending a simulation conference is one of the best ways to expand your knowledge. SSH conducts two conferences on an annual basis. The International Meeting on Simulation in Healthcare (IMSH) is held in the winter, and SimOps is held in the summer. SimGHOSTS is another excellent conference focused on enhancing the role of the healthcare simulation operations specialist. Simulation conferences that are not healthcare-specific are also beneficial. Organizations like the National Center for Simulation conduct conferences and workshops to advance simulation and related technologies. Equipment vendors also conduct their own simulation conferences. There are also several free professional development courses available online. The University of Washington hosts free online modules on designing, facilitating, and debriefing simulations (University of Washington Center for Health Sciences Interprofessional Education Research and Practice, 2023). The modules on selecting the appropriate modality and enhancing fidelity are particularly beneficial for simulation operations specialists.

As the use of simulation has grown, so have the options for certificates and degrees. Several institutions of higher learning offer certificates in simulation and undergraduate, graduate, and doctoral degrees. If you are not ready to commit to a certificate or degree program, I encourage you to consider purchasing and reading one of the many textbooks and comprehensive guides on healthcare simulation offered in stores. They are even available as audiobooks! Professional journals are another great way to gain new knowledge. Periodicals like *STORM, Human Factors in Healthcare, Clinical Simulation in Nursing, Simulation in Healthcare, Journal of Interprofessional Education & Practice, and Advances in Simulation* are all reputable information sources that translate to the simulation operations role.

Simulation Organizations

Becoming a member of an international simulation organization such as SSH will provide you with reliable information about the history of simulation and its future. An SSH membership will unlock access to tools like *SimConnect*, SSH's online network that allows for resource-sharing, networking, and problem-solving. Membership also allows you access to *Simulation in Healthcare* and *STORM*, peer-reviewed journals dedicated to healthcare simulation. Another perk to SSH membership is access to the *Live Learning Center,* with over 200 accredited simulation courses (Society for Simulation in Healthcare, 2023). You will rely heavily on the *Live Learning Center* when you renew your CHSOS certification, discussed further in the next section.

The International Association for Clinical Simulation and Learning (INACSL) also has valuable resources. Most notable is the Healthcare Simulation Standards of Best Practice, which provides an evidence-based foundation for simulation education and operations (Society for Simulation in Healthcare Council for Certification, 2019). The National League for Nursing also hosts a Simulation Innovation Resource Center (SIRC) online forum. Lastly, the Association of SP Educators (ASPE) is another resource for information regarding the use of standardized patients in healthcare simulation.

There are several regional, state, and local simulation collaboratives or consortiums to join. These groups typically meet virtually once a month to share resources that enhance simulation quality. A few of my favorites include the Interprofessional Education Collaborative, California Simulation Alliance, and Simulation Canada. Another collaborative that assists simulation operations specialists in excelling in their role in the Higher Education Makerspaces Initiatives. This collaborative is responsible for the annual International Symposium on Academic Makerspaces (ISAM), where attendees can share knowledge and inspiration for improving education.

CHSOS Certification

One of the many things I love about healthcare simulation is that there is always an opportunity to develop new knowledge. During the pandemic, I pursued my CHSOS certification. I had already obtained my CHSE certification but felt that obtaining the CHSOS would legitimize my simulation operations role and demonstrate value in its operations functions. CHSOS eligibility criteria stipulate that a simulationist must have two years of simulation experience in a simulation operations role and possess a bachelor's degree to take the exam. If you do not have a bachelor's degree, you can apply for a waiver with an equivalent combination of education and experience (Society for Simulation in Healthcare, 2018).

Application

The CHSOS exam application is online, open year-round, and quick and easy to complete. For the application, you will be asked to describe your simulation-based operations experience, advocacy for healthcare simulation, and any activities you have participated in that assist in expanding the field of simulation. You must provide two professional references who will receive an online reference request.

Preparation

I thoroughly reviewed the CHSOS Handbook, Examination Blueprint, and Exam Preparation Guide to prepare for the exam (Society for Simulation in Healthcare, n.d.b; Society for Simulation in Healthcare, 2018; Society for Simulation in Healthcare, 2019a). I then completed the CHSOS Professional Development Worksheet (Society for Simulation in Healthcare, 2022d). All four resources are free to access on the SSH website. The Professional Development Worksheet helped me to identify gaps in my knowledge. From there, I took the Practice Examination provided by SSH and reviewed specific content related to the practice exam questions I missed. I did not utilize a review course in my preparatory activities, but I would encourage others who feel they may benefit to do so. SSH offers live and online CHSOS review courses covering major content areas from the exam blueprint.

Exam

The online certification exam must be taken within 90 days of eligibility of your application approval. You may take the exam at either an approved computer-based testing site or remotely at your chosen location. The test consists of 115 questions, of which 100 are counted towards determining the achievement of the certification. The other 15 questions are being pilot tested for use in future exams. The exam consists of questions from 5 domains (Society for Simulation in Healthcare, n.d.b).

The CHSOS exam has a cumulative total pass rate of 77.48% (Society for Simulation in Healthcare, 2019b). The exam results will be made available immediately, electronically on the screen or on a printed result sheet. A results report for a successful exam will only report the passing result. An unsuccessful exam report will include an overall score and data for the performance on questions from each of the five domains. If unsuccessful, candidates may retake the exam in 90 days.

Renewal

A CHSOS certification is active for three years. Renewal of the CHSOS credential may be accomplished by retesting or demonstrating the achievement of 45 continuing professional development credits over the three-year recertification cycle. Professional development activities must be correlated to one of the five domains covered in the exam. Renewal candidates will need a minimum of one professional development activity for each of the five domains. For example, all 45 professional development credits may not fall under domains I through IV, leaving domain V without an activity. All continuing professional development credits must be documented on the online Candidate Management System. Accurate records must be maintained, as random audits are conducted to verify the validity of the documented continuing professional development credits. The CHSOS Renewal Handbook, available for free on the SSH website, takes you through the renewal process (Society for Simulation in Healthcare, n.d.c).

CHSOS-A Certification

In Fall 2020, SSH announced it would add the Certified Healthcare Simulation Operations Specialist – Advanced® (CHSOS-A) certification. The CHSOS-A credential is reserved for leaders in simulation operations who serve as mentors to others in the field. On March 30, 2021, I received notification that my CHSOS-A application was accepted! I was one of 25 CHSOS-As designated during the first application cycle. At present, there are 33 individuals certified as CHSOS-As (Society for Simulation in Healthcare, 2019b).

I take the mentor role required for the CHSOS-A credential very seriously. If it were not for mentors who supported me in my simulation operations infancy, I would not have been able to accomplish my professional goals. I felt drawn to this new certification as it would push me further into discomfort for growth in my career. I also felt strongly that I wanted to show that women can excel in technology-related fields. Since obtaining my advanced certification, I have become a CHSOS-A application reviewer. It is a privilege to participate in the expansion of the CHSOS-A certification. I want to encourage any eligible individual to consider applying. Hopefully, you will find the following tips helpful when submitting your CHSOS-A application.

Eligibility

To be eligible for the CHSOS-A, you must be a CHSOS, have five or more years of experience in simulation operations, possess a bachelor's degree, or have been granted an education equivalency. Thankfully, SSH assists you in distinguishing whether you operate at the CHSOS or CHSOS-A level by publishing the CHSOS-A Standards and Suggested Evidence, CHSOS-A Handbook, and the Application Worksheet (Society for Simulation in Healthcare, 2020; Society for Simulation in Healthcare, 2022a; Society for Simulation in Healthcare, n.d.a). I encourage you to use these documents as a needs assessment to determine your eligibility. These tools also assist in outlining your professional strengths and areas for growth.

Preparation

Preparing for the CHSOS-A differs from preparing for the CHSOS, as there is no examination, and applications are only accepted twice a year. The CHSOS-A certification process consists of three components. The first component is an exemplar. The exemplar is where the candidate demonstrates their advanced simulation operations talent by providing an example of their work. The second component is an online application with multiple open-ended questions requiring a narrative response. The third component is a simulation-specific CV/resume.

Exemplar

The CHSOS-A application's first and possibly most crucial portion is the exemplar. In this section, the applicant must provide an example of an innovation, activity, or project demonstrating their advanced practice. The specific type of exemplar is not prescribed and may cover various topics. The only requirement is that the applicant must have served as the primary contributor.

To begin brainstorming ideas for your exemplar, I suggest speaking with those you work beside to gather your thoughts about what to include in your application. Ask others about your most significant accomplishments, how you influence change, and the most remarkable thing you have done as a simulation operation expert to enhance learning. We often forget the incredible work we do to advance the field of healthcare simulation. Again, reviewing the preparation documents on the SSH website will help you to develop ideas for your exemplar.

Your narrative responses that describe the exemplar aim to create a clear, comprehensive picture of the project for the reviewers (Society for Simulation in Healthcare, 2022c). If you have created or redesigned equipment or technology, provide the plans and photos of the final product and any iterations of the design process. If you designed or implemented a new process within your program, include evidence of the action and outcome. While most applicants do a great job explaining the exemplar and how it supports or improves simulation, a common stumbling block is a lack of a comprehensive description of the needs assessment and evaluation of the effectiveness of the exemplar. Be sure to adequately describe the needs assessment you conducted to determine the necessity of your exemplar. You also need to include a discussion of how you evaluated the implementation of the exemplar. Be prepared to speak to the complete process of implementing your exemplar, not just the innovation itself.

Application

The CHSOS-A application is like that of the CHSOS (Society for Simulation in Healthcare, 2022a). You must submit two professional references who are familiar with your work and can articulate how you meet the domains of the CHSOS-A. The initial demographic questions are followed by a series of questions requiring a narrative response (Society for Simulation in Healthcare, n.d.a). At first, I was relieved to notice that the required word count for each question was relatively small. However, that later posed a challenge when articulating how I met each prompt without exceeding the word limit.

As mentioned above, the most challenging part about this component is thoroughly demonstrating competence while being succinct. It is also essential to remember the example of your work that you plan to describe in your exemplar and reference that exemplar in your responses. Be sure to review the guiding questions located in the CHSOS-A Application Information document (Society for Simulation in Healthcare, 2022b). The standards and suggested evidence will help you determine if you answer the question with the intended response.

Simulation-Specific CV/Resume

The third and final component of the application is the simulation-specific CV/resume. Most reviewers will begin examining the CHSOS-A candidate by reviewing the CV/resume for key insights supporting the CHSOS-A. Ensure that the CV/resume is simulation-specific and only contains information pertinent to your simulation role. Highlight your work experience in simulation operations, focusing on responsibilities, accomplishments, and your impact on your simulation program and its learners. Describe the projects or initiatives in which you have led or made a significant contribution. Include a detailed list of skills, including technical skills and the soft skills required to succeed in a simulation operations role. Document professional memberships and any leadership roles held within those organizations. If you have formally or informally disseminated information, document the endeavor to demonstrate scholarship. It is also vital to check for consistency in your CV/resume's dates, titles, and details and the application question responses.

Refinement

Prior to submitting your completed application, be sure to have others review your work. I would encourage you to have seasoned simulationists and those outside the simulation world read your application, exemplar, and resume. You must sufficiently describe your experience and exemplar in a way that is comprehensive and easy to understand. Lastly, review the CHSOS-A Standards and Elements for a final time to ensure you have addressed each standard.

Renewal

Like the CHSOS, a CHSOS-A certification is active for three years. The CHSOS-A credential may be renewed by achieving 45 continuing professional development credits over the three-year recertification cycle. Professional development activities must be correlated to one of the five domains covered in the exam. Renewal candidates will need a minimum of one professional development activity for each of the five domains. The CHSOS-A Renewal Handbook, available for free on the SSH website, takes you through the renewal process (Society for Simulation in Healthcare, 2022b). SSH will randomly audit professional development credits used for recertification. Keeping copies of the professional development documents for three years is suggested.

Concluding Remarks

It is an honor to be recognized for our impact as simulation operations specialists. My goal is for everyone who meets the CHSOS or CHSOS-A eligibility qualifications to pursue certification. There are numerous study resources and mentors available to help you. Please never hesitate to contact me or any other CHSOS-A for assistance in achieving your goals.

