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STORM

Simulation Technology & Operations Resource Magazine

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CONTENTS

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Development of an Advanced Ultrasound Intravenous Line Trainer

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SUMMARY

Ultrasound-guided peripheral intravenous access is a valuable technique in patients with difficult venous access, and proficiency with this skill is essential for healthcare providers across a range of clinical settings. There are several commercially available models for ultrasound-guided IV placement; however, they tend to be costly with limited reusability. We sought to develop an advanced USIV model featuring anatomically realistic vessel paths and a high-fidelity ultrasound image which learners can use to practice discriminating between artery and vein. The model was made using ballistics gel to simulate soft tissue, a 3D-printed mold and base, and fluid circuit to simulate vessels. We completed a preliminary evaluation of the model using feedback from Anesthesia residents with clinical experience placing ultrasound-guided IVs. Based on this feedback, we revised the model and completed a formal evaluation with subject matter experts. Most experts rated each aspect of the model as at least somewhat realistic or better, including the vascular anatomy on ultrasound, tissue quality, and overall realism. They reported the model could be improved by adding surrounding structures, such as nerves and muscles, as well as improving the simulated arm shape. Here, we present a cost-effective, reusable ultrasound-guided IV training model along with construction instructions and expert evaluation of model realism.

INTRODUCTION

Establishing peripheral intravenous (IV) access is a fundamental skill for all healthcare professionals, facilitating medical diagnosis and treatment. Usually, this can be achieved by visualization and vessel palpation. However, intravenous access can be difficult to establish in the setting of obesity, intravenous drug abuse, hypovolemia and previous difficult IV access. In these situations, ultrasound guidance can facilitate peripheral IV access while avoiding multiple painful attempts and waste of additional supplies (Adhikari et al., 2015). Importantly, in high-acuity emergent settings where rapid IV access is crucial, adequate training of healthcare professionals performing the procedure can prevent unnecessary delays in patient care (Edwards & Jones, 2017). Given the importance and prevalence of establishing IV access, practicing the procedure on a realistic model is crucial to developing and honing this skill.

There are several manikins, phantoms and models available for teaching ultrasound-guided IV (USIV) placement. The commercially available models tend to be costly with limited reusability (Table 1). At our simulation center, we previously used a basic USIV model (Figure 1). However, a collaboration with the Emergency Medicine Ultrasound Fellowship program highlighted that the simple, straight vessels of our basic model limited its ability to develop skills of experienced learners. We sought to develop an advanced USIV model featuring anatomically realistic vessel paths and a high-fidelity ultrasound image that challenged learners to discriminate between artery and vein. We

sought subject matter expert feedback to evaluate the realism of the vessel anatomy and ultrasound image, and the educational value of the model.

Table 1

Commercially Available USIV Models

Model name	Characteristics	Price
Vata Vascular Access Ultrasound Phantom	4 blood vessels with branching and varying depths	$504.03
FEI SONOtrain Vein Model	3 blood vessels with blood flow Self-closing with injections or punctures	$754.59
HM 4.0 Reusable 4 Vessel Ultrasound Phantom Training	4 blood vessels with blood flow Reusable with self-closing punctures	$378.98
SurgiReal Ultrasound Vascular Access Model	5 separate vessels at different depth	$206.99
Ultrassist Ultrasound Vascular Access Phantom with Multivessel Design	4 blood vessels	$59.99
HM 2.0 Re-Moldable 2 Vessel Ultrasound Training Model	2 blood vessels with blood flow Reusable	$343.45
Blue Phantom Branched 4 Vessel Ultrasound Training Block Model	4 blood vessels with branching and varying depths	$800.87
SimCoach Advanced Ultrasound Vascular Access Phantom Training Kit with Pump System	4 blood vessels with varying depths and blood flow	$169.99

Figure 1

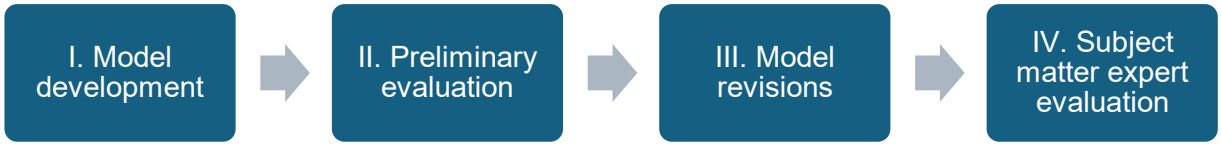
Basic Ultrasound IV Model

METHODS

This is a qualitative study to assess a newly developed ultrasound-guided IV insertion model conducted in four phases: model development, preliminary evaluation, model revisions, and subject matter expert evaluation. During model development, the research team collaborated with an Emergency Medicine Ultrasound Fellow to create a clinically accurate model. Following development, a preliminary evaluation was conducted with anesthesia residents, gathering feedback from trainees familiar with ultrasound-guided IV placement. This feedback informed iterative improvements to the model's design and functionality. Finally, formal evaluation phase was conducted, engaging subject matter experts from Emergency Medicine where USIV is commonly utilized. The development and evaluation process is summarized in Figure 2.

