Simulation-based emergency medicine education in the era of physical distancing: Lessons learned in the COVID-19 pandemic

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Abstract

Background: The COVID-19 pandemic posed significant challenges to traditional simulation education. Because simulation is considered best practice for competency-based education, emergency medicine (EM) residencies adapted and innovated to accommodate to the new pandemic normal. Our objectives were to identify the impact of the pandemic on EM residency simulation training, to identify unique simulation adaptations and innovations implemented during the pandemic, and to analyze successes and failures through existing educational frameworks to offer guidance on the use of simulation in the COVID-19 era.

Methods: The Society for Academic Emergency Medicine (SAEM)’s Simulation Academy formed the SimCOVID task force to examine the impact of COVID-19 on simulation didactics. A mixed-methods approach was employed. A literature search was conducted on the subject and used to develop an exploratory survey that was distributed on the Simulation Academy Listserv. The results were subjected to thematic analysis and examined through existing educational frameworks to better understand successes and failures and then used to generate suggestions on the use of simulation in the COVID-19 era.

Results: Thirty programs responded to the survey. Strategies reported included adaptations to virtual teleconferencing and small-group in situ training with a focus on procedural training and COVID-19 preparedness. Successful continuation or relaunching of simulation programs was predicated on several factors including willingness for curricular pivots through rapid iterative prototyping, embracing teleconferencing software, technical know-how, and organizational and human capacity. In specific instances the use of in situ simulation for COVID-19 preparedness established the view of simulation as a “value add” to the organization.

Conclusions: Whereas simulation educator’s responses to the COVID-19 pandemic can be better appreciated through the lens of iterative curricular prototyping, their successes and failures depended on existing expertise in technological, pedagogical,
and content knowledge. That knowledge needed to exist and synergize within a system that had the human and organizational capacity to prioritize and invest in strategies to respond to the rapidly evolving crisis in a proactive manner. Going forward, administrators and educators will need to advocate for continued investment in human and organizational capacity to support simulation-based efforts for the evolving clinical and educational landscape.

BACKGROUND

Comprehensive integration of simulation with other instructional strategies is “best practice” in emergency medicine (EM) education. The COVID-19 pandemic has imposed significant unanticipated challenges, threatening adherence to best practice. During the initial phases of the pandemic response, face-to-face simulation as previously implemented was no longer possible. “Brick-and-mortar” simulation learning environments, including simulation centers, classrooms, and conference venues, were closed and unavailable to stakeholders (learners, simulationists, simulation faculty, residency administrators) at many institutions for precautionary safety reasons. Further, learner and educator availability to participate in simulation education was restricted due to the escalating need for qualified practitioners to support emergency and critical care patient-centered responsibilities. Simulationists, when available, commonly faced limited or no access to simulation equipment and other instructional adjuncts and tools. When circumstances did afford access to them, simulationists were often unable to fully optimize their deployment due to concern for contamination.

Simulation educators reflecting on lessons learned in the wake of the COVID-19 pandemic understand that best practice must adapt to the “new normal” COVID-19 state of existence. To accommodate the social and physical limitations imposed by COVID-19, new approaches and innovations to learning, such as the incorporation of technological advances, are necessary.

We propose examining the success and failures of reported innovations through the lens of Koehler and Mishra’s TPACK model. TPACK is a theoretical framework originally developed to explore and understand reasons why educators have been successful when attempting to integrate newer learning technologies into existing educational programs. In the original Koehler and Mishra model, educator success or failure depends on four interdependent factors—pedagogical knowledge (PK), content knowledge (CK), technological knowledge (TK), and the contexts connecting them. Koehler and Mishra posit that educators with the best potential for instituting quick, contemporaneous curricular transformations meet minimum competency thresholds within the three aforementioned domains. The potential for change, however, is only effectively realized when educators are appropriately situated within contexts facilitating such transformations. Each stakeholder to whom the curriculum is beholden—educators, learners, administrators, programs, institutions, and organizations—must share common cultural beliefs (ethos, values, mental models, goals, etc.) and ensure adequate minimum standards of organizational infrastructure, along with attaining adequate individual competencies, for success to be likely.

Simulation training in a COVID-19 world is arguably even more crucial than before the pandemic. First, the COVID-19 pandemic represents a natural disaster for which there has already been a precedent set for the use of simulation training, such as during the 2009 SARS and 2013 Ebola epidemics. Second, this pandemic represents exactly the kind of low-occurrence, high-acuity, high-stakes clinical situation that simulation training is most ideally suited to. Additionally, simulation training also identifies systemic issues and latent safety threats for both staff and patients that are particularly relevant now, perhaps more so recently, given the soaring numbers of health care providers contracting COVID-19. Furthermore, rapidly changing clinical recommendations, such as use of intubation barrier devices and powered air-purifying respirator during intubations, represent new kinesthetic skill sets that must be practiced and honed through simulation, ideally before implementation in a real-world scenario. Finally, as a precautionary measure, several training programs are deliberately reserving the care of patients with COVID-19 requiring ventilatory support and cardiopulmonary resuscitation to senior residents or attending physicians, which could impact the development of these skill sets among junior learners.