References

Hayden, J. K., Smiley, R. A., Alexander, M., Kardong-Edgren, S., & Jeffries, P. R. (2014). The NCSBN national simulation study: A longitudinal, randomized, controlled study replacing clinical hours with simulation in prelicensure nursing education. *Journal of Nursing Regulation, 5*(2), S3-S40. https://doi.org/10.1016/S2155-8256(15)30062-4

Healthy Simulation. (n.d.). Home [YouTube Channel]. Retrieved from https://www.youtube.com/@HealthySimulation

INACSL Standards Committee. (2021). Healthcare simulation standards of best practice.™ *Clinical Simulation in Nursing, 56*, 66. https://doi.org/10.1016/j.ecns.2021.08.018

Simulation Tek. (n.d.). Home [YouTube Channel]. Retrieved from https://www.youtube.com/@SimulationTek
Society for Simulation in Healthcare. (n. d.a). *CHSOS-A exemplar cover sheet*. https://www.ssih.org/Portals/48/Certification/CHSOS-A_Docs/CHSOS-A%20Exemplar%20Cover%20Sheet.docx
Society for Simulation in Healthcare. (n. d.b). *Preparing for the exam*. https://www.ssih.org/Portals/48/Certification/Exam%20prep.pdf
Society for Simulation in Healthcare. (n. d.c). *Suggested evidence of performance at the CHSOS and CHSOS-A levels for the certification standards and elements*. https://www.ssih.org/Portals/48/Certification/CHSOS-A_Docs/CHSOS-A%20Standards%20and%20Elements.pdf?ver=N6WNnF70UcPvUg5UcVsDcg%3d%3d
Society for Simulation in Healthcare. (2018). *Certified healthcare simulation operations specialist examination blueprint, 2018 version*. https://www.ssih.org/Portals/48/Certification/CHSOS_Docs/CHSOS_Examination_Blueprint.pdf
Society for Simulation in Healthcare. (2019a). *CHSOS professional development worksheet*. https://www.ssih.org/Portals/48/Certification/CHSOS_Docs/CHSOS%20Professional%20Development%20Worksheet.docx
Society for Simulation in Healthcare. (2019b). *SSH certified healthcare simulation operations specialist renewal and recertification handbook.* https://www.ssih.org/Portals/48/Certification/CHSOS_Docs/CHSOS%20Recert%20Packet.pdf
Society for Simulation in Healthcare Council for Certification. (2019). *SSH certified healthcare simulation operations specialist handbook*. https://www.ssih.org/Portals/48/Certification/CHSOS_Docs/CHSOS%20Handbook.pdf
Society for Simulation in Healthcare. (2020). *SSH certified healthcare simulation operations specialist – advanced handbook*. https://www.ssih.org/Portals/48/Certification/CHSOS-A_Docs/CHSOS-A%20Handbook.pdf
Society for Simulation in Healthcare. (2022a). *Application worksheet*. https://www.ssih.org/Portals/48/Certification/CHSOS-A_Docs/CHSOS-A%20Application%20Worksheet.docx
Society for Simulation in Healthcare. (2022b). *Certified healthcare simulation operations specialist – advanced renewal materials*. https://www.ssih.org/Portals/48/Certification/CHSOS-A_Docs/CHSOS-A%20Recert%20Packet.pdf?ver=zKq477CaTTw5XwphSRR6Mg%3d%3d
Society for Simulation in Healthcare. (2022c). *CHSOS-A application information*. https://www.ssih.org/Portals/48/Certification/CHSOS-A_Docs/CHSOS-A%20Application%20Information.pdf
Society for Simulation in Healthcare. (2022d). *Currently certified individuals*. https://www.ssih.org/Credentialing/Certification/Data
Society for Simulation in Healthcare. (2023). *Membership benefits*. https://www.ssih.org/Membership-Benefits
SSH Certification. (2023). Society for Simulation in Healthcare. Retrieved August 5, 2023, from https://www.ssih.org/Credentialing/Certification
University of Washington Center for Health Sciences Interprofessional Education Research and Practice. (2023). *Teaching with simulation lessons*. https://collaborate.uw.edu/online-training-and-resources/teaching-with-simulation-lessons/

Promoting Psychological Safety through the Incorporation of Diversity, Equity, and Inclusion (DEI) throughout Simulation Centers' Operations

Authors

Laura Daniel, PhD[1]; Therese Justus McAtee, DNP, RN[1]; Donamarie N-Wilfong, DNP, RN[1]

[1]The Simulation, Teaching, and Academic Research (STAR) Center at Allegheny Health Network (AHN), Pittsburgh, Pennsylvania

Conflict of Interest Statement
The authors declare no conflicts of interest.

Corresponding Author
Laura Daniel, PhD, The Simulation, Teaching, and Academic Research (STAR) Center at Allegheny Health Network (AHN), Pittsburgh, Pennsylvania
Email: Laura.Daniel@ahn.org

Brief Description

Simulation centers have an obligation to provide a psychologically safe environment for all users. Many simulation centers have standard policies and procedures or confidentiality agreements and publicity release forms to aid in creating a psychologically safe environment. However, this article challenges simulation operation administrators to go beyond overt forms and describes more covert ways in which simulation centers can promote a psychologically safe environment by incorporating aspects of diversity, equity, and inclusion (DEI) throughout the center. DEI helps people of all backgrounds and life situations feel represented, comfortable, and welcome and therefore will likely increase the psychological safety of the environment. Simulation administrators can integrate DEI throughout the course development and implementation process from start to finish to foster a psychologically safe environment for all.

Introduction

The importance of a psychologically safe environment for simulation education cannot be overstated. Such an environment is professional, supportive, respectful, trusting, and transparent among all simulation participants and facilitators (Picketts, Warren, & Bohnert, 2021). A safe learning environment enables learners and standardized patients (SPs) to perform in reliable ways, free from fears of ridicule, embarrassment, or other negative emotions. Helping simulation participants feel comfortable in the simulated environment aids in lessening potential sources of internal error.

Many simulation centers require learners to sign confidentiality agreements to promote a psychologically safe environment. In fact, confidentiality mechanisms in the form of policies and procedures are a required piece of the Society for Simulation in Healthcare's accreditation standards (2021). Through these forms, all parties involved in the simulation including learners, facilitators, and/or standardized patients pledge not to judge their peers'/learners' performances, not to discuss the performances outside of the simulation center, and/or not to divulge simulation information to other potential participants, helping to establish a psychologically safe environment. These forms will also advise learners of the confidentiality of the data collection tools and video recordings, giving them security in knowing what purpose the recordings serve, how they are stored, and how long they are retained. These overtly signed documents directly contribute to the center's perceived level of a psychologically safe environment.

While deliberate paperwork and signatures are important and fulfill a formal dedication to a psychologically safe environment, this article challenges simulation centers to go beyond rote forms and describes indirect ways in which simulation centers can incorporate DEI methods throughout daily operations to consistently contribute to a psychologically safe environment. Creating a psychologically safe environment begins before any learners set foot in the center during the simulation design phase, is maintained during the course, and is even important when the course is over.

Pre-Course

When course facilitators and/or simulation educators develop a course, they often use course development worksheets or templates. Simulation design templates are used to document the details of the simulation including the specifics of the simulated patient. Many existing templates ask the course developer to articulate only the very basic demographic information about the patient such as age, gender, and/or weight (Northern Virginia Community College, 2023 and Medical College of Wisconsin, 2023). Other templates incorporate additional patient attributes such as ethnicity and/or religion (Texas Tech University, 2023). Nonetheless, several important classifications have typically been omitted from existing simulation design templates.

For simulation centers to truly reach their potential for a diverse and inclusive culture, the simulation design templates need to include more demographic categories, such as their patient's sex assigned at birth, preferred name, pronouns, sexual identity, native language, disabilities, religion, marital status, and educational level. The National League for Nursing's (NLN, 2023) recently revised simulation design template is one of the most diverse design templates to date. The first page of the template asks course facilitators to articulate 26 variables to represent a "brief description of [the] patient." The NLN included the diverse fields of sex assigned at birth, pronouns, gender identity, sexual orientation, marital status, racial group, language, religion, and insurance status. When course facilitators state these additional patient details, it is likely that DEI will surface to the forefront of their minds. It is likely that course facilitators will have a heightened sense of DEI and may choose a variety of patient attributes.

In fact, Laerdal, a world leading medical company, recommends designing entire simulations based on patient populations rather than on a specific clinical task or teamwork strategy to create authentic and diverse simulations (n.d). Laerdal purports many biological and social health determinants are often overlooked but they affect patients in ways that ultimately shape health outcomes. For example, these determinants may affect patient stress levels, access to care, and/or nutrition to name a few. Designing simulations around these often insidious yet powerful factors will help create a wholistic learning environment, appreciative of patient diversity.

Furthermore, many researchers also recommend co-creating simulations with individuals from the community being portrayed in the simulation (Foronda, Everett-Thomas, & Diaz, 2022 and Ibrahim, Lok, Mitchell, et al., n.d.). This real-life content expert can provide genuine insight to the simulation's validity, can help identify potentially offensive language or materials, and/or may help reduce implicit biases that some simulationists may inadvertently overlook. In fact, one of the standards of best practice of the Association of Standardized Patient Educators (2017) reads, "2.1.3 Ensure that cases are based on authentic problems and respect the individuals represented in a case to avoid bias or stereotyping marginalized populations." Therefore, working with standardized patients who have lived through the simulation's problems is an effective way to meet this standard, as they bring genuine insight and authentic guidance to simulation design.

Another way to promote DEI and psychological safety before the simulation begins is by taking inventory of the center's simulators and task trainers. Many of these machines come in different skin tones and ethnicities. One subtle but effective way to help promote a psychologically safe environment is to utilize simulators and task trainers of a variety of races and of both sexes. Indeed, the International Nursing Association for Clinical Simulation and Learning (INACSL)'s healthcare in simulation best practices (2021) for simulation design recommends using manikins with the race and culture of the simulated patient to aid in the fidelity of the simulation.

Similarly, simulation centers can incorporate DEI by diversifying their SP pool as much as possible. A diverse pool of SPs makes it inherently easier for course facilitators to create diverse simulations. Some visual/auditory patient characteristics cannot be simulated such as race and ethnicity, which highlights the need for a large pool of SPs. For example, international patients may have different customs or expectations of healthcare delivery, may speak English as a second language, and/or may speak in heavily accented English. Furthermore, some non-visual attributes are also difficult to simulate, justifying the need to have true SPs of various communities to bring first-hand experiences and lived emotions to the simulation. For example, marginalized and/or vulnerable populations, such as those living under the poverty level and/or transgender patients, may carry rich healthcare experiences that would add value to a simulation. This assertion is parallel to the INACSL's (2021) simulation design best practice of using simulators of varying skin colors and tones to respectfully represent patients' race and culture to promote simulation fidelity. SPs play a vital role in the success of a simulation, and it is essential that they represent all crafted patients well.

Lee Ann Miller, the Assistant Director of Education at West Virginia University's simulation center (2021) articulated the importance of increasing diversity in standardized patient pools, "It is important for the students to experience a diverse patient pool in order to develop cultural competence in a safe environment." Cultural competence has been defined as the delivery of "effective, quality care to patients who have diverse beliefs, attitudes, values, and behaviors" (Tulane University, 2021). Gaining cultural competence is a lifelong process in which healthcare providers continually practice active listening, empathy, and engagement (Guzman, Durden, Taylor, Guzman, & Potthoff, 2016) and diverse simulations can be one outlet to refine such skills and improve interpersonal relationships.

Nonetheless, it would be amiss to think that enrolling diverse SPs will seamlessly promote DEI while also maintaining high psychological security without any additional concerns. SPs themselves are not immune to psychological risks. In fact, Picketts, Warren, and Bohnert (2021) have claimed that enrolling SPs for certain physical characteristics may leave them with feelings of tokenism, misrepresentation, stereotyping, and/or microaggressions. In other words, they may feel like they were only recruited for participation because of their unique heritage rather than their acting abilities. Ethnically rich SPs are not solely defined by their ethnic or cultural membership, and simulationists need to take care in the enrollment of diverse SPs. In fact, ASPE's standards of best practices purport that safe work practices, confidentiality, and respect are the three pillars of safe work environment for SPs (Lewis, Bohnert, Gammon, et al., 2017). For example, these principles assert that SPs need to feel the liberty to opt out from participating if they view it as inappropriate or harmful and need to be aware of the process to report adverse effects.

Course Implementation

There are also methods to incorporate DEI throughout simulation-based education courses. Prebriefing sessions are designated time periods before the simulation to orient learners to the equipment, environment, simulators, roles, time allotment, objectives, and patient situation. INACSL's Healthcare in Simulation Best Practices (2021) for prebriefing, criterion nine, purports that this initial time among facilitators and learners is the ideal setting to “establish a psychologically safe learning environment” through activities that promote integrity, trust, and respect. One such activity that course facilitators can do is to call attention to the diverse attributes of the simulated patient. With pointed attention to certain characteristics and life contexts of the patient, learners may likely feel more comfortable and included if they too in fact, share some of the same diverse attributes as the patient.

Another way course facilitators can nurture a positive learning environment is by structuring the prebriefing in a cultural humility framework (Foronda, Everett-Thomas, & Diaz, 2022). This framework helps facilitators appropriately and sensitively set the tone for controversial topics such as bias or racism through Ground Rules, Acknowledge, Safe Psychological Environment, and Define (GRASPED) (Foronda, McDermott, & Crenshaw, 2022). When course facilitators take care to highlight key aspects of DEI that may affect the patients medically, they also help initiate the establishment of a positive, welcoming, and engaging learning environment for all, thus contributing to learners’ psychological safety.

Once the simulation begins and is underway, course facilitators have the obligation to ensure learners’ psychological safety throughout the education. Course facilitators with keen situational awareness of the simulation’s progression may more easily identify triggered learners. According to Ohio State University (2022), to be triggered means to have an intense, emotional response to some kind of stimuli. It may result when reacting to something that is reflective of past trauma. Being triggered may result in both emotional and/or physical responses, such as feelings of fear, increased heart palpitations, and/or sweating. Course facilitators can become more sensitive to triggered learners through emotional intelligence (EI) training. Positive Psychology (2023) has defined emotional intelligence training as “a set of practical knowledge and skills that help individuals to become fluent in understanding the language of emotions.” The objectives of EI training are to develop self-motivation, productivity, commitment to profession, confidence and flexibility, empathy, communication skills, long lasting and strong interpersonal relationships, self-awareness, and self-control.

Simulation based educators can access virtual emotional intelligence training through reputable universities such as Yale, the University of Michigan, and the University of California Davis or through LinkedIn Learning. These courses are online, self-paced modules in which simulation-based education (SBE) course facilitators complete at their convenience for a nominal fee. Simulation course facilitators who are skilled in recognizing and attending to triggered learners in their own courses would help foster a psychologically safe and inclusive learning environment for learners of all backgrounds and experiences.

Lastly, debriefing sessions are a post-simulation, guided review that provide an outlet to promote learners’ psychological safety even after the simulators are powered off. Indeed, INACSL (2021) standards of best practice purports that debriefing sessions must be conducted in ways that preserve learners’ psychological safety. Debriefing sessions provide an opportunity to explore learners’ emotions and reactions to the simulation and to analyze their performance, in a safe, judgement-free zone. Foronda (2021) described the need for educators to structure debriefing sessions in the transformative learning framework regarding cultural humility. Within this framework, simulationists focus on the idea that learners can change their thinking. When these sessions are consciously conducted in the framework of DEI, more focus will be placed on including all learners, and examining the life variables that affect patient outcomes that may not necessarily be included on the medical chart.