Figure 2

Model Development and Evaluation



We completed the study within a dedicated research space at the Arizona Simulation Technology and Education Center (ASTEC). The space included the advanced USIV model and supplies for performing the procedure. The Institutional Review Board of the University of Arizona approved this study on August 29, 2024 (ID 11008100). Informed consent for inclusion in this research study was obtained electronically prior to enrollment in the study. For both evaluation phases, we collected demographic information on each participant's specialty, training level, experience, and success with USIV placement. Participants then completed a survey created by the research team asking them to rate image quality, tissue, haptics, overall realism, and utility as a training tool. The survey also included two free-response questions: one on suggestions for improving the model and another on its strengths (Appendix A).

RESULTS

The development and evaluation of the ultrasound-guided IV model occurred in four phases: model development, preliminary evaluation, model revision, and subject matter expert evaluation. Results from each phase are presented below.

I. Model Development

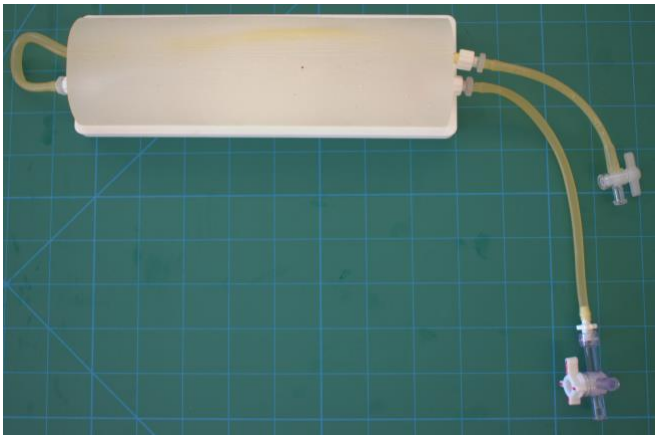
As discussed above, ultrasound-guided IV placement is a commonly performed procedure, especially in Emergency Medicine and Ultrasound training. Although our previous model had adequate appearance under ultrasound, the vessels were shallow and followed a linear path. The model base did not resemble an arm in shape or orientation. To create a higher fidelity model for practicing ultrasound-guided IV placement, we sought to accurately replicate vascular anatomy under ultrasound imaging and deliver realistic needle insertion haptics, bridging the gap between simulation and clinical practice.

Model Design Considerations

Full written and video instructions for the final model can be found in Appendix B and are publicly available the ASTEC Makerspace page (https://astec.arizona.edu/facility-makerspace/makerspace). In brief, the model base was 3D printed. Ballistics gel was used to simulate both the haptics and sonographic appearance of involved structures as it provides a realistic image of human tissue with ultrasound imaging. During model making, a stylet was inserted into the silicone tubing to simulate the irregular path and varying depth of the vessels. The artery is differentiated from the vein by the presence of latex tubing simulating a thick walled, incompressible artery. To simulate the vein, a negative space was created by removing the tubing. Using an IV bag and tubing to create a fluid circuit, the model provides a "flash" when the learner correctly placed the IV catheter in the vein. The model before revisions were made based on preliminary evaluation results is shown in Figure 3.

Figure 3

Preliminary Advanced USIV Model



II. Preliminary Evaluation

Following model development, we completed a preliminary evaluation phase with Anesthesia residents to gather feedback and make improvements to the model as needed. Anesthesia residents were recruited during a simulation session in their residency curriculum at ASTEC in October 2024. Eligible participants were Anesthesia residents present at the event with clinical experience performing USIV placement. In total, 12 participants were recruited, 11 of which were eligible (Table 2). Of the 11 eligible participants, 3 were in their second year of residency, 4 were in their third year, and 4 were in their fourth year. After informed consent, Anesthesia residents were asked to use the model to complete ultrasound-guided IV placement and provide feedback.

Table 2

Preliminary Evaluation Demographics

	n (%)
Previously used US-guided IV models	
Simulation model	8 (72.7%)
Cadaver	2 (16.7%)
Live patient training	5 (45.4%)
Virtual reality simulator	1 (8.3%)
Prior US-guided IV placements in clinical practice	
< 50	8 (72.7%)
51-100	1 (9.1%)
101-200	1 (9.1%)
> 200	1 (9.1%)
Successful US-guided IV placements	
< 25%	0 (0.0%)
25-50%	1 (9.1%)
50-75%	3 (27.3%)
> 75%	7 (63.6%)

Preliminary Evaluation Results

The results of the preliminary evaluation are shown in Appendix C. Most participants rated each aspect of the model as at least somewhat realistic or better, including the vascular anatomy on ultrasound (90.9%), tissue quality (73.6%), and overall realism (81.8%). Regarding its usefulness for learning ultrasound-guided IV line placement, 63.6% were "likely" or "extremely likely" to recommend the model, while 36.4% were neutral or unlikely to recommend it. When evaluating whether the model allowed for training the necessary steps in establishing IV access with ultrasound guidance, 8 (72.7%) participants indicated it included "most" or "all" steps, while 3 (27.3%) reported it included "some steps."