Medical students have been impacted even more significantly with limited or no exposure to patients with COVID-19 and other clinical conditions, they are likely to start residency training with persistent, unresolved knowledge and skill gaps. There are also some concerns that medical student’s clinical skills may be somewhat less developed upon medical school graduation, relative to expected norm, as a good number of third-year clerkships are being offered virtually. Simulation training, therefore, is vital both for successfully navigating this pandemic and ensuring that essential educational experiences for current and future trainees are maintained. We therefore seize this moment and calling for thoughtful, disruptive innovation in simulation-based emergency medical education. Accordingly, the main objectives of this paper are to (1) describe the impact of the COVID pandemic on EM residency simulation in the United States, (2) evaluate the responses by successful/unsuccessful simulation innovations and strategies implemented, and (3) analyze successes and failures through the TPACK educational–theoretical framework to obtain a better understanding of why they occurred.
METHODS

We employed a mixed-methods approach as depicted in Figure 1. This study was deemed “non-human subjects research” by a local institutional review board. Qualitative methods were utilized in addition to quantitative methods for this study to describe the interconnections of people, situations, events, and processes, which allows for discovery, exploring a new area, and developing hypotheses. Quantitative methods illustrated the impact of the pandemic on simulation training and the qualitative methods inductively built theory regarding the unique simulation adaptations and the determinants of their success or failure.

SimCOVID taskforce development

The Society for Academic Emergency Medicine (SAEM)’s Simulation Academy is one of the premier academies, sponsored by the SAEM with a broad membership of simulation faculty, directors, and researchers, collectively representing 130 academic centers across the United States. In May 2020 during the SAEM Sim Academy’s annual executive meeting, a need for more guidance on simulation didactics in the COVID era was discussed by the Simulation Academy executive committee. As a direct result of the discussions a SimCOVID Task Force comprising various Simulation Academy members, including simulation researchers, faculty, and directors at various academic sites across the country, was convened. Participants were purposefully selected from the SAEM’s Simulation Academy to study information-rich cases to yield insight and understanding.

Survey instrument development and deployment

The SimCOVID task force met in late May 2020 and after reviewing existing literature and anecdotal reports of simulation innovations, during the pandemic, recommended developing an informal, exploratory survey examining the impact. A survey of open-ended questions (Data Supplement S1, Table S1, available as supporting information in the online version of this paper, which is available at http://onlinelibrary.wiley.com/doi/10.1002/aet2.10586/full) was thus drafted. It included quantitative questions on cessation of training, level of simulation operations during the pandemic at simulation centers, and in situ simulations, in addition to open-ended questions on successes and challenges associated with the innovative simulation strategies deployed. This survey was piloted within the simulation executive committee membership and any subsequent suggestions were incorporated into the survey design. It was then circulated through SurveyMonkey on the Simulation Academy list serve. For the purposes of grounded theory building, the number of survey participants was left emergent and stopped once theoretical saturation was achieved.

FIGURE 1 An outline of the methodology employed to ascertain the response of the COVID pandemic on EM simulation training
Thematic analysis

Survey data (responses to open-ended questions) were independently evaluated by three task force members (NN, JK, MC) and inductively coded. Consensus agreement between the three coders was used to draft initial codes. Coded data were further organized into distinct themes. When new themes became apparent, survey data were reanalyzed and the codes were modified.

Through subsequent iterative discussions among all members of the SimCOVID task force, each theme thus identified was further refined, combined, or divided into the following specific categories: in situ training, procedural training, physical or social modifications, and virtual simulations (Table 1). Qualitative data were also analyzed by task force member (NN, PZ, JK) on the perceived impacts of the pandemic on simulation programs, which were further categorized into five categories: learner, simulation operations, innovation