Post-course

At the conclusion of the course, facilitators often administer evaluations to their learners. In fact, evaluating educational activities is a standard for teaching/education accreditation by the Society for Simulation in Healthcare (2021). Evaluative surveys are best anonymous and confidential to decrease social desirability bias and acquiescence. The anonymity of surveys provides learners with a safe venue to voice concerns and/or accolades. Survey items can include questions about the perceived level of psychological safety before, during, and after the course and the perceived level of diversity, equity, and inclusion in the center's operations and facilities. Evaluations can be administered in paper and pencil or electronic formats.

If simulation centers have more time and resources available, Foronda, Everett-Thomas, and Diaz (2022) purport that learner interviews or focus groups are another viable way to glean learner perspectives about the center's culture. These more personal data collection methods may yield rich discussions and/or impactful anecdotes. These meetings can be conducted in-person or virtually. Nonetheless, regardless of the methodology, soliciting first-hand data from the learners will help simulation center administrators gauge the culture of the center and garner ideas for DEI improvement from the perspective of its main users. Similarly, the perspectives of course facilitators are often overlooked but also important. Center administrators can implement similar data gathering methods with facilitators as they do with learners via anonymous evaluative surveys, interviews, and/or focus groups.

By triangulating data from multiple sources, center administrators will likely gain a more holistic perspective. As center operators make a dedication to consistently administer and analyze data from its users, it demonstrates a vigilance to self-reflection and a drive toward improvement. Such good-natured activities may help to build a culture wherein learners and facilitators feel psychologically safe. Moreover, Buchanan and O'Connor (2020) also claimed that gathering such needs assessment data will help simulation administrators create strategic actions to enhance the DEI of their center.

Conclusion

Incorporating DEI into simulation centers not only satisfies today's societal demands but also helps the learners feel more comfortable, likely yielding more valid performances. By recognizing and appreciating the differences among patients and learners, being culturally sensitive to marginalized groups, and making a genuine effort toward equity and inclusion, the psychological environment becomes safer for all. Without the burden of feeling misrepresented, unequal, and/or excluded, learners experience the freedom to participate in the simulations in a more positive and relaxed state of mind, thus contributing to more reliable and valid experiences.

References

Baker, J.C. (2022). What does it mean to be triggered? Ohio State University, Heath & Discovery. https://health.osu.edu/health/mental-health/what-does-it-mean-to-be-triggered

Buchanan, D.T. & O'Connor, M.R. (2020). Integrating diversity, equity, and inclusion into a simulation program. *Clinical Simulation in Nursing, 49*, 58-65. doi:10.1016/j.ecns.2020.05.007

de Guzman, M.R.T., Durden, T.R., Taylor, S.A., Guzman, J.A., & Potthoff, K.L. University of Nebraska. (2016). Cultural competence: An important skill set for the 21st century. https://extensionpublications.unl.edu/assets/html/g1375/build/g1375.htm

Foronda, C. (2021). Debriefing for cultural humility. *Nurse Educator, 46*(5), 268-270.

Foronda, C., Everett-Thomas, R., & Diaz, D.A. Josiah Macy Foundation. (2022). Redesigning simulation-based learning environment to promote DEI and cultural humility. https://macyfoundation.org/news-and-commentary/redesigning-simulation-based-learning-environments-to-promote-dei-and-cultural-humility

Foronda, C., McDermott, D.S., & Crenshaw, N. (2022). Prebriefing for cultural humility. *Clinical Simulation in Nursing, 17*, 141-145. doi:10.1016/j.ecns.2022.02.008

Ibrahim, S., Lok, J., Mitchell, M., Stoiljkovic, B., Tarulli, N., & Hubley, P. (n.d.) Equity, diversity and inclusion in clinical simulation healthcare education and training: An integrative review. *International Journal of Healthcare Simulation*, doi/10.54531/brqt3477.

INACSL Standards Committee, Decker, S., Alinier, G., Crawford, S.B., Gordon, R.M., & Wilson, C. (2021, September). Healthcare Simulation Standards of Best Practice: The Debriefing Process. *Clinical Simulation in Nursing, 58*, 27-32. https://doi.org/10.1016/j.ecns.2021.08.011.

INACSL Standards Committee, McDermott, D.S., Ludlow, J., Horsley, E. & Meakim, C. (2021, September). Healthcare Simulation Standards of Best Practice: Prebriefing: Preparation and Briefing. *Clinical Simulation in Nursing, 58*, 9-13. https://doi.org/10.1016/j.ecns.2021.08.008.

INACSL Standards Committee, Watts, P.I., McDermott, D.S., Alinier, G., Charnetski, M., & Nawathe, P.A. (2021, September). Healthcare Simulation Standards of Best Practice: Simulation Design. *Clinical Simulation in Nursing, 58*, 14-21. https://doi.org/10.1016/j.ecns.2021.08.009.

Laerdal. (n.d.) How to use simulation-based training to reduce implicit bias and promote equitable care. https://laerdal.com/cdn-4a5dc2/globalassets/documents/20-18575---diversity-ebook_final.pdf

Lewis, K.L., Bohnert, C.A., Gammon, W.L., Hölzer, H., Lyman, L., Smith, C., Thompson, T.M., Wallace, A., & Gliva-McConvey, G. (2017). The association of standardized patient educators (ASPE) standards of best practices (SOBP). *Advances in Simulation, 2*(10). doi:10.1186/s41077-017-0043-4

Medical College of Wisconsin. (2023). *Simulation case template.* https://www.mcw.edu/-/media/MCW/Departments/Pediatrics/Medical-Education/Simulation/SIMULATION-CASE-TEMPLATE_final.pdf

National League for Nursing. (2023). *Simulation design template – Revised February 2023.* https://www.nln.org/education/education/sirc/sirc/sirc-resources/sirc-tools-and-tips

Northern Virginia Community College. (2023). *Scenario design worksheet.* Clinical Simulation Center. https://www.nvcc.edu/medical/_files/ScenarioDesignWorksheet.pdf

Picketts, L., Warren, M.D., & Bohnert, C. (2021). Diversity and inclusion in simulation: Addressing ethical and psychological safety concerns when working with simulated patients. *BMJ Simulation & Technology Enhanced Learning, 7*(6), 590-599. doi:10.1136/bmjstel-2020-000853

Positive Psychology. (2023). *How to improve emotional intelligence through training.* https://positivepsychology.com/emotional-intelligence-training/#:~:text=Emotional%20Intelligence%20Training%20is%20a,Commitment%20to%20profession

Society for Simulation in Healthcare. Committee for Accreditation of Healthcare Simulation Programs. (2021). Core Accreditation Standards Companion Document. https://www.ssih.org/Portals/48/2021%20SSH%20CORE%20STANDARDS%20COMPANION%20DOCUMENT.pdf

Society for Simulation in Healthcare. Committee for Accreditation of Healthcare Simulation Programs. (2021). Teaching/Education Accreditation Standards Companion Document. https://www.ssih.org/Portals/48/2021%20SSH%20TEACHING%20EDUCATION%20ACCREDITATION%20STANDARDS%20%281%29.pdf

Texas Tech University Health Science Center. (2023). *Template for SP cases*. Simulation Resources. https://www.ttuhsc.edu/simulation/documents/Template_for_SP_Cases.pdf

Tulane University. (2021). How to improve cultural competence in health care. https://publichealth.tulane.edu/blog/cultural-competence-in-health-care/

West Virginia University. (2021). *WV STEPS features diverse manikin, standardized patients for students to gain experience working with diverse populations*.

https://health.wvu.edu/news/story?headline=wv-steps-features-diverse-manikins-standardized-patients-for-students-to-gain-experience-working-wit

The Use of Escape Room Simulations in Undergraduate Medical Education

Authors
Alexa R. Lauinger, BS[1], Athena Ryals BS[3,] Mae Vogel, MS[3,] Shandra Jamison, MA[1,3] Carlos E. Brown Jr, MD[1,2]

[1] University of Illinois Urbana- Champaign, Carle Illinois College of Medicine, Urbana, Illinois
[2] Carle Foundation Hospital, Emergency Department, Urbana, Illinois
[3] University of Illinois Urbana-Champaign, Health Care Engineering Systems Center, Urbana, Illinois

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

Corresponding Author
Shandra Jamison, MA, University of Illinois Urbana-Champaign, Carle Illinois College of Medicine, Urbana, Illinois
Email: shandraj@illinois.edu

Brief Description
Undergraduate medical education is constantly growing and adapting to offer students diverse learning strategies while aiming to improve engagement from students and competency of medical skills. Two changes that have been implemented in recent years include the use of simulation and gamification of teaching experiences. Combining aspects of simulation with gamification has led to the use of escape rooms. Studies into the benefits of using escape rooms demonstrate improved student reactions and retention of content. However, there have been few studies looking at the effectiveness of escape room simulations in medical undergraduate education. Most of the research in this area uses nursing students as participants. This review examines the current evidence of outcomes for escape rooms in medical school and the overall format of designing and implementing escape rooms as a teaching strategy. However, there are limitations of small sample sizes, limited follow-up, and heterogeneous methods for implementing this type of simulation, but current research supports the integration of escape room-type sessions into medical schools.

Introduction
Medical education is an evolving and adapting field that works to incorporate modern teaching techniques and technologies. Traditional teaching strategies implemented a didactic-based approach for the first part of undergraduate medical education followed by clinical experiences (Pock, et al., 2013). Recently, there has been a shift to earlier clinical experiences, including simulated sessions to give students a safe context to facilitate learning (Herrera-Aliaga, 2022). The outcome of this change led to increased interest in the material, confidence in decision-making, and overall performance (Kimura et al., 2021; Everson et al., n.d.; McInerney et al., 2022). With the development of technology and the continued integration of simulated sessions into medical school, we would expect future simulations to improve these aspects of learning even further. Along with the push for more simulated experiences, gamification has infiltrated undergraduate medical training to allow for diverse educational opportunities with similar benefits to those we saw in simulation-based education

(Krishnamurthy et al., 2022). Gamification and the advancement of technology both play a role in escape room simulations for medical education.

Escape rooms are a type of interactive experience in which a team of players are locked inside a room and must work together to solve puzzles and accomplish tasks within a given timeframe to escape. Recently, escape rooms have been integrated into educational environments to improve student engagement (Backhouse & Malik, 2019; Kinio, 2019). The use of escape room simulations has also been implemented in professional settings to consolidate knowledge, improve interdisciplinary relationships, and evaluate competency (Zhang et al., 2019; Reinkemeyer et al., 2022). An escape room simulation can be a health-care-focused simulated interactive activity that incorporates traditional parts of an escape room into training (Anderson et al., 2021). Educational escape rooms have been adopted across different medical settings, such as nursing schools and medical graduate or residency programs. Healthcare programs using this method of education show improvement in retention, engagement, and teamwork through escape room simulations (Zhang et al., 2019; Reinkemeyer et al., 2022). However, there has been a lack of undergraduate medical programs or medical schools adopting this teaching strategy up to now.

Although escape room simulations have shown promising results in several healthcare training programs, there is not a validated framework to adapt these teaching strategies to undergraduate education. A more thorough understanding of the key aspects and longitudinal outcomes of escape room simulations is needed before implementation into the current education system. This review aims to 1) describe the current format of escape room simulations, especially in the wake of the COVID-19 pandemic, 2) examine the types of skills which can be effectively taught in medical escape rooms, and 3) summarize the outcomes of studies that evaluate the inclusion of escape room simulations in undergraduate medical training programs.

Methods

Three databases (PubMed, Web of Knowledge, and Scopus) were queried for publications relating to the implementation of escape room simulation in medical education with a focus on the undergraduate level. The search strategy for the databases used was: (Escape AND Room) AND (Medical AND School) OR (Residency) OR (Nursing AND school). The included papers were limited to full-text articles published in English. Abstracts, editorials, and reviews were excluded. The included papers were reviewed for skills utilized in the simulation, assessment types, and outcomes. Results are summarized in this literature review.

Results

Our literature search hit upon nine papers that focused on the outcomes and effectiveness of utilizing escape room simulations in medical undergraduate education (Table 1). Together these studies involved 568 medical students as participants, with most sessions catering to preclinical students.

Of the studies included, eight out of nine integrated a post-simulation assessment to gauge students' attitudes toward the escape room experience, conversely only one study conducted a pre-simulation survey. Additionally, two out of nine studies employed both pre- and post-simulation tests to evaluate participants of which one study assigned grades to the assessment while the other included a follow-up test two weeks after the session.

Published papers included a debriefing session to answer questions and discuss objectives with participants following the escape room activity. Only one study compared the escape room simulation with another type of learning session, specifically case-based learning. Notably, the escape room simulation was implemented across a diverse array of medical topics (Table 1).

Table 1: Publications that evaluate the use of escape room simulations in undergraduate medical education.