To improve the model, participants recommended adding a flash to confirm the needle was in the correct location (n = 5), making the vascular anatomy more superficial (n = 2), adding tortuous veins (n = 1), and modifying the tissue to be more pliable (n = 3). Participants identified the appearance of anatomy on ultrasound (n = 5), tissue resistance (n = 2) and inclusion of deep veins (n = 1) as strengths of the model. Two respondents reported the model would be good for novice learners practicing the procedure.

III. Model Revisions

To address the feedback from the preliminary evaluation, we added internal silicone tubing to represent the vessels. Leaving the tubing in the model eliminated leaking to allow for enough pressure to provide a flash to confirm correct needle placement. By leaving the tubing in, the artery and vein can be differentiated by the thicker walled, less compressible tubing simulating an artery and thinner walled for vein. Silicone tubing was chosen over latex as it is more heat-resistant and not altered when exposed to the heat of the melted ballistics gel. Although several participants suggested making the tissue more pliable, the research team prioritized preserving the realistic ultrasound appearance of the ballistic gel. Because the model's sonographic anatomy was consistently identified as one of its greatest strengths, we did not change the material.

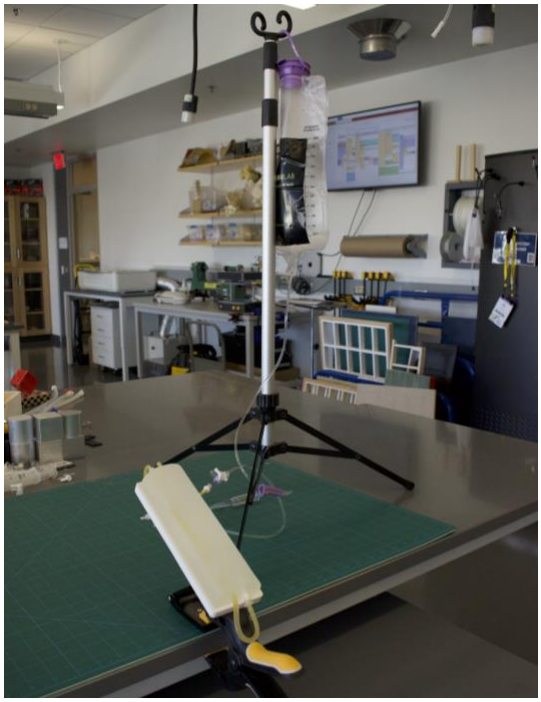
In addition to the above changes, the research team noticed several participants struggled with the unsteady base of the model. To address this, a new base was designed to improve stability during learner operation. The updated model can be seen in Figure 4. Written and video instructions on how to make the model are provided elsewhere (Appendix B).

(continued on next page)

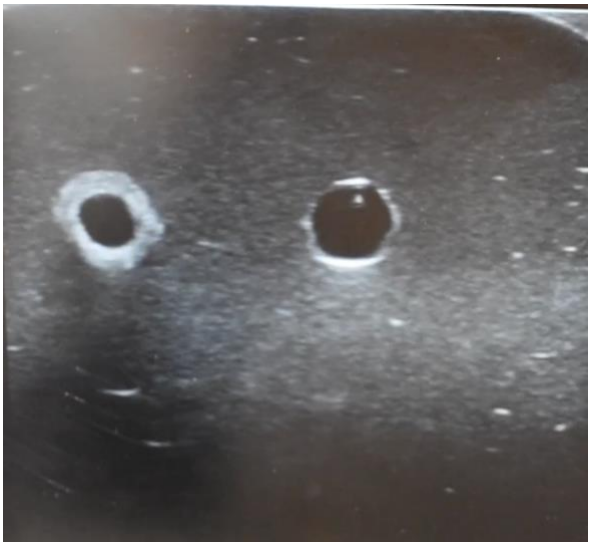
Figure 4

Advanced USIV Model

A



B



Note. A. Final version of the advanced ultrasound IV model. B. Example of two vessel view, artery on left and vein on right, using ultrasound.

The materials and costs required to construct a single model are listed in Table 3. For our fluid circuit, we used an IV bag, tubing and stand already in our lab; however, any cost-effective and accessible alternative is suitable. Similarly, while we used a 3D-printed mold and base fabricated from tough PLA filament, any comparable container and stand can be substituted based on available resources.

Table 3

Materials and Cost

Materials	**Total cost**	**Cost per model**
Tough PLA Filament (250 g)*	$75.00	$35.00
Ballistics gel (1 L)	$50.00	$50.00
Silicone tubing - 1/8” ID, 3/16” OD (1 ft)	$5.19	$0.78
Silicone tubing - 1/12” ID, 1/4" OD (1 ft)	$6.39	$2.13
IV bag, tubing and stand*	variable	variable
Total cost	$136.58	$87.91

Note. *Starred materials are variable and may be substituted with any option that is accessible, cost-effective, and functional. ID: inner diameter; OD: outer diameter.

IV. Subject Matter Expert Evaluation

The research team recruited subject matter experts from the Emergency Medicine Airway Day at ASTEC in October 2025. Eligible participants included faculty and residents from Emergency Medicine who have clinical experience placing USIV. We defined subject matter experts as participants who have more than 50 prior USIV placements. This threshold is based off recommendations from the American College of Emergency Physicians and American Institute of Ultrasound in Medicine (American College of Emergency Physicians, 2023; American Institute of Ultrasound in Medicine, 2025). In total, of the 17 participants recruited, 10 qualified as subject matter experts. The participant demographics of the subject matter experts are shown in Table 4.