### TABLE 1 Simulation strategies deployed during the COVID-19 pandemic and associated successes and challenges

| Strategy implemented                                      | Successes                                                                 | Challenges                                                                 |
|-----------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| **In situ training**                                      |                                                                           |                                                                           |
| In situ simulation                                        | Strategic timing matched to lower ED census (early mornings/late nights)  | Fewer participants than traditional                                        |
| example: "Essential Sims," that is ACLS/COVID             | Testing systems for safety threats                                         | Limited acceptance                                                        |
| surge preparation/ nursing competency/ COVID code blue    |                                                                           | Considered "nonessential"                                                 |
| simulations.                                              |                                                                           | Clinical demands can supersede training participation                    |
| JITT (procedures)                                        | Skill training on the shift,                                              | Time                                                                      |
| example: PPE training                                     | Ease of scheduling learners                                               | Space                                                                     |
| COVID airway management                                    |                                                                           | Patient census                                                            |
| Barrier device training                                    |                                                                           |                                                                           |
| Real-time debriefing (post-critical events)               | Reflection on real-world events using simulation debriefing principles    |                                                                           |
| Example post-cardiac arrest                               |                                                                           |                                                                           |
| **Procedure skills training**                             |                                                                           |                                                                           |
| "Essential procedures" designation                        | JITT                                                                      | Simulation equipment/laboratory accessibility                              |
| Examples:                                                 | Organizational support through COVID                                      | Simulation considered nonessential                                         |
| COVID airway/Intubation barrier devices; PPE practice;    | preparation planning                                                       |                                                                           |
| Resident procedure skill labs                             | Departmental/residency support of essential procedures                    |                                                                           |
| Independent procedure skills training                     |                                                                           |                                                                           |
| Example                                                   | Individual learner driven                                                | Loss/damage of equipment                                                  |
| Suture kit and pads mailed to learners.                   | Deliberate practice opportunity                                           | Learner engagement                                                        |
| **Physical or social modifications**                      |                                                                           |                                                                           |
| Social distancing and masking guidelines adopted for      | Smaller group sizes (6)                                                  | Impedes interprofessional group training                                  |
| simulation training.                                      | Distancing (6 feet apart)                                                 | Impeded traditional residency "simulation day"                            |
|                                                                           | Masks (mandatory)                                                         |                                                                           |
| **Virtual simulations**                                   |                                                                           |                                                                           |
| VTC platform-based simulations                            | Easy accessibility                                                        | Student disengagement                                                      |
| VTC case discussions/PBL                                  | Case-based learning, problem-based learning                              | Poor interlearner interactions                                              |
| VTC with video prompts                                    | Tabletop learning                                                         | Difficult to debrief                                                       |
| VTC with online monitor                                   | Video prompts and online monitors can serve as adjuncts                    | No kinesthetic skill practice                                               |
| VTC with standardized participants for communication     | SPs allow for communication and interpersonal skill practice              | No interprofessional or interdisciplinary team training aspect             |
| skills                                                    | Turn based increases learner engagement                                   |                                                                           |
| Tele-sim                                                  | Live streaming                                                            | Learner engagement                                                        |
| Standardized participants/faculty and simulation center    | Laerdal Learning Application (LLEAP) streaming platform                   |                                                                           |
| staff conducted in person simulations with learners online |                                                                           |                                                                           |
| **VR simulations**                                        | Communication/leadership/                                                 | Expense                                                                   |
| Examples:                                                 | Team-working skills                                                       | Learning curve                                                            |
| Online VR escape rooms                                    | Immersive technology                                                      | Accessibility                                                              |
| Head-mounted device Immersive VR–ACLS training and stroke training |                                                                           | Skill acquisition                                                          |

Abbreviations: JITT, just-in-time training; PPE, personal protective equipment; VR, virtual reality; VTC, video-teleconferencing.
and research, financial implications and organizational response (Table 2). Determination of the nature of impact (positive or negative) occurred through an iterative consensus-building process from all members of the SimCOVID task force. Data, thus generated, were evaluated through the lens of existing educational theoretical frameworks to gain an understanding of rationale behind successes and failures of various strategies and innovations.

RESULTS

We received a total of 30 responses from 130 represented institutions (response rate 23%). Multiple responses from the same intuition were collated for the purposes of this study. Respondents represented 30 institutions across the United States, with four from the New England region, six from New York State, three from the Mid-Atlantic region, one from the Midwest, five from the Great Plains, three from the Southeastern region, two from the South Central region, and five from the Western region (Table S2). There was significant variation in responses with respect to strategies deployed, resources available to centers during the pandemic and overall simulation operations. Likely these factors were affected by the size and resources of a center as well as the geographical location of the hospital during different phases of the pandemic. This survey was conducted in May, when Southeastern and some Western states were just beginning their peak and Northeastern/New York areas were decreasing in COVID-19 incidence.

Table 1 illustrates the various innovations and strategies identified, along with noted successes and failures in implementation. Five broad categories were identified that included in situ simulations, procedure skill training modifications, physical or social modifications, and virtual simulations. The impacts, both positive and negative, of the pandemic on various aspects (learner, simulation operations, innovation and research, financial implications, and organizational response) of simulation are depicted in Table 2.