Publication	**Sample Size**	**Level**	**Topic**	**Assessment Type**	**Results**
Wu, 2018	28	Various levels of medical students	Leadership	Post-simulation survey	Students reporting using ≥3 leadership competencies during the simulation
Backhouse, 2019	19	Third-year students	Patient safety	Post-simulation survey	Students reported enjoying the simulation and increased confidence after the session
Kinio, 2019	13	Preclinical students	Vascular surgery	Post-simulation survey	Students reported that the escape room consolidated their knowledge
Guckian, 2020	16	Third-year students	Dermatology	Pre- and Post-simulation survey	The simulation helped inform students about the specialty topic
Liu, 2020	19	Various levels of medical students	Pediatric Radiology	Test before, after, and two weeks post-simulation; post-simulation survey	There was a score increase from the pretest that was retained two weeks later
Donovan, 2021	88	Third-year students	Clinical experience	Post-simulation survey	Students reported enjoying the simulation and learning from it
Akatsu, 2022	140	First-year students	Medical interview and physical exam	Graded assessment; post-simulation survey	The simulation enhanced student motivation and had educational value
Faysal, 2022	97	Fourth-year students	Dermatology	Test before and after	Similar increase in scores for the simulation versus case-based learning
Martin, 2022	148	Preclinical students	Medical environment	Post-simulation survey	The simulation prepared students for future medical environments

Discussion

Format of Escape Room Simulations

Since the implementation of escape room simulations into medical education, there have been specific frameworks and key aspects that have been suggested as necessary for successful outcomes (Hawkins et al., 2020). There has also been an increase in the number of studies which outline the process of designing, testing, and implementing escape rooms into the curriculum (Dittman et al., 2022; Eukel & Morrell, 2021). The important facets to include when creating and implementing an escape room simulation are:

- *Objectives:* define specific, measurable skills the simulation will teach participants
- *Design:* determining the resources and time available for the simulation then develop appropriate puzzles and tests for the escape room
- *Piloting:* testing the simulation, especially for the inability to skip clues
- *Prebrief:* preparation by participants for the simulation
- *Debrief:* discussion post-simulation to discuss questions and review objectives with participants

The above aspects of the experience allow for an informal and low-pressure challenge for students (Hawkins et al., 2020). The use of these tactics can help standardize the development of simulations to ensure the effectiveness of escape room simulations and can improve the ability of programs to incorporate escape room models into their curriculum without increased obstacles from trial and error.

Adaptation to Remote Simulations

In the wake of the COVID-19 pandemic, there has been a push to convert some lessons into remote learning opportunities which includes simulated sessions. The study of escape room simulations in this context demonstrates the adaptability of strategies such as escape rooms that are encouraging Donovan et al. outlines the creation, implementation, and outcomes of a remote escape room using create-your-own-adventure software combined with online surveys and educational programs (Donovan, n.d.). Horn also used a combination of standalone, online programs to create and publish a remote escape room based on cardiac physiology (Horn, 2023). The use of remote platforms for the medical escape room demonstrates similar responses in engagement, enjoyment, and functionality as the in-person sessions (Grupel et al., 2022; Diaz et al., 2021). Results further support the use of escape room simulations since they are adaptable and can accommodate a variety of school curriculums and resources. The use of virtual escape rooms has shown the ability to be targeted towards developing nontraditional skills such as information searching and summarization (Diaz et al., 2021). This can add to the variety of skills that simulations have been used to build and solidify students' education.

Context of Teaching

Apart from objectives, piloting, and briefing, it is also important to examine the learning content that is being targeted. Escape room simulations have been employed within medical residency programs, nursing schools, and pharmacy schools to not only teach procedures, dosage calculations, and conduct assessments, but also to foster the development of interpersonal skills and other such soft skills (Powers et al., 2022; Millsaps et al., 2022; Fusco et al., 2022; Rosenkrantz et al., 2019); studies focused on medical schools have targeted nontechnical skills, orientation to simulations, knowledge development, and assessments (Liu et al., 2020; Akatsu et al., 2022; Martin & Gibbs, 2022). Across the different objectives previously listed, there have been similar outcomes in the engagement and enjoyment of students throughout the experiences.

The broader context demonstrates the ability of escape rooms to teach soft skills, such as teamwork, communication, and leadership; the use of escape room simulations to solidify procedures suggests that similar experiences can be applied to medical schools to teach students technical practices (e.g., intubation and CPR). An unexpected application of simulation escape rooms is their use in the assessment of the aforementioned skills. Unlike traditional simulations, escape rooms vary in the puzzles used and the possible measurements which can be used to assess success. Consequently, the frameworks and objects of the simulation must be set well before implementing the assessment.

Outcomes of Escape Room Simulations

As previously mentioned, escape room simulations have been used for several years across healthcare training programs. In comparison, there have been few studies on the impact of escape room simulations within undergraduate medical education. However, the studies found do support the use of escape room simulations to create a low-pressure setting to teach a variety of material, including nontechnical skills and competency (Akatsu et al., 2022; Rosenkrantz et al., 2019). Overall, the studies demonstrate improved student reactions, retention, and teamwork in the teaching sessions (Wu et al., 2018; Rosenkrantz et al., 2019; Podlog et al., 2019). Escape room simulations are an effective teaching method compared to case-based learning (Faysal et al., 2022). In each study, there were a variety of puzzles and challenges implemented to evaluate and practice different technical skills. Apart from the technical knowledge utilized in the simulation, each study noted a degree of development in communication and teamwork. Consistently, there was an increase in student engagement and enjoyment during the sessions (Wu et al., 2018; Rozenkrantz et al., 2019; Podlog et al., 2019). Overall, early studies examined the use of escape room simulations in undergraduate medical education and support the integration of these techniques into medical schools.

The Future of Escape Rooms in Medical Education

Escape room simulations have been successful for several years across a range of healthcare training programs, and early evidence of their integration into undergraduate medical education has shown encouraging results (Diaz et al., 2021; Cerenzio & Ocheretyaner, 2021; Khanna et al., 2012). The simulations have the potential to train students in an exciting, low-pressure environment that improves engagement, enjoyability, and consolidation of the material. In addition to being effective, simulations are also highly adaptable to a variety of skills, resources, and settings (Grupel et al., 2022). Drawing from the reported results, escape room simulations are likely to be integrated further into undergraduate medical education in the next several years. As escape room simulations become more standardized across schools, we will better understand the long-term impacts of the sessions and their ability to improve students' learning experiences. We will also see the adaptation of such methods to a wider variety of skills that are necessary for students to practice.

Limitations of Current Research

Limitations of current research in this field are the short length of studies that have been published. Only recently have escape rooms been used in medical schools. As a result, there is limited information on the long-term effects of these teaching methods. Most outcomes are measured using a post-simulation survey and lack a baseline or a follow-up assessment for retention. The current studies also include a limited number of participants. As demonstrated in Table 1, several of the studies mentioned a limitation being sample size due to enrollment and the difficulty of running the escape room (Backhouse & Malik, 2019; Kinio et al., 2019; Guckian et al., 2020; Liu et al. 2020). The small sample sizes of the studies reported on naturally lend themselves to higher potential errors in the data; it is more difficult or impossible to eliminate outliers. Further research is needed comparing the outcomes of escape room simulations to other forms of teaching with more objective outcome measures and a longer follow-up time.

Conclusion

Undergraduate medical education is an ever-changing field that must utilize a range of teaching strategies to improve student engagement, confidence, and competency. The newest addition to teaching strategies is the simulated medical escape room which combines medical simulation and gamification into interactive, low-pressure sessions. Although these methods have been integrated into other healthcare training programs, there are limited studies of their effectiveness in medical schools. While early evidence indicates success with integrating the methods, escape room simulations should be explored further for long-term outcomes and improved sample sizes during the integration of these strategies into standard practice.

References

Pock, A. R., Pangaro, L. N., Green, C. B., & Laughlin, L. (2013). Undergraduate Medical Education: Past, Present, and Future. *Military Medicine, 178(5),* 474–478. https://doi.org/10.7205/MILMED-D-12-00456

Herrera-Aliaga, E., & Estrada, L. D. (2022). Trends and Innovations of Simulation for Twenty First Century Medical Education. *Frontiers in Public Health, 10,* 619769. https://doi.org/10.3389/fpubh.2022.619769

Kimura, T., Kojo, K., Shiga, M., Chihara, I., Ikeda, A., Kandori, S., Kojima, T., Haruta, J., & Nishiyama, H. (2021). Impact of Early Exposure to Simulation Program on Undergraduate Medical Students' Interest in Urology. *Journal of Medical Education and Curricular Development, 8,* 23821205211020750. https://doi.org/10.1177/23821205211020750

Everson, J., Gao, A., Roder, C., & Kinnear, J. (n.d.). Impact of Simulation Training on Undergraduate Clinical Decision-making in Emergencies: A Non-blinded, Single-centre, Randomised Pilot Study. *Cureus, 12(4),* e7650. https://doi.org/10.7759/cureus.7650

McInerney, N., Nally, D., Khan, M. F., Heneghan, H., & Cahill, R. A. (2022). Performance effects of simulation training for medical students – a systematic review. *GMS Journal for Medical Education, 39(5),* Doc51. https://doi.org/10.3205/zma001572

Krishnamurthy, K., Selvaraj, N., Gupta, P., Cyriac, B., Dhurairaj, P., Abdullah, A., Krishnapillai, A., Lugova, H., Haque, M., Xie, S., & Ang, E.-T. (2022). Benefits of gamification in medical education. *Clinical Anatomy, 35(6),* 795–807. https://doi.org/10.1002/ca.23916

Backhouse, A., & Malik, M. (2019). Escape into patient safety: Bringing human factors to life for medical students. *BMJ Open Quality, 8(1),* e000548. https://doi.org/10.1136/bmjoq-2018-000548

Kinio, A. E., Dufresne, L., Brandys, T., & Jetty, P. (2019). Break out of the Classroom: The Use of Escape Rooms as an Alternative Teaching Strategy in Surgical Education. Journal of *Surgical Education, 76(1),* 134–139. https://doi.org/10.1016/j.jsurg.2018.06.030

Zhang, X. C., Diemer, G., Lee, H., Jaffe, R., & Papanagnou, D. (2019). Finding the 'QR' to Patient Safety: Applying Gamification to Incorporate Patient Safety Priorities Through a Simulated 'Escape Room' Experience. *Cureus, 11(2),* e4014. https://doi.org/10.7759/cureus.4014

Reinkemeyer, E. A., Chrisman, M., & Patel, S. E. (2022). Escape rooms in nursing education: An integrative review of their use, outcomes, and barriers to implementation. *Nurse Education Today, 119,* 105571. https://doi.org/10.1016/j.nedt.2022.105571

Anderson, M., Lioce, L., M. Robertson, J., O. Lopreiato, J., & A. Díaz, D. (2021). Toward Defining Healthcare Simulation Escape Rooms. *Simulation & Gaming, 52(1),* 7–17. https://doi.org/10.1177/1046878120958745

Wu, C., Wagenschutz, H., & Hein, J. (2018). Promoting leadership and teamwork development through Escape Rooms. *Medical Education, 52(5),* 561–562. https://doi.org/10.1111/medu.13557

Guckian, J., Sridhar, A., & Meggitt, S. J. (2020). Exploring the perspectives of dermatology undergraduates with an escape room game. *Clinical and Experimental Dermatology, 45(2),* 153–158. https://doi.org/10.1111/ced.14039

Liu, C., Patel, R., Ogunjinmi, B., Briffa, C., Allain-Chapman, M., Coffey, J., Kallam, N., Leung, M. S. T., Lim, A., Shamsad, S., El-Sharnouby, F., Tsang, E., Whitehead, J., Bretherton, J., Ramsay, L., & Shelmerdine, S. C. (2020). Feasibility of a paediatric radiology escape room for undergraduate education. *Insights into Imaging, 11(1*), 50. https://doi.org/10.1186/s13244-020-00856-9

Donovan, C. M., Cooper, A., & Kim, S. (n.d.). Ready Patient One: How to Turn an In-Person Critical Care Simulation Scenario Into an Online Serious Game. *Cureus, 13(9),* e17746. https://doi.org/10.7759/cureus.17746

Akatsu, H., Shiima, Y., Gomi, H., Hegab, A. E., Kobayashi, G., Naka, T., & Ogino, M. (2022). Teaching "medical interview and physical examination" from the very beginning of medical school and using "escape rooms" during the final assessment: Achievements and educational impact in Japan. *BMC Medical Education, 22(1),* 67. https://doi.org/10.1186/s12909-022-03130-2

Faysal, L. R., Yasmin, R., Zaman, A., & Khan, R. A. (2022). Effectiveness of medical escape room on learning of undergraduate medical students in comparison with case-based learning in teaching of clinical dermatology. *Rawal Medical Journal, 47(1).*

Martin, A., & Gibbs, S. (2022). An Escape Room to Orient Preclinical Medical Students to the Simulated Medical Environment. *MedEdPORTAL : The Journal of Teaching and Learning Resources*, *18*, 11229. https://doi.org/10.15766/mep_2374-8265.11229

Hawkins, J. E., Wiles, L. L., Tremblay, B., & Thompson, B. A. (2020). Behind the Scenes of an Educational Escape Room. *AJN The American Journal of Nursing, 120(10),* 50. https://doi.org/10.1097/01.NAJ.0000718636.68938.bb

Dittman, J. M., Amendola, M. F., Ramraj, R., Haynes, S., & Lange, P. (2022). The COMET framework: A novel approach to design an escape room workshop for interprofessional objectives. *Journal of Interprofessional Care, 36(1),* 161–164. https://doi.org/10.1080/13561820.2020.1870442

Eukel, H., & Morrell, B. (2021). Ensuring Educational Escape-Room Success: The Process of Designing, Piloting, Evaluating, Redesigning, and Re-Evaluating Educational Escape Rooms. *Simulation & Gaming, 52(1),* 18–23. https://doi.org/10.1177/1046878120953453

Horn, M. A. (2023). Design and evaluation of a new consolidation exercise for students studying cardiac physiology: A digital escape room. *Advances in Physiology Education, 47(1),* 82–92. https://doi.org/10.1152/advan.00176.2022

Grupel, D., Wennstroem, E., & Moran-Gilad, J. (2022). Escape room—The next generation of problem-based learning? *Clinical Microbiology and Infection, 28(6),* 768–770. https://doi.org/10.1016/j.cmi.2022.03.017

Diaz, D. A., McVerry, K., Spears, S., Díaz, R. Z., & Stauffer, L. T. (2021). Using Experiential Learning in Escape Rooms to Deliver Policies and Procedures in Academic and Acute Care Settings. *Nursing Education Perspectives, 42(6),* E168. https://doi.org/10.1097/01.NEP.0000000000000691