Table 4

Subject Matter Expert Demographics

Demographics	**n (%)**
Current position	
Resident	2 (20.0%)
Faculty	8 (80.0%)
Year of residency	
First year	1 (50.0%)
Third year	1 (50.0%)
Have you ever completed or are currently completing an ultrasound fellowship?	
Yes	3 (30.0%)
No	7 (70.0%)
What models of ultrasound-guided IV line placement have you previously used?	
Simulation model	9 (90.0%)
Cadaver	2 (20.0%)
Live patient training	10 (100.0%)
Virtual reality simulator	1 (10.0%)
How many times have you performed ultrasound-guided IV placement on a patient?	
51-100	2 (20.0%)
101-200	6 (60.0%)
> 200	2 (20.0%)
What percentage of ultrasound-guided IV placements were successful in establishing IV access?	
< 25%	0 (0.0%)
25-50%	0 (0.0%)
50-75%	2 (20.0%)
> 75%	8 (80.0%)

Note. Demographics from Emergency Medicine subject matter experts (n = 10). *IV: intravenous.*

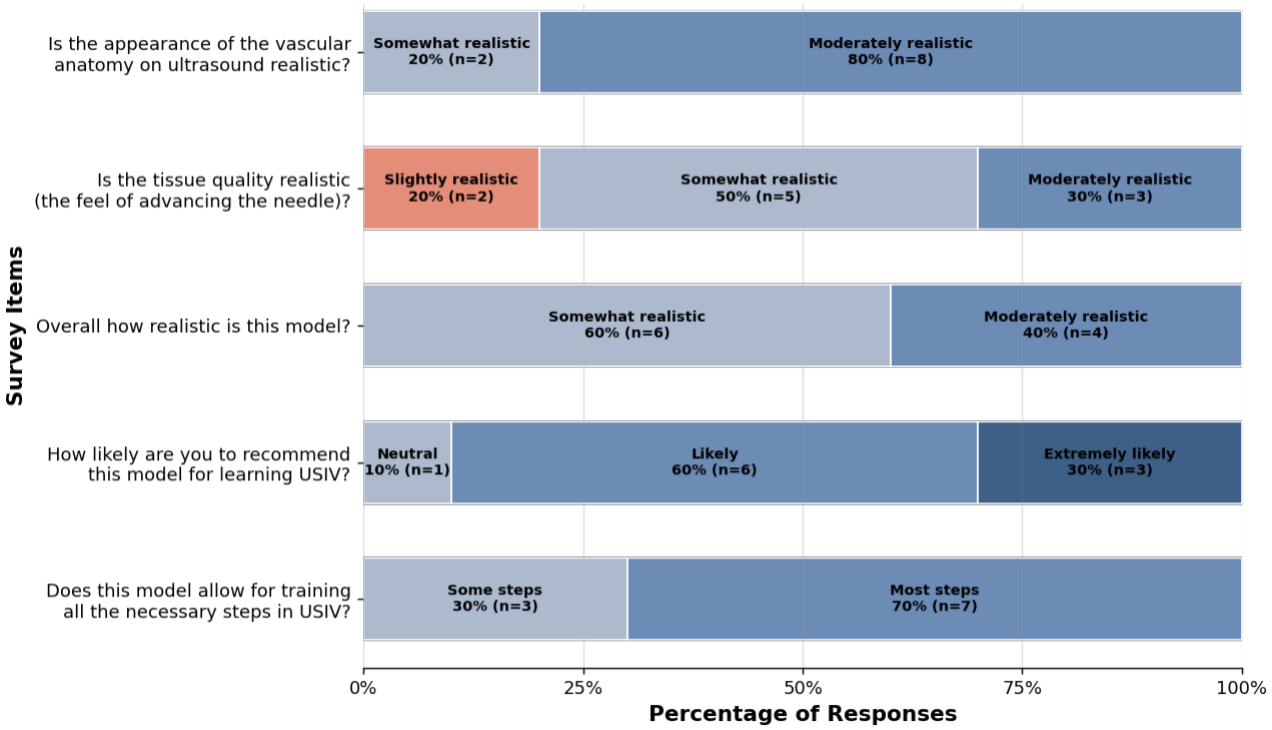
Subject Matter Expert Feedback

The survey results from subject matter experts are shown in Figure 5. Most experts rated each aspect of the model as at least somewhat realistic or better, including the vascular anatomy on ultrasound (100.0%), tissue quality (80.0%), and overall realism (100.0%). Regarding its usefulness

for learning ultrasound-guided IV line placement, 90.0% were "likely" or "extremely likely" to recommend the model, while the remaining were neutral (10.0%). When evaluating whether the model allowed for training the necessary steps in establishing IV access with ultrasound guidance, 7 (70.0%) participants indicated it included "most" or "all" steps, while 3 (30.0%) reported it included "some steps."