Analysis

Simulation education programs, especially those located within America’s early pandemic epicenters, were thrust into one of three

| TABLE 2 | Impact of the COVID pandemic on simulation programs |
|---------|--------------------------------------------------|
| **Negative impact** | **Positive impact** |
| **Learner** | • Loss of educational opportunities  
• Cancellation of a fellowship  
• Loss of contact time | • Realization of “value” of in-person simulation didactics by learners  
• Preference of small-group didactics  
• Adaptation to varying didactic styles and strategies  
• Incorporation of learner feedback for rapid prototyping of curriculum |
| **Simulation operations** | • Unclear guidelines regarding when and if to resume traditional simulation  
• Simulation considered nonessential  
• Significant impact on smaller simulation centers | • Increased in situ simulations  
• Simulation facilitation remotely (at-risk individuals)  
• Simulation center housekeeping (for example, inventory control, equipment maintenance) |
| **Innovation & research** | • Decreasing simulation research  
• Decrease funding for simulation research | • Development and improvisation with alternate teaching technologies.  
• Faculty development in alternate teaching modalities.  
• Increased research specific to COVID simulations  
• Increased time for scholarship/research for faculty.  
• New task trainer/model development/testing. |
| **Financial** | • Staff furlough  
• Job insecurity given lack of in-person simulations  
• Diversion of funds/resources to other departments | • Resources diverted specifically into COVID preparedness  
• COVID-specific grants |
| **Organization** | • Complete shutdown of all simulation activities  
• Simulation considered nonessential | • Simulation considered value-add in disaster preparedness.  
• Firmer establishment of simulation center role within organization |
predominant "states": online/video conference-based case scenarios (in lieu of traditional in-person simulation); in situ training (specifically targeting COVID-19 preparedness or psychomotor skill adaptations); or closure (either completely or temporarily; for this, we propose the term "pause"). The simulationists, programs, methodologies, and organizations most effective in maintaining their activities outright or resuming them (after brief pauses) were those capable of adapting to the dynamic, evolving situation. Rapid curricular pivots were required. From an instructional design (ID) perspective, rapid curricular pivots can be better understood through Allen and Site’s Successive Approximation Model (SAM).\textsuperscript{20,21} SAM is an iterative, agile model, characterized by rapid curricular prototyping. The goal here is to get curricula off the ground quickly and to modify based on early and frequent stakeholder (learner/simulationist/faculty/residency administration) feedback. The first iteration of said curricula or "beta-prototype" can be refined upon in future iterations, in a rapid cyclical manner as opposed to the more traditional linear and time-consuming ID models. Some of the more successful simulation strategies reported in our results were similarly notable for varying degrees of iterative, rapid curricular prototyping and informed by frequent and early situational and stakeholder feedback. In the rapidly shifting pandemic landscape, therefore, it makes logical sense to employ the more agile SAM for future time-sensitive simulation innovations and adaptations.

The programmatic, procedural, and curricular transitions from conventional simulation practice which emerged (Table 1) reflect a remarkable diversity of innovative practice no doubt directly informed and influenced by many local factors. Heterogeneity in approach and design is the only consistent unifying characteristic among the descriptions of innovations we gathered from respondents. Curricular efficacy and impact was also variable; neither were universal nor guaranteed. While a comprehensive description of every attempted innovation listed in Table 1 is beyond the scope of this article, a few are worth describing here.

Video teleconferencing platform-based simulations ("VTC simulations") immerse one or more learners into scenarios, involving simulated or standardized patients (portrayed by simulation faculty or scripted standardized participants/actors). Logging in remotely and synchronously, learners are presented with a simulation case that is either live-streamed from a simulation laboratory...
Learners are asked to verbalize their actions and clinical decision making and their verbal responses are assessed. Facilitators can reveal dynamic (e.g., continuous electrocardiography, pulse oximetry, capnography, ultrasonographic image loops) and static (e.g., 12-lead electrocardiograms, conventional radiographs, serology test results) stimuli at key moments in response to and consistent with learners' actions and decisions. Commercially available platforms like Laerdal's Learning Application (LLEAP)22 facilitated the easy streaming of audio-visual cues. In another variation, standardized participant-actor or confederates playing roles of patient or relatives or various team members further engage with learners specifically for the practice of communication, teamwork, and interpersonal skills. This mirrors current trends in the use of audio-visual telehealth platforms for delivery of critical news, allowing learners to further develop this skill set. VTC simulations appeared to maintain consistency with most features of traditional simulation case play by providing a synchronous milieu in which learners' performances could be observed and assessed. VTC simulations were able to allow information dissemination to unfold consistent with in-person simulation practice.

In traditional simulation, learners are situated in a simulation learning environment (often with faculty members known as "confederates") with a patient (either a mannikin or a standardized participant-actor) presenting with various undifferentiated signs and symptoms. Learners are asked to perform critical management and problem-solving tasks: primary and secondary assessment, interviewing, clinical reasoning, diagnostic test selection and interpretation, implementation of pharmacologic and nonpharmacologic therapeutic interventions, consultation, and disposition and other decision-making.