Powers, K., Brandon, J., & Townsend-Chambers, C. (2022). Preparing nursing students for home health using an escape room: A qualitative study. *Nurse Education Today, 108,* 105215. https://doi.org/10.1016/j.nedt.2021.105215

Millsaps, E. R., Swihart, A. K., & Lemar, H. B. (2022). Time is brain: Utilizing escape rooms as an alternative educational assignment in undergraduate nursing education. *Teaching and Learning in Nursing, 17(3),* 323–327. https://doi.org/10.1016/j.teln.2022.01.013

Fusco, N. M., Foltz-Ramos, K., & Ohtake, P. J. (2022). An Interprofessional Escape Room

Experience to Improve Knowledge and Collaboration Among Health Professions Students. *American Journal of Pharmaceutical Education, 86(9).* https://doi.org/10.5688/ajpe8823

Rosenkrantz, O., Jensen, T. W., Sarmasoglu, S., Madsen, S., Eberhard, K., Ersbøll, A. K., & Dieckmann, P. (2019). Priming healthcare students on the importance of non-technical skills in healthcare: How to set up a medical escape room game experience. *Medical Teacher, 41(11),* 1285–1292. https://doi.org/10.1080/0142159X.2019.1636953

Podlog, M., Husain, A., Greenstein, J., & Sanghvi, S. (2019). Escape the Trauma Room. *AEM Education and Training, 4(2),* 158–160. https://doi.org/10.1002/aet2.10410

Cerenzio, J., & Ocheretyaner, E. R. (2021). Impact of an interactive, clinical decision-making workshop on student learning of antimicrobial stewardship principles. *Currents in Pharmacy Teaching and Learning, 13(11),* 1492–1497. https://doi.org/10.1016/j.cptl.2021.09.006

Khanna, A., Ravindran, A., Ewing, B., Zinnerstrom, K., Grabowski, C., Mishra, A., & Makdissi, R. (2021). Escape MD: Using an Escape Room as a Gamified Educational and Skill-Building Teaching Tool for Internal Medicine Residents. *Cureus, 13(9),* e18314. https://doi.org/10.7759/cureus.18314

Development of an Inexpensive, Reusable, Novel Emergency Department Thoracotomy Partial Task Trainer

Authors

Mark J. Bullard[1], MD, MS-HPEd, Christie L. Bullard[2], RN, John D. Ehlers III, BA[2], Kyle W. Cunningham[3], MD, MPH, Jeffrey W. Bullard, MD

[1]Atrium Health, Carolinas Simulation Center, Carolinas Medical Center, Department of Emergency Medicine, Charlotte, North Carolina
[2]Atrium Health, Carolinas Simulation on Center, Charlotte, North Carolina
[3]Atrium Health, Carolinas Simulation Center, Carolinas Medical Center, Department of Surgery, Charlotte, North Carolina

Conflict of Interest Statement
Authors have no conflicts of interest.

Authors would like to acknowledge: Carolinas Simulation Center, Atrium Health

Corresponding Author
Mark J. Bullard, MD, MS-HPEd, Wake Forest School of Medicine, Department of Emergency Medicine, Carolinas Medical Center, Carolinas Simulation Center, Atrium Health
Email: Mark.bullard@atriumhealth.org

Brief Description

We designed and built a reusable, durable, low-cost emergency department thoracotomy (EDT) partial task trainer with functional and structural fidelity for repetitive practice of EDT. Learning objectives focused on the step-by-step cognitive process and experience of emergent thoracotomy. Trainer description (Figure 1), components and total cost (Table 1) are outlined within the manuscript.

Background

EDT requires immediate, decided action by emergency providers. Survival rates vary depending on mechanism and literature, however victims of penetrating thoracic trauma requiring EDT have shown a survival rate of 9-38% if used in appropriate patients (Hunt et al., 2006). While indications and timing of EDT continue to be refined and debated, emergent thoracotomy remains a procedure required of emergency physicians, yet still represents a low frequency, high-risk procedure in even the highest volume trauma centers. Further, it has been demonstrated that patients undergoing EDT at higher volume trauma centers have significantly greater odds of survival (Dumas et al, 2018). Lack of educational exposure in EDT is due to many facets: limited indication, invasiveness of EDT, ethical debate surrounding post-mortem procedures, variation of regional and hospital policy and limited, albeit expensive commercial thoracotomy task trainers. Frequency of training and repetition improves outcomes. Unfortunately, some emergency medicine (EM) residents graduate training programs without performing or observing this unique procedure, despite EDT being a required skill for independent EM practitioners. Unfortunately, there are very few commercial thoracotomy models on the market, and these task trainers are very expensive. Further, recognizing that skills decay can affect learning retention, it is important for learners to have reusable, low-cost mechanisms for repetitive practice.

Objective

Addressing the above challenges, we aimed to design and build an inexpensive, reusable thoracotomy task trainer with high functional fidelity. While structural fidelity (physical resemblance) certainly influences suspension of disbelief for learners, we emphasized our design to focus on specific learning objectives and the "functional correspondence between the simulator and the applied context" (Hamstra et al., 2014). For our learners, we determined it most important that they become facile with using the necessary equipment for the step-by-step process involved in an EDT. Our designed trainer functionality was based on specific learning objectives which included: 1) Incising integumen at the 5th intercostal space to gain entry into the thorax, 2) Proper positioning and use of rib spreaders to maximize the surgical field, 3) Using long pick-ups and curved Mayo scissors to incise the pericardium while avoiding the phrenic nerve, 4) Delivering the heart from a clotted pericardium, and 5) Cross-clamping the descending aorta.

EDT is not a technically complex procedure; arguably, EDT requires few technical steps relative to other procedures, however, the procedure does require step-by-step cognitive processes and experience to act quickly. EDT requires a clinician to decidedly use appropriate equipment to gain access into the thorax and pericardial space, deliver the heart from the pericardium and subsequently cross-clamp the descending aorta. The left anterolateral thoracotomy is the most common approach used in the emergency department because this approach addresses the major causes of acute deterioration due to penetrating trauma: pericardial tamponade, tension pneumothorax, and acute hemorrhage from the left hemi-thorax. A left anterolateral thoracotomy approach also enables the cross-clamping of the descending aorta with resultant maintenance of perfusion to vital organs. Therefore, we primarily aimed to design a reusable EDT trainer to appropriately entertain these vital steps for frequent learner repetition while limiting expense.

Methods

We designed a reusable, durable left anterolateral thoracotomy partial task trainer with the outlined materials (Table 1). A recycled airway manikin was attached to the thoracotomy task trainer to add to the overall structural fidelity (Figure 4), however, this was not felt a necessity for the desired learning objectives and functionality of the trainer. Skin was made at our simulation center using Smooth-On (Smooth-on Inc, Macungie, PA). The pericardium was created by taping a string in a sagittal plane on a gallon Ziplock (S.C. Johnson & Son, Racine, WI) bag. We also filled the Ziplock bag with Red Hots (Ferrara Candy Company, Chicago, IL) candy to represent clotted pericardial blood causing tamponade physiology. This candy was chosen due to its red color, ability to be reused, and to also avoid any gelatinous or liquid material that would require trainer clean-up after relief of tamponade physiology. The heart (Figure 6) was created by our simulation center using Ecoflex silicone rubber (Smooth-on In, Macungie, PA) poured into a cardiac mold and placed in the gallon Ziplock bag. The heart was not attached to simulated vessels, but rather placed loosely within the pericardium for the representative step and experience of delivering the heart from the pericardium during the procedure.

Table 1: Materials for EDT partial task trainer (cost without airway head/artificial skin: $225)

2 pieces of $^{3}/_{4}$" plywood 24" x 48”
½” solid aluminum rod 72” (total)
Compression springs ½” I.D. (36 pieces)
Pex tube ¾” I.D.* (blue) 18”
Pex tube ¾” I.D.* (red) 18”
Clear vinyl tube $^{5}/_{8}$” I.D.* 18”
Aluminum tube $^{3}/_{16}$” O.D.** 12”
Acetal sleeve bearing ½” I.D.* ¾” long pieces (4) McMaster-Carr
Alligator clips (4)
$^{5}/_{8}$” hardwood dowel
¾” hardwood dowel
6” x ½” x 48” hardwood for head support/insert
1-gallon Ziplock bag
String
Red Hots candy
Airway training head
Artificial skin
Molded heart
*I.D. = internal diameter
**O.D. = outside diameter

Construction of Task Trainer

The items used in the construction of the EDT trainer are available at local hardware stores. The only exception: the sleeve bearing/bushing for two of the ribs, which can be ordered online.

1. The base of the trainer was cut to size from $^{3}/_{4}$" thick plywood (23” x 20”).
2. A dado was cut in the base 2" from each end that was $^{3}/_{4}$" wide and $^{3}/_{8}$" deep.
3. The semicircular end pieces were cut with a 10" radius (Figure 1).
4. ½" wide holes were drilled $^{3}/_{8}$" deep in the semicircular end pieces for the four aluminum rods.
5. 12 ribs were cut from a template traced on ¾” plywood (Figure 2).
6. All pieces were rounded over with a ¼” round-over bit and carefully sanded.
7. Ribs #3 and #4 on the left hemithorax required larger holes to account for a sleeve bearing/bushing permitting easier sliding. All the other rib holes were 1⁄2 inch in diameter (Figure 3).
8. A 1-Gallon Ziplock bag simulated the pericardium and was held in place by four brass rods ($^{1}/_{8}$” in diameter) with alligator clips on each end (Figure 5).
9. Except for the glued surfaces, the trainer bottom and sides were varnished prior to assembly.
10. Ribs were spray-painted white with an appropriate size temporary dowel in each hole to prevent paint getting into the surface that slides on the aluminum rods.
11. Upright semicircular end pieces were installed into the previously dados. One end piece was glued and screwed into place followed by four aluminum rods.

12. Each rib was placed on the aluminum rods and separated each with ½" (internal diameter) compression springs.
13. The other end was installed with glue and screws.
14. A 2" wide brace was attached off-center on each outside end to prevent "racking" of the trainer.
15. The brass rods with alligator clips on the tips were inserted into the holes.
16. An airway manikin head was available and was attached to the cephalad portion of the trainer.
17. Vena cava, aorta, and esophagus were inserted using out of different colored PEX tubing in appropriate anatomical position.

Figure 1: Semicircular end pieces for task trainer.

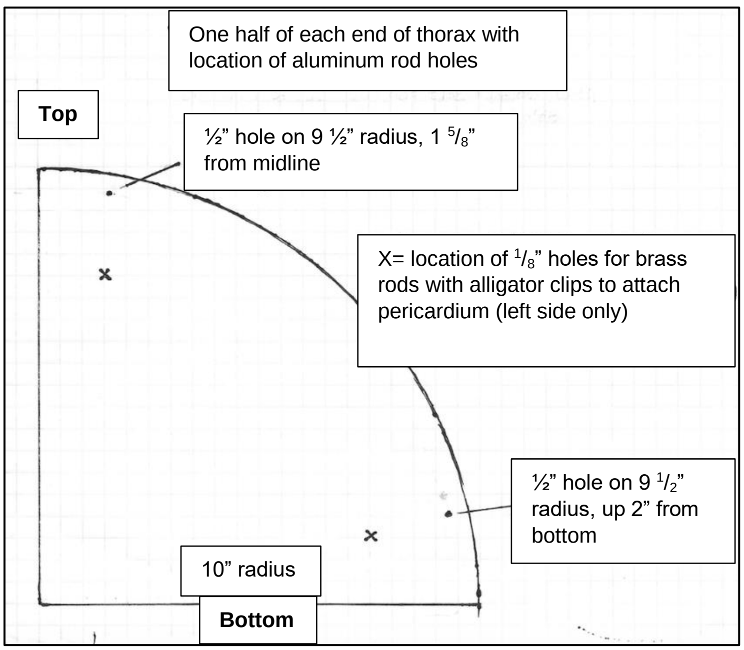


Figure 2: Rib template.

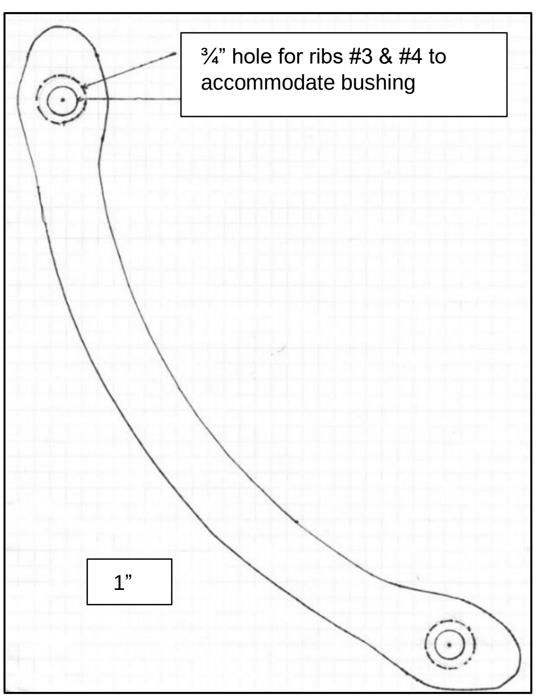


Figure 3: Task Trainer without 1-Gallon Ziplock pericardium, alligator clips in place. Ribs #3 and #4 with bushings.