Figure 5

Subject Matter Expert Feedback



Note. Survey results from Emergency Medicine subject matter experts (n = 10). *IV: intravenous.*

The most common suggestion to improve the model was to make the vasculature more irregular by including branch points or placing them laterally (n = 5). Participants also recommended reducing air artifact (n = 3), adding surrounding structures such as muscles and nerves (n = 3), and improving the simulated arm shape by making it flatter, including antecubital space and space for a tourniquet (n = 3). There were also several suggestions on how to improve the vasculature (n = 3), such as making a pulsatile artery, adding fibrinous vessels for additional difficulty, and improving distinction between artery and veins. Participants identified the realistic resistance of the tissue (n = 5) and appearance of anatomy on ultrasound (n = 4) as strengths of the model. Two participants praised the model for its functionality and usability, noting that it does not leak and can be reused.

DISCUSSION

In this study, we developed a cost-effective, reusable model for advanced ultrasound-guided IV placement. Based on preliminary feedback, we modified the model to make vessel path more tortuous, provide a flash to confirm correct location, and stabilize the model base. Subject matter experts found the vascular anatomy under ultrasound and the model overall to be realistic. This

finding supports the model's potential usefulness as a training tool for learners practicing ultrasound-guided vascular access.

Although several experts also commented that the tissue was somewhat firmer than human tissue, most agreed the sonographic image was a major strength of the model. Because the ballistic gel provided highly realistic ultrasound visualization, we prioritized preserving this rather than modifying the current materials. In future iterations, we plan to trial a softer ballistic gel to determine whether tissue realism can be improved without sacrificing the ultrasound image quality.

Experts also provided additional suggestions to enhance realism, such as incorporating a superficial skin layer, adding red dye to fluid to resemble blood, and replacing the IV bag with a syringe for an easier set up. While these modifications were not implemented in the present version, they represent practical options that could be integrated depending on educational goals. This highlights the versatility of this model. It is designed to be easily customized and adapted to different educational objectives, such as teaching vessel localization, needle visualization, or catheter advancement.

For our model, the total cost of materials to create one model was approximately $87.91 USD. Although the model's longevity has not been formally assessed, ballistics gel is well established to withstand multiple needle passes before degradation of ultrasound image quality (Ewald et al., 2018). Other commercially available models ranged in price from $59.99 to $800.87, with an average price of $402.39. When accounting for the reusability of both the ballistic gel and the model base, this approach is substantially less expensive than commercially available models.

Limitations

This study has several limitations. Our sample of subject matter experts were all Emergency Medicine physicians. While this is a common procedure utilized in Emergency Medicine, especially as part of the training for ultrasound fellowship, the model would be strengthened by feedback from experts in various specialties. Additionally, this study does not assess the validity of this model and its effectiveness in improving skills associated with ultrasound-guided IV placement. The durability of the model has not been formally tested, and future studies are needed to determine the number of uses or needle passes possible before remelting of the ballistic gel is required to maintain ultrasound image quality. Future studies will aim to gather feedback from experts in different specialties, assess clinical improvement with model use, and monitor the model's longevity after several uses.

CONCLUSIONS

This study demonstrates a low-cost, modifiable approach to developing a realistic ultrasound-guided IV model suitable for advanced training. Future versions of this model will focus on improving tactile feedback and testing the model's effectiveness in improving learner skill acquisition.

Conflict of interest statement: The authors have no conflicts of interest to declare.

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Appendix A
Survey

Please indicate your primary specialty.	○ Internal Medicine ○ Critical Care ○ Anesthesia ○ Emergency Medicine ○ Surgery ○ Other: _____
Please indicate your current position.	○ Faculty ○ Resident ○ Fellow
What year of residency are you in?	_____
Have you ever completed or are you currently in the process of completing an ultrasound fellowship?	○ Yes ○ No
What previous models of ultrasound peripheral line placement have you used? (select all that apply)	○ Simulation model ○ Cadaver ○ Live patient training ○ Virtual reality simulator
In your clinic practice, have you performed ultrasound-guided peripheral line placement on a patient?	○ Yes ○ No
If you answered yes to the above question, please indicate how many times you have done this procedure.	_____
What percentage of the ultrasound-guided peripheral line placements were successful in establishing intravenous access?	○ < 25% ○ 25-50% ○ 50-75% ○ > 75%

Below is a list of statements regarding the ultrasound-guided intravenous line model. Please indicate how realistic the model is based on your clinical experience.

	Not realistic at all	Slightly realistic	Somewhat realistic	Moderately realistic	Extremely realistic
Is the appearance of the vascular anatomy on ultrasound realistic?	○	○	○	○	○
Is the tissue quality realistic (the “feel” of advancing the needle)?	○	○	○	○	○
Overall, how realistic is the model?	○	○	○	○	○

How likely are you to recommend this model for learning ultrasound-guided intravenous line placement?	○ Extremely unlikely ○ Unlikely ○ Neutral ○ Likely ○ Extremely likely
Does this model allow for training of all the necessary steps in establishing IV access with ultrasound guidance?	○ None of the steps ○ Very few steps ○ Some steps ○ Most steps ○ All steps

Please provide any feedback you have on how to improve the realism of this model.	_____
Please provide feedback on the strengths of this model in representing ultrasound-guided IV placement.	_____