Simulations of "essential procedures" were also among the more universally attempted simulations within the COVID-19 period. Essential psychomotor skills at the forefront of most emergency care providers' consciousness included personal protective equipment (PPE) donning and doffing; advanced airway management (including video laryngoscopy) wearing PPE, advanced airway management while using aerosol-limiting barrier devices (acrylic sheets and boxes), and mechanically ventilated patient positioning (transfer from supine to prone and vice versa). These procedures were labeled "essential" thereby allowing organizational and administrative support for continued training. In some cases, the terminology was extended to include all critical procedures (central lines, tube thoracostomy, etc.) relevant to COVID-19 patients.

In situ training in the form of just-in-time training (JITT), in situ simulations, and real-time debriefings were also well represented in our survey results. Traditionally, simulations for psychomotor skill development follow principles of mastery learning and have been situated in simulation laboratories, to allow for a more controlled environment for individualized instruction, feedback, oversight, and consistency. In situ training approaches have been considered more effective for on-the-job learning and better suited to advanced learners for skill retention and performance improvement.22 Due to the mandated simulation laboratory closures, some simulationists transitioned toward in situ training for an essential procedure or in situ simulation COVID-19 code trainings. As expected, the main limitations of in situ approaches were time, space availability, and clinical demands. The in situ simulation training, however, was specifically noted to be particularly useful for "testing" new COVID-19–related work flows, rapid delivery of updated COVID-19 management protocols, and identification of broader systems and process issues as pertaining to disaster situations, which helped in cementing the "value-add" for simulation for the organization at large.

With respect to the data depicted in Tables 1 and 2, we are better able to comprehend the types of pivots observed and gain richer insights into the characteristics of programs, institutions, and organizations that made more effective in-pandemic transitions by using a TPACK-oriented perspective. The TPACK model is a convenient and relevant starting point because, from our data, most curricular pivots attempted during the pandemic involved the migration of learning activities away from centralized, resource rich simulation milieus to more local, intimate, learning environments, where the burden of embracing technology, pedagogical, and other evolving curricular changes was placed squarely on simulationists and their learners. For example, within actual patient care settings such as in situ simulations, JITTT for essential procedure, or real-time debriefings for application of simulation theory to real time critical patients or adoption of virtual content delivery environments such as VTC-mediated simulations as discussed previously.

Emergency medicine simulation educators were suddenly expected to shift their programs' content, pedagogy, instructional and implementation methods, and contexts ("organizational capacities") and the burden of embracing technology, pedagogical, and other evolving curricular changes was placed squarely on simulation educators and their learners. In many cases, EM simulationists faced new barriers as they attempted to export simulation learning activities to actual patient care settings within the pandemic's new landscape. One example would be the access to simulation equipment and personnel (simulation technicians) for in situ or JITT due to simulation center lockdowns. Time, space, and clinical demands also impacted the ability to implement in situ learning opportunities. Our data suggest that when curricular transitions were effectively implemented, simulation educators had unfettered access to alternative learning environments such as the Laerdal's LLEAP platform, various video-conferencing software (for example, Zoom or Teams) as well as access to virtual reality/augmented reality platforms (for example, HealthScholars, CAE, or Oxford Simulations).

Effective pivots also dependent on high levels of simulation-specific (pedagogical) knowledge to easily translate critical learning objectives from a traditional learning environment to in situ or to virtual learning and finally a sufficient technology proficiency such as manikin simulator operation or web-based video teleconferencing application proficiency, to troubleshoot independent of simulation technicians/internet technology (IT) support, who were often furloughed.
Supportive contexts were also critical to success. EM simulationists with unwavering institutional will and organizational commitment to simulation, and recognition of its “value” in supporting the clinical service mission during the pandemic, were clearly more successful in maintaining or resuming their educational programs. The TPACK model explains the observation that the most successful simulation-based curricular pivots were possible when stakeholders (simulationists, learners, administrators); infrastructure; and organizations met minimum prerequisite knowledge, competencies, values, and cultural thresholds.

While the classic TPACK model offers adequate rationales for many of the successes and failures of the curricular transformations we analyzed, we believe that it omits a fifth dimension not originally described but clearly evident from our data: stakeholder cognitive load. We apply the phrase “human capacity” to this concept. Our data reveal that, even when other criteria are met, curricular redirection attempts still failed when human capacity demands exceeded the available supply. Within the academic EM simulation community, educators, learners, and administrators (even those with expert-level competency, situated within ideal contexts and systems and with substantial nonclinical protected time) were immediately required to shift priorities and workload toward patient care needs. All health care systems were similarly impacted. Educational service (usually complementary to and supportive of actual patient care) understandably yielded to the suddenly heightened clinical service needs and personal (self- and family-centered) priorities. Stakeholder cognitive load was so markedly increased in the face of the surging COVID-19 pandemic that human capacity (among educators, learners, and administrators) for simulation education was inadequate, even when the requisite competencies and other contextual needs were met.