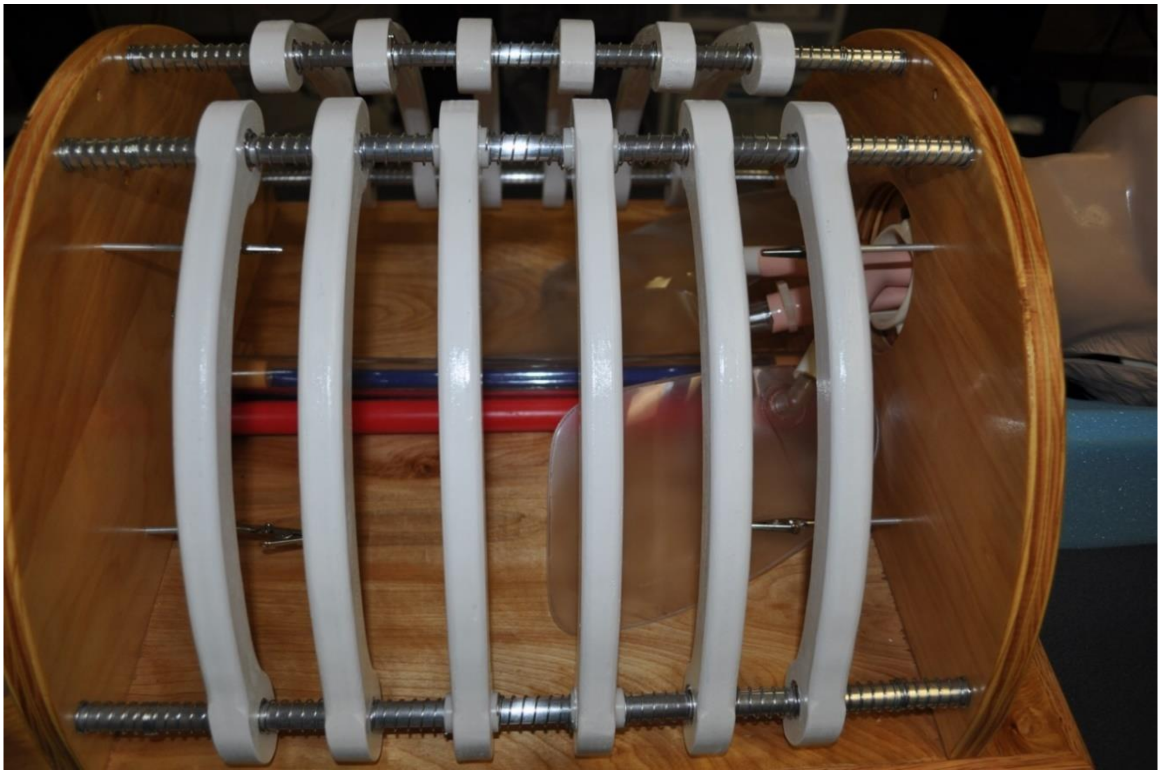


Figure 4: Task Trainer without surgical towel prep and skin

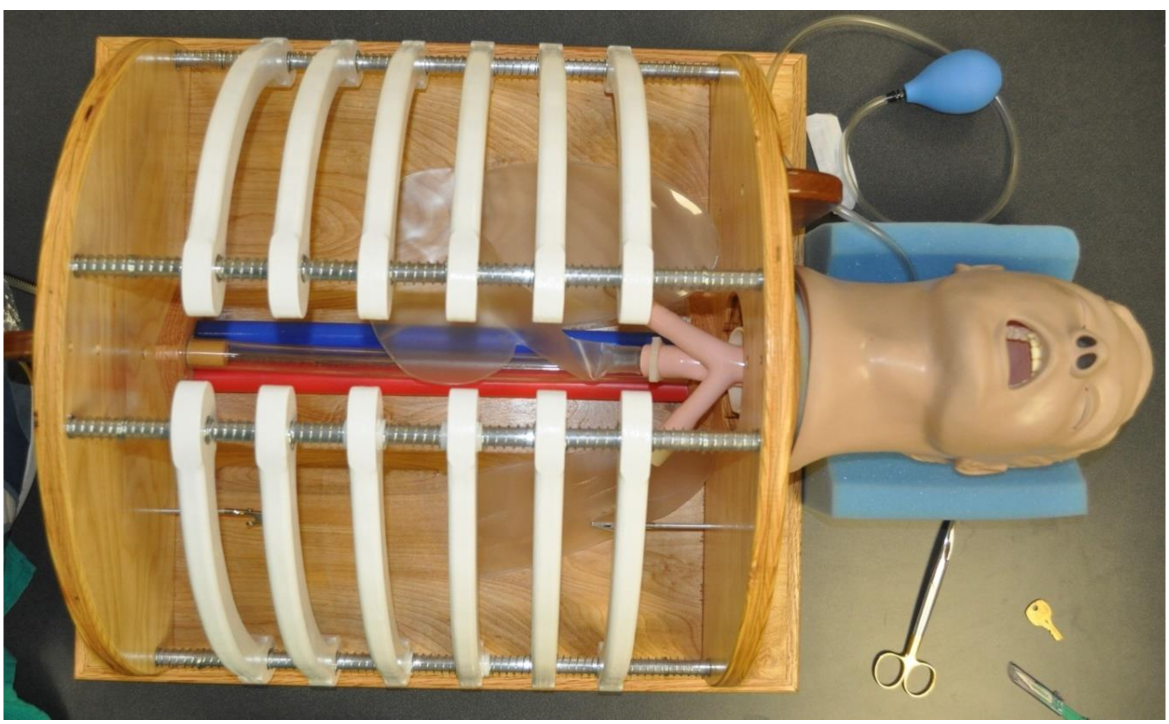


Figure 5: Task trainer prepped and draped with latex heart and Red Hots candy within pericardium.

Figure 6: Silicone heart

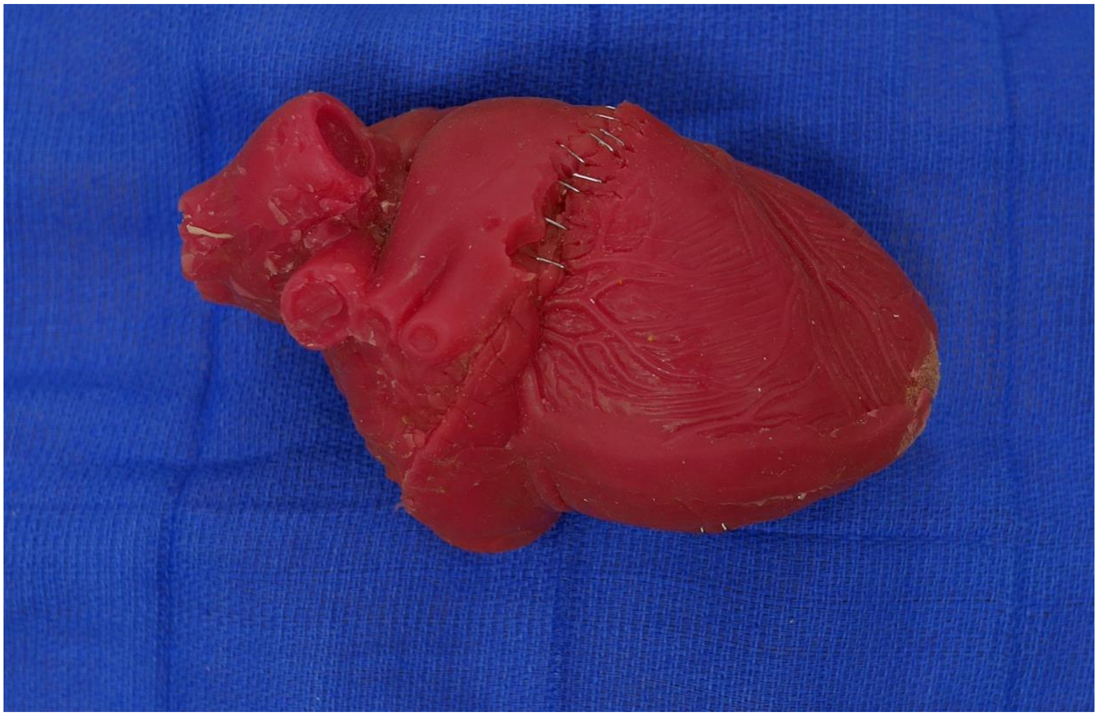
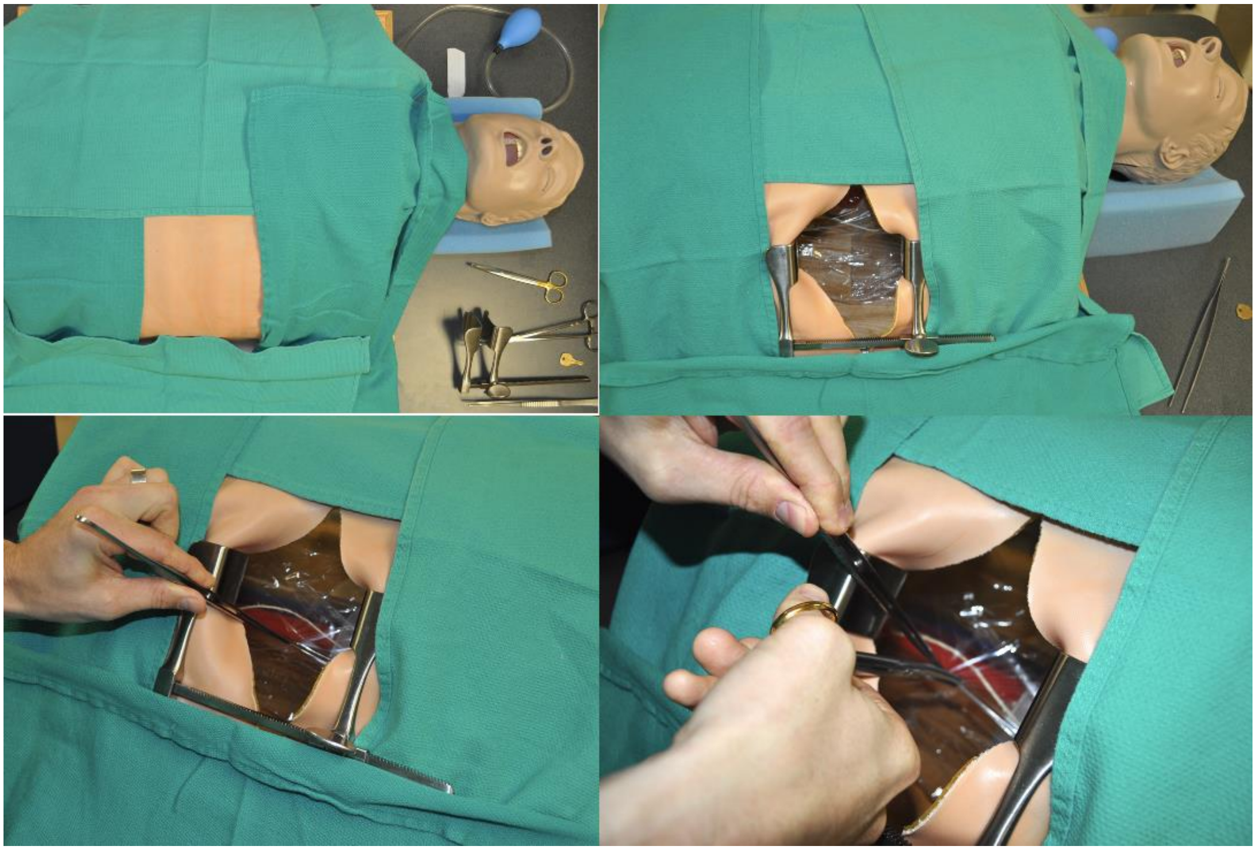


Figure 7: EDT procedure



Supplemental Digital Content 1: (https://youtu.be/Pn1H5KcS2Vw)

Discussion

This model represents a novel, inexpensive, durable, reusable EDT task trainer with high functional fidelity and quality physical resemblance. This EDT trainer focuses on specific learning objectives based on the functional task of the step-by-step process of performing an EDT (Supplemental Digital Content 1). When used within a hybrid human-patient manikin simulation context, this EDT trainer further adds to the cognitive experience of making the decision to proceed with EDT, and allows learners to: intubate, incise the integumen to gain access into the thorax, use surgical rib spreaders, perform a pericardiotomy while avoiding the phrenic nerve, deliver the heart from the pericardium, and cross-clamp the aorta using a vascular clamp. Similar task trainers have demonstrated improved learner confidence (Yates et al., 2018, Bengiamin et al., 2019, O'Connell et al., 2020), improved time to thoracotomy incision and over-all procedural time (Park et al., 2020, Hamilton et al., 2015). The authors: a retired physician (JB) and two experts in performing EDT (MB and KC), agreed that the EDT trainer allowed learners to meet the designed learning objectives and thus had high functional fidelity. Additionally, it was felt by these experts that the trainer had quality physical resemblance. Inclusion of lungs may have increased the trainer's physical resemblance, however, incising of the inferior pulmonary ligament was not a designed learning objective as this step is not necessary in EDT and risks injury to the inferior pulmonary vein (Cothren & Moore, 2006). Thus, the exclusion of lungs did not affect the functional fidelity of the trainer and ultimately saved on cost.

Current commercial thoracotomy trainers are both limited in number and are costly, with prices ranging from 10 to 20 thousand dollars (Yates et al., 2018, Bengiamin et al., 2019). This cost would be prohibitive for many simulation programs. Additionally, commercial thoracotomy trainers often place emphasis on high physical resemblance or structural fidelity. Unfortunately, it is an often-misheld belief that the more physically accurate a trainer, the higher quality. High physical resemblance, however, exponentially adds cost to trainers. The overemphasis on structural fidelity can steer away from the educational effectiveness of a simulator (Hamstra et al, 2014). Furthermore, when design emphasis is shifted from the physical resemblance of a trainer to the functional aspects of a trainer when used within a more global simulation context, learning is not affected (Hamstra et al, 2014). Thus, when viewed in this construct, the physical resemblance of a trainer can be greatly reduced and consequently, non-commercial trainers can be easily created without exponential costs and without affecting learning (Hamstra et al, 2014).