Appendix B

Full written instructions and video

Written instructions:
https://astec.arizona.edu/sites/default/files/2026-05/US-IV-Advanced-Instructions.pdf

Video:
https://arizona.app.box.com/s/xp83j2ygc3wbyqusgq0lvphcn658g0f9

Appendix C

Preliminary Evaluation Results

Survey question and response	**n (%)**
Is the appearance of the vascular anatomy on ultrasound realistic?	
Not realistic at all	0 (0.0%)
Slightly realistic	1 (9.1%)
Somewhat realistic	5 (45.5%)
Moderately realistic	4 (36.4%)
Extremely realistic	1 (9.1%)
Is the tissue quality realistic (the 'feel' of advancing the needle)?	
Not realistic at all	1 (9.1%)
Slightly realistic	3 (27.3%)
Somewhat realistic	2 (18.2%)
Moderately realistic	4 (36.4%)
Extremely realistic	1 (9.1%)
Overall, how realistic is this model?	
Not realistic at all	0 (0.0%)
Slightly realistic	2 (18.2%)
Somewhat realistic	6 (54.5%)
Moderately realistic	2 (18.2%)
Extremely realistic	1 (9.1%)
How likely are you to recommend this model for learning ultrasound-guided intravenous line placement?	
Extremely unlikely	0 (0.0%)
Unlikely	2 (18.2%)
Neutral	2 (18.2%)
Likely	6 (54.5%)
Extremely likely	1 (9.1%)
Does this model allow for training of all the necessary steps in establishing IV access with ultrasound guidance?	
None of the steps	0 (0.0%)
Very few of the steps	0 (0.0%)
Some steps	3 (27.3%)
Most steps	7 (63.6%)
All steps	1 (9.1%)

From Scratch to Full SSH Accreditation: A Practical Implementation Roadmap from a Simulation Center in Vietnam

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SUMMARY

Achieving international simulation accreditation in low- and middle-income countries presents persistent operational challenges, including limited infrastructure, financial constraints, and workforce capacity gaps. While the Society for Simulation in Healthcare (SSH) provides comprehensive accreditation standards, practical guidance on implementing them in resource-limited settings remains scarce. This article presents a practical implementation roadmap describing how the Center for Advanced Training in Clinical Simulation (ATCS) in Vietnam operationalized SSH standards over a seven-year period. Specifically, we describe how policies were developed, procedures were standardized, and a continuous quality improvement (CQI) framework was established and iteratively refined to align with accreditation requirements. We further detail the operational processes, governance structures, documentation systems, and internal review mechanisms that supported progression toward full SSH accreditation, with an emphasis on how these components were adapted to local constraints. Practical lessons and a replicable, step-by-step implementation roadmap are provided to support simulation centers pursuing accreditation in similar resource-limited contexts.

INTRODUCTION

Patient safety remains a global priority, particularly in low- and middle-income countries, where resource constraints often limit access to standardized training environments (WHO, 2021; WHO, 2023; Kruk et al., 2018). Simulation-based education (SBE) offers a structured and safe platform for improving clinical competence and reducing preventable harm (Issenberg et al., 2005; McGaghie et al., 2011). However, sustaining high-quality simulation programs requires more than instructional innovation; it demands strong governance, standardized procedures, and ongoing quality oversight.

The Society for Simulation in Healthcare (SSH) accreditation standards provide a comprehensive framework for simulation program quality (SSH, 2021). While these standards are widely recognized, practical guidance on how to operationalize them in resource-limited settings remains limited. Beginning in 2017, the Center for Advanced Training in Clinical Simulation (ATCS) at the University of Medicine and Pharmacy at Ho Chi Minh City (UMP) undertook a phased institutional strategy to align operations with SSH standards. Over seven years, ATCS developed structured policies, standardized procedures, documentation systems, and a continuous quality improvement (CQI) process to support sustainable accreditation readiness. This article describes the operational processes, governance structures, policy development, and internal review mechanisms used to implement SSH standards in a resource-limited context. Practical lessons and replicable strategies are shared to support other simulation centers pursuing accreditation. This paper aims to provide a

practical, step-by-step implementation roadmap to support simulation centers in aligning with SSH accreditation standards in resource-limited settings.

INSTITUTIONAL CONTEXT AND EDUCATIONAL SETTING

Establishment of the ATCS took place during a university-wide transition toward competency-based medical education (CBME) at the UMP, beginning in 2016-2017. The CBME reform emphasized integrated learning, professionalism, interprofessional education, and competency-based assessment aligned with national healthcare priorities. SBE was identified as a core strategy to standardize skills training and ensure safe clinical practice. ATCS was founded to support the university's educational mission by enhancing the quality of clinical skills training and competency assessment, while advancing medical education research to improve patient safety and healthcare quality in Vietnam and the Southeast Asia region. The center's development was guided by international evidence demonstrating that SBE improves learning outcomes, promotes interprofessional collaboration, and facilitates the transfer of clinical skills into real-world practice.

In 2017, UMP established a formal collaboration with Texas Tech University Health Sciences Center at El Paso (TTUHSC El Paso) to strengthen faculty capacity and provide technical consultation for the development and operation of the simulation center. This partnership delivered structured faculty development programs, guidance on simulation pedagogy and assessment, as well as consultation on operational management and governance, thereby supporting the establishment of ATCS as a dedicated simulation center.

