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Editorial

Simulation: past, present, and future

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THE PAST: WHAT WE HAVE LEARNED ABOUT SBHE

Simulation-based healthcare education (SBHE) is a widely used method for teaching and assessing novice to advanced learners' clinical skills, teamworking, interprofessional healthcare skills, and more, in many disciplines [1–3]. Experience, knowledge, and empirical research have incrementally guided growth of effective methods and techniques. As an example of iterative progress, early simulation-based education in anesthesia sought to present learners with realistic real-time representations of intraoperative care [4]. Experience with this approach revealed that real-time representation of entire surgical cases was impractical and unnecessary to reach teaching and learning objectives. Time-compression became a standard approach in the design of many simulation scenarios.

In emergency medicine SBHE was first focused on resuscitation and has expanded to include evidence-based training and assessment of technical and non-technical fundamental and advanced skills such as trauma care [5], airway management, and extracorporeal cardiopulmonary resuscitation [6,7]. Simulation is used to teach teamworking skills and delivery of care in an interprofessional setting [8]. The patient safety movement's epidemiologic data revealed targets for improving patient care and SBHE has been integrated into patient safety and quality improvement programs, with demonstrated improvement in patient outcomes [9].

Best practices for SBHE have been described in several domains, including debriefing, scenario design, faculty development, and educator skills [3,10–12]. Optimization of SBHE continues to evolve and requires recognition of validated educational outcome metrics [3]. When contrasted with traditional healthcare education methodologies, including didactic lectures and bedside teaching, SBHE can offer improved learning outcomes in some situations [2].

SBHE is a resource intensive technique compared to traditional established education methods. Increased resource requirements can be easily understood in terms of not only capital expenses for equipment and variable cost of supplies, but also in terms of educator to student ratios, physical space, and requirements for training of skilled simulation educators, instructional designers, and technicians. Efficiency is a function of the relationship between value of resources expended and the value of output, measured as educational effectiveness in the case of healthcare education and training. Quantitation of required SBHE resources is straightforward regarding equipment supplies and space but is more difficult to quantify with regard to time and resources required for the development of effective faculty skills for simulation instructional design, facilitation, and assessment of learners.

Metrics which reliably reflect educator skills and curricular design resulting in optimal educational outcomes remain an ongoing challenge in SBHE [13]. One example is educator debriefing skills which can be measured by validated tools such as the Debriefing Assessment for Simula-

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tion in Healthcare (DASH) and Objective Structured Assessment of Debriefing (OSAD) rubrics [14,15] for assessment of debriefing events and debriefer skills. These tools are incomplete in that they reliably rate a single debriefer's skills but have yet to be proven to correlate with improved learner outcomes.

THE PRESENT: WE HAVE A LOT OF TOOLS

Advances in simulation have relied upon parallel progress in technology and educational design. Simulation technologies have become increasingly sophisticated, offering ever-more realistic representations. Realistic dynamic representations of physiology and anatomy in mannequins and task trainers present students with scenarios and training which are responsive to learner inputs, offering educators opportunity to observe and rate performance for both formative and summative purposes.

The potential for SBHE future applications depends upon thoughtful use of technological advances to support evidence-based instructional design principles. Demonstrated learning outcomes and ultimately clinical performance should guide development and integration of technologies for SBHE. High levels of realism and fidelity, originally thought to enhance learning, require careful design consideration, since the degree of realism does not always correlate with improved education outcomes, yet usually requires more resources than less realistic simulation [16,17]. Refinement and advances in instructional design, facilitation, assessment, and optimization of SBHE will assure efficient utilization and effective learning outcomes including valid competency assessment. An example of evidence-based design is the deliberate practice and mastery learning competency development and assessment strategy [18,19].

The combination of effective instructional methods and advanced technological developments offers a powerful synergy for creative applications of simulation to fill existing gaps in training and to address problem areas in the provision of clinical care such as patient safety. The Event-based Approach to Simulation-based Teamwork (EBAT) published in 2008 offers a structured approach to curriculum development which incorporates elements of current SBHE guidelines and teamwork training strategies [20]. Validation of rubrics such as EBAT and dissemination of accessible techniques to rapidly develop, assess, and implement targeted training outcomes is required to accelerate efficient and effective SBHE. Education outcomes research should be used to guide and accelerate the design of new simulators and simulation training rubrics. SBHE is a mature educational method, with both old and new implementation barriers such as individual, institutional, and academic resistance to change, unclear efficiency metrics, budgets, faculty availability and training, and sustainability [12,21–23].

THE FUTURE: BUILDING EVIDENCE-BASED EDUCATION

Breakthroughs in technology hold exceptional promise for mitigating SBHE implementation barriers and for improving efficiency and effectiveness. The scope of simulation technologies has expanded from physical task trainers and manikins with computer interfaces, to include immersive environments including computer augmented virtual environments and virtual reality (VR) headsets, and synchronous distance simulation [22,24–26]. Remarkable advances in simulators capable of representing increasingly realistic learner interactions during SBHE have outpaced advances in evidence-based educational processes to most effectively and efficiently employ simulation. SBHE educational paradigms, such as rapid cycle deliberate practice [27], virtual simulation [24], and simulation at a distance, must leverage the expanding portfolio of simulation devices and other SBHE enabling technologies to enhance healthcare learner outcomes and educational systems' effectiveness. Optimizing existing and future technologies including fully immersive environments using augmented reality (AR) and VR displays, interactions in the metaverse, airway haptics [28], and olfactory stimuli [17] will require research into many fundamentally unanswered questions regarding pedagogies, assessment, and outcomes. The Society for Simulation in Healthcare (SSH) recently established the top ten questions and priorities for healthcare simulation research, including uncovering best research designs to investigate simulation effectiveness, studying the dose response relationship between simulation training and patient care outcomes, effective approaches to patient safety, and the impact of learning strategies [13].

Advances in simulating reality have grown rapidly with multiple marketed devices and systems. Real-time synchronous learner interactions in roles represented by avatars are a technological achievement, yet this methodology like others has yet to find an optimal place in healthcare education and requires new paradigms, such as how to debrief an avatar or artificial intelligence (AI)-based interaction?

AI considerations for educational design reveal potential to significantly enhance SBHE [29,30]. AI algorithms for industries including finance, social media, advertising, and digital image design provide a jumpstart to guide SBHE applications. We can imagine that AI applications could be used to author scenarios with integrated key learning points, checklists, and other intelligent assessment tools. Facilitation and debriefing guides could be based upon not only evidence-based best practices, but on individual

learning curves. Automated design could integrate and control responsive real-time "on-the-fly" scenario modifications to support learner engagement, in the same way that current AI engines present players challenges in the world of online games.

Imagine, automated personalized learning! New pedagogical tactics for designing learning in an AI world will guide the future of educational design in many dimensions, including simulation. One such example is the application of AI using neural networks and real-time assessment of learner performance. AI could enable integration of sensor data from existing haptics based systems to easily provide real-time feedback based on individual learners' performance of complex and simple tasks, and application of knowledge in increasingly realistic simulation experiences. Real-time feedback is already available and effective in guiding learner performance in quality cardiopulmonary resuscitation, for both simulated training and actual clinical applications. AI systems could significantly enhance SBHE learning process' by providing greater precision and more accurate feedback, generating personalized training experiences.

I think the future of SBHE will focus on making teaching and learning more efficient. Improvements in instructional design, educator training, personalized learning experiences, and assessment will generate efficient learning curves, and valid competency assessments. Advances in educational methods and technologies will shift from parallel activities to aligned and integrated activities to enhance efficiency and accessibility of SBHE.

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CONFLICT OF INTEREST

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