EDT is not a technically complex procedure. Arguably, the most challenging component of EDT is making the cognitive leap to proceed. EDT is time sensitive; needs quick action to incise, rib spread, release pericardial tension, deliver the heart and cross-clamp the aorta. None of these steps are difficult, but knowing the step-by-step process and tools needed is imperative for haste. Simulation training for resuscitative thoracotomy has demonstrated decreased time to intervention (O'Connell et al., 2020, Park et al., 2020). Decreased time saves lives.

Skill and knowledge can quickly decay after simulation-based education (Ellis et al. 2015, Braun et al., 2016, Aqel & Ahmad, 2014). Thus, it is imperative that learners have repetitive practice in cognition and physical tasks such as EDT to attain and maintain skills. With this in mind, non-commercial skin, pericardium, phrenic nerve and coagulated blood were designed for quick and inexpensive replacement allowing the model to be used again, within minutes, at a fraction of the cost of commercial trainers. Logistical considerations such as expense and time needed for repetitive practice must be considered for iterative training. Afterall, centers that perform more EDTs have better patient outcomes (Dumas et al., 2018).

EDT remains a critical skill for EM residents to learn prior to completing residency. The ability to inexpensively create opportunities for repetitive practice with well-designed functional fidelity further argues the importance of prioritizing functional requirements of a non-commercial trainer over the often cost-prohibitive high physical resemblance of a commercial trainer. This model adds to a small but growing group of non-commercial EDT task trainers for experiential instruction on a unique, high-risk, low frequency procedure (Cothren & Moore, 2006, Yates et al., 2018, Bengiamin et al., 2019) (Figure 7).

SDC Legend

SDC 1. Video of EDT trainer in use by EDT content expert. (https://youtu.be/Pn1H5KcS2Vw)

References

Aqel, A. A., & Ahmad, M. M. (2014). High-fidelity simulation effects on CPR knowledge, skills, acquisition, and retention in nursing students. Worldviews on evidence-based nursing, 11(6), 394–400. https://doi.org/10.1111/wvn.12063.

Bengiamin, D. I., Toomasian, C., Smith, D. D., & Young, T. P. (2019). Emergency Department Thoracotomy: A Cost-Effective Model for Simulation Training. The Journal of emergency medicine, 57(3), 375–379. https://doi.org/10.1016/j.jemermed.2019.06.022

Braun, L., Sawyer, T., Smith, K., Hsu, A., Behrens, M., Chan, D., Hutchinson, J., Lu, D., Singh, R., Reyes, J., & Lopreiato, J. (2015). Retention of pediatric resuscitation performance after a simulation-based mastery learning session: a multicenter randomized trial. Pediatric critical care medicine : a journal of the Society of Critical Care Medicine and the World Federation of Pediatric Intensive and Critical Care Societies, 16(2), 131–138.

Cothren, C. C., & Moore, E. E. (2006). Emergency department thoracotomy for the critically injured patient: Objectives, indications, and outcomes. World journal of emergency surgery : WJES, 1, 4. https://doi.org/10.1186/1749-7922-1-4

Dumas, R. P., Seamon, M. J., Smith, B. P., Yang, W., Cannon, J. W., Schwab, C. W., Reilly, P. M., & Holena, D. N. (2018). The epidemiology of emergency department thoracotomy in a statewide trauma system: Does center volume matter?. The journal of trauma and acute care surgery, 85(2), 311–317. https://doi.org/10.1097/TA.0000000000001937

Ellis, S. M., Varley, M., Howell, S., Trochsler, M., Maddern, G., Hewett, P., Runge, T., & Mees, S. T. (2016). Acquisition and retention of laparoscopic skills is different comparing conventional laparoscopic and single-incision laparoscopic surgery: a single-centre, prospective randomized study. Surgical endoscopy, 30(8), 3386–3390. https://doi.org/10.1007/s00464-015-4619-6

Gallagher, A. G., Jordan-Black, J. A., & O'Sullivan, G. C. (2012). Prospective, randomized assessment of the acquisition, maintenance, and loss of laparoscopic skills. Annals of surgery, 256(2), 387–393. https://doi.org/10.1097/SLA.0b013e318251f3d2

Hamilton, A. J., Prescher, H., Biffar, D. E., & Poston, R. S. (2015). Simulation trainer for practicing emergent open thoracotomy procedures. The Journal of surgical research, 197(1), 78–84. https://doi.org/10.1016/j.jss.2015.04.037

Hamstra, S. J., Brydges, R., Hatala, R., Zendejas, B., & Cook, D. A. (2014). Reconsidering fidelity in simulation-based training. Academic medicine : journal of the Association of American Medical Colleges, 89(3), 387–392. https://doi.org/10.1097/ACM.0000000000000130

Hunt, P. A., Greaves, I., & Owens, W. A. (2006). Emergency thoracotomy in thoracic trauma-a review. Injury, 37(1), 1–19. https://doi.org/10.1016/j.injury.2005.02.014

O'Connell, A., Zhang, X. C., Crossman, M., Misuro, S., & Stobart-Gallagher, M. (2020). Making the Cut: Implementing a Low Cost, Low Fidelity Simulation Model for Teaching Emergency Thoracotomy Procedure. Cureus, 12(5), e8088. https://doi.org/10.7759/cureus.8088

Park, C., Grant, J., Dumas, R. P., Dultz, L., Shoultz, T. H., Scott, D. J., Luk, S., Abdelfattah, K. R., & Cripps, M. W. (2020). Does simulation work? Monthly trauma simulation and procedural training are associated with decreased time to intervention. The journal of trauma and acute care surgery, 88(2), 242–248. https://doi.org/10.1097/TA.0000000000002561

Yates, E., Chirurgi, R., Adamakos, F., Habal, R., Jaiswal, R., Kalantari, H., & Hassen, G. W. (2018). Development and Utilization of 3D Printed Material for Thoracotomy Simulation. Emergency medicine international, 2018, 9712647. https://doi.org/10.1155/2018/9712647

Examining the Use of a Digital Stethoscope within an Academic Medical Center Nursing Program

Authors

Joseph W. Tacy, Ph.D., RN[1], Alaina Herrington, DNP, RN, FAAN, FSSH, ANEF, CHSE-A, CNOR(E)[1], James Hughes, MD, FACS[2], Masoumeh Karimi, PhD., MPH[1], Robyn MacSorley, PhD, RN, CHSE[1], Sharon McElwain, DNP, RN, FNP-BC[1], Daniel Weiss, MD, FACS, BSEE[2], Lei Zhang, PhD, MBA[1]

[1]University of Mississippi Medical Center, School of Nursing, Jackson, Mississippi
[2]Bongiovi Medical & Health Technologies, Port Saint Lucie, Florida

Conflict of Interest Statement
Dr. Weiss is the Chief Medical Officer of Bongiovi Medical and Dr. Hughes is the Medical Director of Bongiovi Medical. This study utilized a stethoscope that is a product of Bongiovi Medical.

Corresponding Author
Joseph W. Tacy, Ph.D., RN, University of Mississippi Medical Center School of Nursing, Jackson, Mississippi
Email: jtacy@umc.edu

Brief Description

The conventional method of auscultation has not progressed alongside the introduction of new technologies. With the advent of computer-aided audio enhancement, healthcare professionals now have the ability to listen to amplified sound waves. However, it remains uncertain whether this enhancement can improve skill levels and offer the same ease of use as traditional stethoscopes. This study aimed to compare the effectiveness of an analog stethoscope with intelligent auscultation technology in clinical diagnosis and the training of nursing students. The results revealed that electronic digital stethoscopes deliver enhanced sound compared to the traditional method, potentially advancing educational practices and disease diagnosis in the field.

Introduction

Auscultation is one of the basic techniques for diagnosing heart, lung, and bowel abnormality and normality. However, the interpretation of sounds is a subjective and difficult skill to develop with significant inter-listener variability (Kevat, Kalirajah, & Roseby, 2020). Computer-aided audio enhancement (making relevant diagnostic sounds more audible to the human ear) and detection technology (using Artificial Intelligence [AI], to help make the diagnosis) are fast and efficient instruments for the use of quantitative acquisition and the analysis of sound signals. Currently, intelligent auscultation technology has not been widely used in clinical diagnosis and training (Li et al., 2020). The current primary method used for auscultating sound detection is manual stethoscope auscultation. Therefore, the research and application of computer-aided techniques for sound detection will promote development in the field of education and disease diagnosis.

In this study, nursing students at an academic medical center observed and compared an analog stethoscope with two different electronic stethoscopes (Figures 1 and 2) to determine if there is a significant difference in the diagnostic utility of each device. Further analysis was completed to examine if perceived usefulness, perceived ease of use, attitude toward using, and behavioral intent to use the electronic digital stethoscope showed variation in actual use.

Background

Stethoscopes have been widely utilized in medical and healthcare education since its introduction in 1816 by Rene Laennec, which consisted of a monoaural wooden tube (Silverman & Bulk, 2019). In 1840 a flexible tube was introduced, and then by 1852 a binaural stethoscope was developed and brought to the commercial market. The design has not significantly changed with present-day stethoscopes, with the most popular ones either being a Littmann or Sprague design with improved materials (Silverman & Bulk, 2019). The traditional stethoscope design operates via a disc-shaped resonator that is placed upon the body will transmit sound through a hollow air-filled tube to the listener's ears. Electronic stethoscopes were first introduced in the 1950s but did not enter the clinical field until the mid-1990s when 3M introduced their model (Leng et al., 2015). This new model provided the ability to amplify and convert sound waves into electrical signals that were processed and produced for enhanced listening. However, this new form of electronic listening led to amplified artifacts and sound alteration due to conduction thresholds which led some to question whether this was an improvement. Some in the healthcare industry have called the current stethoscope a "relic", noting that other devices that connect to smartphones can amplify heartbeats, help with diagnosis, and the data can be sent wirelessly to patients' electronic medical records (Taylor, n.d.). Current advances in technology seem impressive, and its impact on healthcare practice is heading down the high-tech superhighway.

With the prevalence of unhealthy living habits, adverse acute and chronic disease has become one of the major risks to human health. The health disadvantage is pervasive, affecting all age groups, and is witnessed in multiple diseases, biological and behavioral risk factors, and injuries (NRC, 2013). Most heart and lung diseases are associated with and reflected by the sounds that the body organ produces. Auscultation, defined as listening to the resonance sound the body makes, whether it be heart, lung, or bowel sounds, historically is an important method for the early diagnosis of dysfunction (Cleveland Clinic, 2022). Traditional auscultation requires substantial clinical experience and competent listening skills. As a result of the electronic stethoscope, a new field of computer-aided auscultation has emerged.

Methods

The aim of this study is to compare and contrast an analog stethoscope versus two digital stethoscopes in healthcare education among nursing students. This study utilized a quasi-experimental design implemented in two phases. The first phase utilizes classroom instruction and simulated sounds within the lab setting. The second phase of the study is to examine the devices within the clinical and telehealth setting. This article will focus on the first phase of the study.

Devices

The Aria Stethoscope (Bongiovi Medical and Health Technologies) (Figure 1) is designed to be an integrated, high-quality, extended frequency range capture device for biological sounds. The Aria is supplemented by a Medical Device Power Station (MDPS), a proprietary audio signal-processing software solution that optimizes the sound for intelligibility during telemedicine and other extreme acoustic environments. The Aria stethoscope integrates with a mobile application that provides the MDPS processing as part of an audio loopback feature, as well as audio recording and note-taking. The mobile application enables easy integration into multiple systems, hardware, or environments. The Aria is also designed to function as a stand-alone auscultation instrument with proper hardware attachments. The Aria stethoscopes used in this study were three-dimensional (3D) printed prototypes, as this stethoscope has not yet entered mass production.

The M1 Telehealth Stethoscope (Medaica) (Figure 2) is a new stethoscope released in the low-cost tele-auscultation market. It has Food and Drug Administration (FDA) approval for home use and features a built-in digital interface for use with smartphones and computers, as well as a separate microphone for voice communication. The M1 also utilizes MDPS audio processing for sound optimization. In this study, the M1 stethoscope was used with the Aria mobile application and MDPS audio processing to standardize the student workflow for the electronic stethoscopes. The standard traditional stethoscope used was a Sprague type. All students were given this stethoscope to use as a participant in the study to reduce variability among their personal stethoscopes.

Figure 1: Aria Stethoscope

Figure 2: Medaica Stethoscope

Participants

The classroom instructional phase of this study included 32 pre-licensure and 4 advanced practice nursing students. It was conducted between 06/01/2022 and 06/01/2023. The inclusion criteria for the study consisted of traditional and accelerated pre-licensure Bachelor of Science in Nursing (BSN), and advanced nursing students eligible to participate in the study if they provided consent. The study information flyer with a quick response (QR) code was hung up in the back of the classroom and disseminated via email and the learning management system email to solicit participants. Participants had the option to sign consent and enroll electronically by using the QR code link. Participation was on a first come, first serve basis per consent received. Participants received a $20 gift card to Walmart for their time. Participants were instructed on the use of all devices and provided surveys at the start of the session. Examination occurred with all 3 stethoscopes and subsequently completed the survey responses in order as outlined in Table 1.

Figure 3: Participant Procedure Process.

Standard Stethoscope	Aria Digital Stethoscope	Medaica Digital Stethoscope
1. Examine Peer with Stethoscope a. Complete General Stethoscope Survey 2. Examine Simulators with Stethoscope a. Complete Normal/Abnormal Survey Sheets: i. Heart ii. Lungs iii. Bowel	1. Examine Peer with Stethoscope a. Complete General Stethoscope Survey 2. Examine Simulators with Stethoscope a. Complete Normal/Abnormal Survey Sheets: i. Heart ii. Lungs iii. Bowel 3. Complete TAMS Experience Survey	1. Examine Peer with Stethoscope a. Complete General Stethoscope Survey 2. Examine Simulators with Stethoscope a. Complete Normal/Abnormal Survey Sheets: i. Heart ii. Lungs iii. Bowel 3. Complete TAMS Experience Survey

Survey and Operational Definitions

The instructional classroom phase of the study utilized three survey instruments and a verbal qualitative debriefing activity. The general stethoscope survey, the Normal/Abnormal survey, and the technology acceptance survey. The general stethoscope survey consists of 12 questions that ascertain the quality and or clarity of sound while using all 3 stethoscopes to listen to the participant's heart, lung, and bowel sounds using a 7-point Likert scale. In addition to this, there was a question posed to assess and record a blood pressure reading using a manual cuff on a simulated arm. The Normal/Abnormal survey consists of ascertaining the quality of sound while using all 3 stethoscopes to listen to simulated heart and lung sounds via 3B Scientific Heart & Breath Sounds Simulator and bowel sounds via Gaumard Adult HAL simulator using a 7-point Likert scale.