INTERVENTION DESCRIPTION

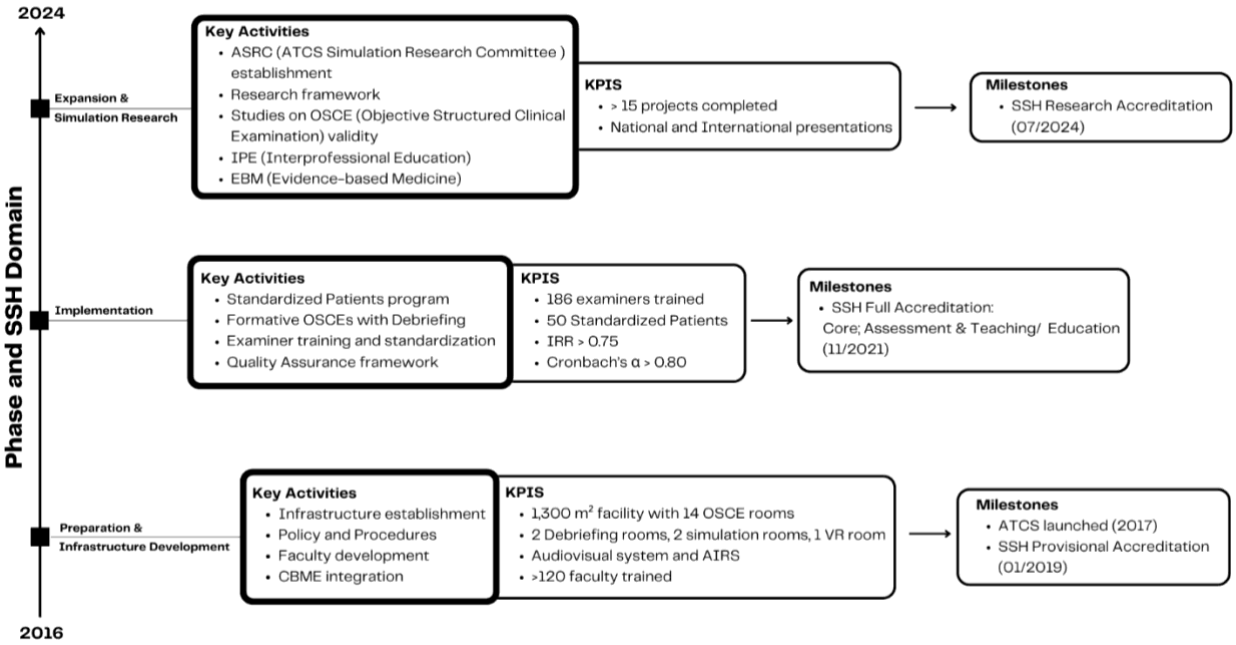
Strategic Intervention: Phased Development of a Simulation Center

The implementation roadmap consists of four key operational components: (1) governance structure, (2) instructional design standardization, (3) assessment and quality assurance, and (4) continuous quality improvement systems. The central initiative involved developing an SBE system aligned with SSH accreditation standards over seven years. An initial Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted through multidisciplinary stakeholder engagement, with faculty, administrators, and technical staff, to systematically evaluate infrastructure, workforce capacity, operational processes, and existing training programs. This analysis ensured that strategic planning was grounded in both institutional realities and accreditation requirements. Findings from the SWOT analysis informed the development of a phased strategic roadmap, in which priorities were sequenced based on feasibility and impact. Leadership support and international collaboration were leveraged as enabling factors, while gaps, such as variability in faculty competency, resource limitations, and increasing learner demand were addressed in each phase.

To operationalize this roadmap within a resource-limited context, ATCS implemented iterative strategic cycles (Figure 1) incorporating predefined key performance indicators (KPIs), milestone-based benchmarks, and embedded CQI processes. KPIs were regularly monitored through internal review meetings and documentation audits, enabling data-driven adjustments to implementation strategies. Each phase was explicitly mapped to specific SSH accreditation domains, with clearly defined activities, measurable outcomes, and structured review mechanisms. This phased operational model was intentionally designed to balance structure and flexibility, allowing incremental alignment with international standards while adapting to evolving institutional capacity and resource constraints.

Figure 1

Key Activities, KPIs, and Milestones in the Accreditation Process of ATCS



Note. Five-year strategic development roadmap of ATCS aligned with SSH accreditation domains, implemented across sequential phases.