Our revised TPACK model (see Figure 3) represents the interplay of these five variables (three critical competencies and two capacities). The emergence of unresolved issues, barriers, and challenges (such as time, space, clinical needs) within one or more of these domains was associated with a high likelihood of complete closure among simulationists, programs, institutions, and organizations during the pandemic.

While most experts are certain of a COVID-19 resurgence in the near future, fewer are certain about the accuracy and reliability of timing and severity-related predictions associated with a “next wave” of the pandemic. None seem confident to propose knowledge of all short- and long-term implications a COVID-19 resurgence may have on the future practice of EM simulation education. In the section that follows, we explore the implications and impact of the “lessons learned” from our initial experience in the COVID-19 era on learners, educators, the learning environment, infrastructure, and stakeholders engaged and invested in EM simulation-based education.

**Implications: Providing educational value to building a road map**

The COVID-19 pandemic has severely disrupted medical education and simulation practices. Decreased opportunities for usual procedural training and clinical learning have the potential to cause

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**FIGURE 3** The modified TPACK model. CK, content knowledge; IT, information technology; JITT, just-in-time training; PBL, practice-based learning; PCK, pedagogy–content knowledge; PK, pedagogy knowledge; TCK, technology–content knowledge; TPK, technology–pedagogy knowledge; TPACK, technology, pedagogy and content knowledge; TK, technology knowledge
educational gaps in trainees.\textsuperscript{24} Health care simulation presents a critical strategy for both identifying and bridging such gaps.\textsuperscript{25} Instead of a nonessential component in the health care sector, simulation technology becomes even more critical for training and assessment of graduates during the pandemic. As our survey results suggest, particular focus on procedural instruction, preparedness, and innovation for COVID-19–specific challenges through in situ simulation, and simulation platforms such as LLEAP, that can rapidly shift between virtual or remote and in-person formats are particularly high yield for EM as we face the new normal of a prolonged pandemic response.

Whereas SAM serves as a foundational agile instructional design framework for describing the “how to” of successful rapid curricular pivoting in a continuously evolving landscape, the TPACK framework better explains “the why” of said successful curricular innovations. In other words, TPACK addresses the determinants of successes and failures of the various innovations and adaptations, after implementation. Successful simulation strategies, with respect to our modified TPACK framework, require expertise for technological, pedagogical, and content knowledge need to concurrently exist and synergize within a system that has human and organizational capacity to prioritize and invest in strategies to process and respond to the rapidly evolving crisis in a proactive and innovative manner.

Administrators and educators in our field will need to advocate for continued investment in human and organizational capacity to support simulation-based efforts to address the new clinical and educational landscape. Simulationists are innovators and disruptors by nature, especially when incorporating expertise traditionally outside of the health care sector including design thinking, human factors, and systems engineering principles.\textsuperscript{26,27} The rapidly changing educational needs coupled with dynamic operational conditions will require continued simulation innovations to meet the learning and safety needs of the health care workforce.

Going forward, the feasibility of hosting traditional simulation programs will depend on local and institutional regulations. Establishing simulation training as an “essential service,” particularly for pandemic response preparation, is critical to the continuation or relaunch of simulation activities within an organization. Working with administrators to show that the value-add in this context is essential for maintaining or restarting simulation training, which might otherwise be seen as an unnecessary risk. Rather than proposing a complete return to simulation education as it was before COVID-19, compromise and incremental changes can be effective.\textsuperscript{3,28–30} When working with administrators, consider making a “roadmap” for how to safely conduct simulation sessions describing incremental changes and the triggers for implementing those changes that eventually leads toward simulation that resembles how simulation was being performed before COVID-19. This roadmap can also serve as a helpful tool for reverting changes made should more restrictive quarantine measures become necessary in the future. When constructing a roadmap, pay particular attention to the following factors: alternatives to in-person simulation, safe group size, and methods of preventing viral transmission during the session.

While the value of in-person simulation should not be discounted, there are numerous creative ways to conduct useful simulation education sessions without situating all participants in the same physical space. Alternatives include virtual tabletop exercises, simulation performed over teleconferencing platforms and using a small group of confederates to record video of a simulation that is then shown and debriefed with multiple groups.\textsuperscript{31,32} Procedural competency can be assessed remotely by giving the learners a task trainer to use at home and having the learners record themselves performing the procedure for critique.

As of July 2020, the Centers for Disease Control and Prevention recommended following local guidance on group size to prevent viral transmission.\textsuperscript{33} If group size is a significant limitation, consider whether the roles of simulation technician and/or facilitator can be performed remotely over teleconferencing or in a nearby area such as a simulation control room. Additional creative solutions to limit group size may include combining simulation roles that would otherwise be distinct but keep the learning objectives of the session in mind (e.g., pharmacist and medication nurse could be combined in a session focusing on medical management).