The Technology Acceptance Model (TAM) was adapted to explicate the factors affecting technology use (Davis, 1989; Venkatesh & Davis, 2000). Davis's model postulates that technology usage is determined by two leading beliefs, perceived usefulness, and perceived ease of use. Attitude towards use and behavioral intention to use technology will affect how individuals respond to technology; therefore, attitude and behavior is inferred to partially impact the effect of perceived ease of use and perceived usefulness on actual use of technology.

Participants utilized the TAM scale to rate both digital stethoscopes during the classroom/lab instruction and is based on 5 sub-scales in a 7-point-Likert type format defined here. Perceived usefulness (PU) is defined as the degree to which an individual believes that using a particular technology will enhance job performance (Davis, 1989). Perceived ease of use (PEU) is considered the extent to which an individual believes that using technology/system would be free of effort (Venkatesh et al., 2008). Attitude toward using (AT) is defined as an individual's positive or negative feelings about performing the target behavior. Attitude toward using electronic learning will be measured using Mishra and Panda's Attitude Toward E-learning (ATEL) scale (Mishra & Panda, 2007). Seven statements on the ATEL are negatively worded and thus will be reversed scored. Behavioral intent to use (BI) is the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior (Venkatesh et al., 2008; Kim, Chun, & Song, 2009).

Data Analysis

The data were imported from REDCap to IBM Statistical Package for the Social Science (SPSS) 28.0 for analysis. One-way Analysis of Variance (ANOVA) was used to compare the mean responses from the three different devices. Independent sample t-test was conducted to compare the result of the survey between the two digital devices. The linear regression model was used to investigate factors associated with the actual use intention given that the participant has access to either one of the devices. All statistical tests were two-sided. Level of significance (alpha) was set at 0.05. $P<0.05$ from ANOVA or linear regression shows a significant difference in means or indicates a significant factor for certain outcome measures.

Results

Qualitative

Verbal feedback gained during the debriefing session with students varied greatly. Overall, the participants expressed the inability to hear well with the standard stethoscope used in the study. The students were comfortable with the use of the stethoscope and felt it was easy to carry and could be quickly accessed for use. Students had mixed feedback on which digital stethoscope they preferred, primarily most students enjoyed the Aria. Multiple students reported that the Aria was able to provide the sound they were trying to hear while reducing other environmental artifacts. They did not have any prior knowledge of the device and its ability to perform this function, but they were able to detect this. Others preferred the Mediaca stating it picked up all sounds and they could hear everything, which gave them the confidence to identify the sounds they were attempting to hear. This is something health care professionals are familiar with standard stethoscopes and could be the rationale for this. All students felt the sound of the digital devices were far superior to that of the standard Sprague but in terms of utility, the Sprague was the easiest to use. The Mediaca was also identified as slightly easier to due to the handlebar like design, but students equally agreed that this design could create difficulties depending on where you were listening.

Quantitative

Comparing the three stethoscope survey results, showed slightly higher preference rate for Aria compared to the other 2 devices but the differences were not statistically significant. This result is similar to the qualitative results stated above. Within the general stethoscope survey, students measured a standardized blood pressure of 120/80 on a simulated arm using all 3 stethoscopes. In all 3 devices, the average recorded systolic BP was lower than 120 mmHg and diastolic BP was higher than 80 mmHg set values. Among all 3 stethoscopes, there were no significant findings based on the survey results in variation of measured blood pressure. The only statistically significant difference among devices was with the performance of a manual

blood pressure assessment with manual cuff (F(2,87) = 8.33, p < 0.001). A Bonferroni post hoc test revealed that it is significantly easier to use Sprague stethoscope (mean= 6.10, SD=0.9) compared to Aria (mean= 4.36, SD=2.28) and M1 (mean= 4.61, SD=1.94) stethoscopes to obtain a result from a manual cuff.
Using the Normal/Abnormal survey, students rated the quality of the heart, lung and bowel sound. The overall result showed that students rated the digital stethoscopes higher than the analog one. The summary of the analysis is provided in Table 2.

Table 2: Comparing the rates of the 3 stethoscopes in sound quality.

	Normal/Abnormal Survey	Sprague		Aria		M1		F	df	p-value
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**			
Heart	Heart Normal heart Sound	2.46	1.59	4.42	1.79	5.5	1.59	30.37	2,104	**< 0.001**
	Heart Friction Rub	4.69	1.69	5.56	1.55	6.42	0.9	13.09	2,104	**< 0.001**
	Heart Austin Flint Murmur	3.97	1.65	5.31	1.58	6.31	0.95	23.82	2,104	**< 0.001**
	Heart Systolic Murmur	3.23	1.73	5.06	1.8	5.64	1.71	18.26	2,104	**< 0.001**
	Normal Heart Sound - Apex	2.68	1.78	4.74	1.67	5.8	1.54	31	2,104	**< 0.001**
	Average heart score	3.4	1.27	4.99	1.38	5.92	1.02	37.68	2,104	**< 0.001**
Lung	Lung Normal	4.86	1.78	5.75	1.46	6.03	1.23	5.83	2,104	**0.004**
	Crackles (Fine)	5.17	1.5	5.69	1.48	6.14	1.16	4.24	2,103	**0.017**
	Crackles (Coarse)	2.89	1.67	4.14	1.83	4.78	1.58	11.29	2,104	**< 0.001**
	Wheezes	5.46	1.4	6.19	1.06	6.36	1.19	5.43	2,104	**0.006**
	Pleural Friction Rub	4.29	1.84	5.33	1.49	6.03	1.25	11.42	2,104	**< 0.001**
	Stridor	6.2	1.02	6.47	1.05	6.69	0.63	2.42	2,103	**0.094**
	Average lung score	4.8	1.12	5.59	1.04	6	0.81	12.88	2,104	**< 0.001**
Bowel	Bowel Normal	4.63	1.43	4.94	1.54	5.06	1.57	0.74	2,103	0.475
	Borborygmus	4.77	1.35	5.17	1.25	5.17	1.5	0.98	2,103	0.378
	Hyperactive Bowel	5.49	1.14	5.31	1.43	5.63	1.3	0.54	2,103	0.579
	Average bowel score	4.96	1.07	5.13	1.19	5.28	1.31	0.64	2,103	0.528

According to Table 2, there was a statistically significant difference in the quality of heart sound between devices (F(2,104) = 37.68, p < 0.001). A Bonferroni post hoc test revealed that while listening to heart sound, M1 (mean= 5.92, SD=1.02) stethoscope rates the most excellent one, followed by Aria (mean= 4.99, SD=1.38), and Sprague stethoscope rates the poorest (mean= 3.4, SD=1.27). The same results were found rating the lung sound quality (ANOVA (F(2,104) = 12.88, p < 0.001). A Bonferroni post hoc test revealed that M1 (mean= 6.0, SD=0.81) stethoscope rates the most excellent one, followed by Aria (mean= 5.59, SD=1.04); And Sprague stethoscope rates the poorest (mean= 4.8, SD=1.12). Although the participants rated M1 (Mean= 5.3, SD= 1.31) and Aria (Mean= 5.1, SD= 1.19) higher than Sprague (Mean=

4.9, SD= 1.07) stethoscopes in bowel sound quality, the differences were not statistically significant (F(2,103)= 0.64, p=0.528).

Utilizing the Technology Acceptance Model, this study intended to examine the use of digital stethoscopes. The result of the Independent Sample t-test didn't show any significant difference in TAM items rating between the 2 digital stethoscopes. A linear regression analysis performed on TAM average score of the "Actual Use" item in Aria and M1 stethoscopes to find the significant predictor of the actual use intention given that the participant has access to either one of the devices.

Table 3: Linear regression analysis of TAM.

	Beta	SE	95% CI		t	p-value	Adjusted R-square	F	df	p-value
			LL	UL						
Aria	1.43	0.14	1.13	1.73	9.77	**< 0.001**	0.730	95.52	1,34	**< 0.001**
M1	1.09	0.12	0.84	1.34	8.84	**< 0.001**	0.688	78.16	1,34	**< 0.001**

Predictor: Average score of Attitude Toward Using
Outcome: Average score of Actual Use

The result of both linear regression models (Table 3) found "attitude toward using" being the only significant predictor of "actual use" of both Aria and M1 stethoscopes. The higher the attitude score, the higher the possibility of "actual use" (Aria: b=1.43, t=9.77, p < 0.001; M1:b=1.09, t=8.84, p < 0.001).

Discussion

Studies over time have found the stethoscope to be a valuable diagnostic instrument in the daily use of health assessment (Silverman & Balk, 2019). Unlike traditional stethoscopes based on the physics of sound movement via a diaphragm and air-chambered tube, digital stethoscopes can provide enhanced sound with cutting-edge AI-infused technology. Both Aria and M1 utilize the same technology to listen to enhanced sound movement, with the Aria having the ability to compensate to remove artificial artifact when compared to other devices. This result could be related to the feedback that the students were more comfortable hearing all the surrounding artifacts given that is how they were trained using a standard stethoscope and were comfortable learning by this method. If they knew the original intent of the device to assist by isolating the sound they were attempting to hear, this could have created a different viewpoint and resultant outcome. As noted above in the qualitative results, some students did ascertain this from the use.

Various weaknesses/limitations were discovered during the deployment of this study. One unexpected issue was the rate at which student participation was anticipated. 32 out of 270 pre-licensure students agreed to participate in this study, which represents a 12% participation rate. Four out of 100 advanced practice students also participated, which represents a 0.04% participation rate. This was an unexpectedly low response rate from students to volunteer in the study. The original intent was to pay all study participants at the end of the phases of the study, this had to be altered during phase 1 participant data collection. Due to very low volunteer enrollment, the Institutional Review Board (IRB) was modified to permit payment at the end of each phase, which did increase participant enrollment by 44%. Future scholarly endeavors in the realm of teaching and learning would benefit from the alignment of studies within course delivery to garner higher participation. Another weakness was the prototype nature of the devices used, the prototypes sometimes would have interference and feedback that required interruption by the PI to troubleshoot the devices to achieve the required use of the device through corrective adjustments.

Conclusion

In this study, the latest technology-aided audio detection technologies were utilized to provide enhanced sound compared to the traditional diagnostic modalities to promote development in the field of education and disease diagnosis. Results from this study validated the performance, quality, and generalizability for the use of a digital stethoscope utilizing a mobile application that provides the MDPS processing for audio presentation within healthcare education. Further studies are required to explore functionality, design, and applicability of these prototypes in alternate settings. This study manuscript represents the completion of the first phase of the project. The next phase of this study will be performed to examine the use of the digital stethoscope within the clinical and telehealth training environments.

References

Cleveland Clinic. (2022). Auscultation. https://my.clevelandclinic.org/health/diagnostics/23080-auscultation#:~:text=The%20medical%20definition%20of%20auscultation,the%20sounds%20of%20your%20body

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. Mis Quarterly, 13(3), 319-340.

Kevat, A., Kalirajah, A., & Roseby, R. (2020). Artificial intelligence accuracy in detecting pathological breath sounds in children using digital stethoscopes. Respiratory research, 21(1), 253. https://doi.org/10.1186/s12931-020-01523-9 https://doi.org/10.1186/s12931-020-01523-9

Kim, Y.J., Chun, J.U., & Song, J. (2009) Investigating the role of attitude in technology acceptance from an attitude strength perspective. International Journal of Information Management, 29(1), 67-77. doi:10.1016/j.ijinfomgt.2008.01.011

Leng, S., Tan, R. S., Chai, K. T., Wang, C., Ghista, D., & Zhong, L. (2015). The electronic stethoscope. Biomedical engineering online, 14, 66. https://doi.org/10.1186/s12938-015-0056-y

Li, S., Li, F., Tang, S., & Xiong, W. (2020). A Review of Computer-Aided Heart Sound Detection Techniques. BioMed research international, 2020, 5846191. https://doi.org/10.1155/2020/5846191

Mishra, S. & Panda, S. (2007). E-learning in a mega open university: Faculty attitude, barriers, and motivators. Educational Media International,44(4), 323-338.

National Research Council (NRC) (US), Institute of Medicine (US), Woolf, S. H., & Aron, L. (Eds.). (2013). U.S. Health in International Perspective: Shorter Lives, Poorer Health. National Academies Press (US).

Silverman, B., & Balk, M. (2019). Digital Stethoscope-Improved Auscultation at the Bedside. The American journal of cardiology, 123(6), 984–985. https://doi.org/10.1016/j.amjcard.2018.12.022

Taylor, P. (n.d.) Why are doctors still using the stethoscope? Health Debate https://healthydebate.ca/2016/02/topic/are-stethoscopes-passe/

Venkatesh, V. & Davis, F. (2000) A theoretical extension of the technology acceptance model: four longitudinal field studies. Management Science, 46(2), 186-204. https://doi.org/10.1287/mnsc.46.2.186.11926

Venkatesh, V., Brown, S.A., Maruping, L.M., & Bala, H. (2008). Predicting different conceptualizations of system use: The competing roles of behavioral intention, facilitating conditions, and behavioral expectation. MIS Quarterly, 32(3), 483–502. https://doi.org/10.2307/25148853