Even with limited group size there is a risk for transmitting COVID among participants.\textsuperscript{34} Balancing participant safety with limited supplies of PPE, participants should use PPE appropriate for close social interaction unless proper PPE donning and doffing are goals of the session.\textsuperscript{28} Consider whether PPE can be reused safely or if participants can bring their own masks. Between sessions allow for additional time for thorough cleaning of surfaces, manikins, and other items used during the session. Common disinfectants such as ethanol, bleach, and hand soap have been proven to be effective in inactivating COVID-19 but be sure that the cleaning solution is safe for the materials being disinfected.\textsuperscript{35} Due to additional time needed to clean between sessions the amount/number of materials provided to the participants may need to be more limited than usual (e.g., providing five medication syringes relevant to the session rather than 15 more general medication syringes).

LIMITATIONS

One of the limitations of our study is that it represents only 30 programs/organizations, a response rate of 23%. The reported strategies, successes, and failures are therefore not all inclusive and there may be other innovations and strategies that were not captured by our survey. Although the responding programs are spread out across the United States there are more programs on the Eastern seaboard and more urban programs represented that can potentially lead to a geographical or urban bias to the data retrieved. Furthermore, some of the innovative in-person strategies described in addition to the concept of value-add largely depended on the perceived role of the simulation program within the larger organization. This can be difficult to accomplish in smaller simulation operations, largely due to lack of staff and especially with ongoing staff furloughs. Finally, to date, reported innovations and
adaptations lack formal evaluations; therefore, long-term impacts such as their utility for competency assessment remain unclear.

CONCLUSIONS

The evolution of the COVID-19 pandemic has seen a parallel evolution of various simulation strategies and innovations being deployed to meet the demands of the moment. Rapid curricular prototyping with frequent, timely feedback provides one framework for simulation curriculum innovation and adaptation. Successes and failures of various innovation can be explained through preexisting simulation faculty expertise in technological, pedagogical, and content knowledge. That knowledge needed to exist and synergize within a system that had the human and organizational capacity to prioritize and invest in strategies to respond to the rapidly evolving crisis in a proactive manner. In the future, administrators and educators will need to advocate for continued investment in human and organizational capacity to support simulation-based efforts for the evolving clinical and educational landscape.

FUTURE DIRECTIONS

Building on the lessons learned during this pandemic, there is a need for dedicated faculty development on the newer modalities that have developed such as the various video-conferencing platform-based simulations. In addition, there is a definite need for exploring augmented reality and immersive virtual reality as potential options for training. The role and utility of the latter has yet to be clarified and an in-depth review is needed. Whether these newer modalities are comparable to traditional simulations with respect to competency assessment also needs to be investigated. Finally, given the success of in situ simulations and procedure training for COVID-19 preparedness, it is critical to reemphasize the scope and utility of simulation as “essential” to facilitate simulation program maintenance or relaunch, during the pandemic. Finally, the strategic alignment of simulation programs to organizational needs, mission, visions, and goals, especially as pertaining to disaster preparedness, need to be further explored and clarified.

REFERENCES

1. Barry Issenberg S, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach. 2009;27:10-28.
2. Choi B, Jegatheeswaran L, Minocha A, Alhilani M, Nakhoul M, Mutengesa E. The impact of the COVID-19 pandemic on final year medical students in the United Kingdom: a national survey. BMC Med Educ. 2020;20(1):206.
3. Brydges R, Campbell DM, Beavers L, et al. Lessons learned in preparing for and responding to the early stages of the COVID-19 pandemic: one simulation’s program experience adapting to the new normal. Adv Simul (Lond). 2020;5:8.
4. Sandars J, Correia R, Dankbaar M, et al. Twelve tips for rapidly migrating to online learning during the COVID-19 pandemic. MedEdPublish. 2020;9.
5. Goh PS, Sandars J. A vision of the use of technology in medical education after the COVID-19 pandemic. MedEdPublish. 2020;9.
6. Koehler MJ, Mishra P, Cain W. What is Technological Pedagogical Content Knowledge (TPACK)? J Educ. 2017;193:13-19.
7. Gardner AK, DeMoya MA, Tinkoff GH, et al. Using simulation for disaster preparedness. Surgery. 2016;160:565-570.
8. Wang EE, Quinones J, Fitch MT, et al. Developing technical expertise in emergency medicine—the role of simulation in procedural skill acquisition. Acad Emerg Med. 2008;15:1046-1057.
9. Cassara M, Schertzer K, Falk MJ, et al. Applying educational theory and best practices to solve common challenges of simulation-based procedural training in emergency medicine. AEM Educ Train. 2019;4(Suppl 1):S22-S39.
10. Sim MR. The COVID-19 pandemic: major risks to healthcare and other workers on the front line. Occup Environ Med. 2020;77:281-282.
11. Nassar AH, Zern NK, McIntyre LK, et al. Pandemic. JAMA Surg. 2019;2020:155.
12. Rose S. Medical student education in the time of COVID-19. JAMA. 2020;323.
13. Ferrel MN, Ryan JJ. The impact of COVID-19 on medical education. Cureus. 2020;12(3):e7492.
14. Sani I, Hamza Y, Chedid Y, Amalendran J, Hamza N. Understanding the consequence of COVID-19 on undergraduate medical education: medical students’ perspective. Ann Med Surg. 2020;58:117-119.
15. Shorten A, Smith J. Mixed methods research: expanding the evidence base. Evid Based Nurs. 2017;20:74-75.
16. Maxwell JA. Applied Social Research Methods. 3rd ed. Thousand Oaks, CA: SAGE Publications; 2013.
17. Miles MB, Huberman AM, Saldaña J. Qualitative Data Analysis: A Methods Sourcebook. 3rd ed. Thousand Oaks, CA: SAGE Publications, Inc; 2014.
18. Patton MQ. Qualitative Research & Evaluation Methods: Integrating Theory and Practice. 4th ed. Thousand Oaks, CA: SAGE Publications, Inc.; 2015.
19. Saunders B, Sim J, Kingston T, et al. Saturation in qualitative research: exploring its conceptualization and operationalization. Qual Quant. 2017;52:1893-1907.
20. Allen MW, Sites R. American Society for Training and Development. Leaving ADDIE for SAM: An Agile Model for Developing the Best Learning Experiences. Alexandria, VA: American Society for Training and Development; 2012.
21. Jung H, Kim Y, Lee H, Shin Y. Advanced instructional design for successive E-learning: based on the Successive Approximation Model (SAM). Int J E Learning. 2019:18:191-204.
22. LLEAP. Laerdal learning application. Laerdal Medical. 2016. Accessed December 26, 2020. http://www.laerdal.com/us/nav/3081/LLEAP-Laerdal-Learning-Application.
23. Sorensen JL, Ostergaard D, LeBlanc V, et al. Design of simulation-based medical education and advantages and disadvantages of in situ simulation versus off-site simulation. BMC Med Educ. 2017;17:20.
24. Hall AK, Nourainen MT, Campisi P, et al. Training disrupted: practical tips for supporting competency-based medical education during the COVID-19 pandemic. Med Teach. 2020;42:756-761.
25. Chick RC, Clifton GT, Peace KM, et al. Using technology to maintain the education of residents during the COVID-19 pandemic. J Surg Educ. 2020;77:729-732.
26. Petrosoniak A, Hicks C, Barratt L, et al. Design thinking-informed simulation. Simul Healthc. 2020;15:205-213.

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27. Cheung VK, So EH, Ng GW, So SS, Hung JL, Chia NH. Investigating effects of healthcare simulation on personal strengths and organizational impacts for healthcare workers during COVID-19 pandemic: a cross-sectional study. *Integr Med Res*. 2020;9(3):100476.

28. Chaplin T, McColl T, Petrosoniak A, Hall AK. "Building the plane as you fly": simulation during the COVID-19 pandemic. *CJEM*. 2020;22:576-578.

29. Dieckmann P, Torgeirsen K, Qvindesland SA, Thomas L, Bushell V, Langli EH. The use of simulation to prepare and improve responses to infectious disease outbreaks like COVID-19: practical tips and resources from Norway, Denmark, and the UK. *Adv Simul (Lond)*. 2020;5:3.

30. Ingrassia PL, Capogna G, Díaz-Navarro C, Szyld D, Tomola S, Leon-Castelao E. COVID-19 crisis, safe reopening of simulation centres and the new normal: food for thought. *Adv Simul (Lond)*. 2020;5:13.

31. Dedelias A, Sotiropoulos MG, Hanrahan JG, Janga D, Dedelias P, Sideris M. Medical and surgical education challenges and innovations in the COVID-19 era: a systematic review. *In Vivo*. 2020;34:1603-1611.

32. Hanel E, Blic M, Hassall K, et al. Virtual application of in situ simulation during a pandemic. *CJEM*. 2020;22:563-566.

33. Schwartz AM, Wilson JM, Boden SD, Moore TJ, Bradbury TL, Fletcher ND. Managing resident workforce and education during the COVID-19 pandemic. *JBJS Open Access*. 2020;5.

34. Chiu M, Crooks S, Fraser AB, Rao P, Boet S. Physical health risks during simulation-based COVID-19 pandemic readiness training. *Can J Anesth*. 2020;67(11):1667-1669.

35. Chan KH, Sridhar S, Zhang RR, et al. Factors affecting stability and infectivity of SARS-CoV-2. *J Hosp Infect*. 2020;106:226-231.

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.

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