IMPLEMENTATION PROCESSES

Governance Structure to Support Simulation Operations

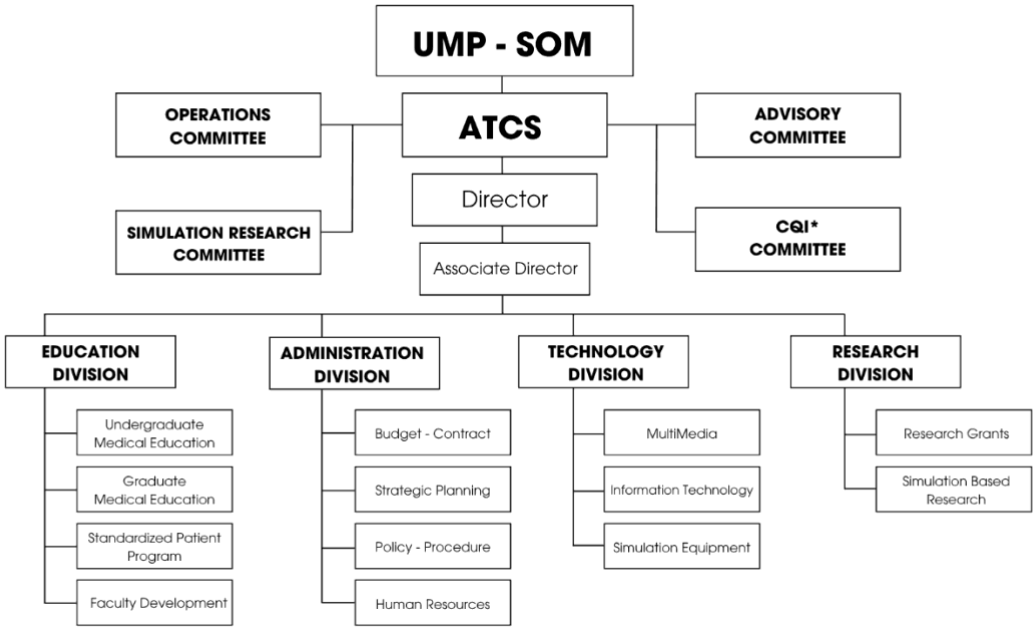
As ATCS expanded its scope and complexity, a decentralized governance structure was implemented to ensure operational consistency, accountability, and sustainable growth (Figure 2). Rather than centralizing decision-making within a single leadership role, responsibilities were distributed across committees and operational divisions with clearly defined reporting lines. All operational activities are guided by formal policies, standard operating procedures, and written role descriptions. These documents serve as the foundation for onboarding, quality assurance, and operational continuity. Four standing committees support governance:

- The Advisory Committee provides strategic oversight and reviews program performance.
- The Operations Committee coordinates daily scheduling, workflow management, and resource allocation.
- The ATCS Simulation Research Committee ensures ethical oversight and research integrity.
- The CQI Committee applies Plan–Do–Study–Act (PDSA) cycles to evaluate performance metrics and drive process improvements.

Operational responsibilities are implemented through four core divisions: Education, Administration, Technology, and Research. Each division maintains defined deliverables while functioning within an integrated reporting framework led by the Director and Associate Director. This governance model allows simulation operations to scale while maintaining quality control, research compliance, and operational transparency. Embedding CQI processes into routine workflow has strengthened sustainability and improved responsiveness to stakeholder needs.

Figure 2

Organizational Chart and Governance Framework of Four Divisions



Note. Organizational governance structure of ATCS under University of Medicine and Pharmacy at Ho Chi Minh City – School of Medicine, illustrating a decentralized model led by the Director and Associate Director, supported by Advisory, Operations, Research, and Continuous Quality Improvement committees, and operationalized through four core divisions (Education, Administration, Technology, and Research) to ensure integrated management, accountability, and CQI in simulation-based education. UMP: University of Medicine and Pharmacy at Ho Chi Minh City. CQI: Continuous Quality Improvement.

INSTRUCTIONAL DESIGN OF SIMULATION ACTIVITIES

As part of the implementation roadmap, ATCS implemented a standardized instructional design workflow to ensure consistency and quality across programs for all simulation activities. This approach was adopted to reduce variability in teaching practices and to ensure alignment with CBME outcomes and national healthcare priorities, while maintaining flexibility across disciplines and learner levels.

Learning objectives are developed through a structured gap analysis process that integrates multiple data sources, including learner performance data, faculty feedback, and observed deficiencies in clinical practice. This is complemented by stakeholder consultation to ensure relevance to both educational and clinical needs. Proposed activities then undergo a multidisciplinary review involving curriculum committees, assessment units, quality assurance teams, and simulation operations staff, ensuring both educational rigor and operational feasibility prior to institutional approval. All simulation activities follow a defined seven-step development pathway designed to ensure systematic alignment between objectives, instructional strategies, and assessment:

1. Conduct gap analysis to identify priority learning needs.
2. Develop SMART learning objectives (Chatterjee & Corral, 2017) to ensure clarity in expected learning outcomes and to enable objective assessment of learner performance. SMART

learning objectives are defined as Specific, Measurable, Achievable, Relevant, and Time-bound.
3. Map objectives to program outcomes to maintain curricular alignment.
4. Select appropriate instructional strategies based on learning goals and context.
5. Develop scenario scripts and facilitator guides to standardize delivery.
6. Determine simulation modality and fidelity level based on resource availability and educational value.
7. Implement sessions with structured pre-briefing and debriefing using the Promoting Excellence and Reflective Learning in Simulation (PEARLS) framework (Eppich & Cheng, 2015) to optimize learning outcomes.

Standardized templates, scenario development checklists, and facilitator guides are maintained in a shared digital repository with version control. This system supports consistency, facilitates iterative updates, and enables efficient scaling of simulation activities across programs.

SIMULATION MODALITY AND FIDELITY

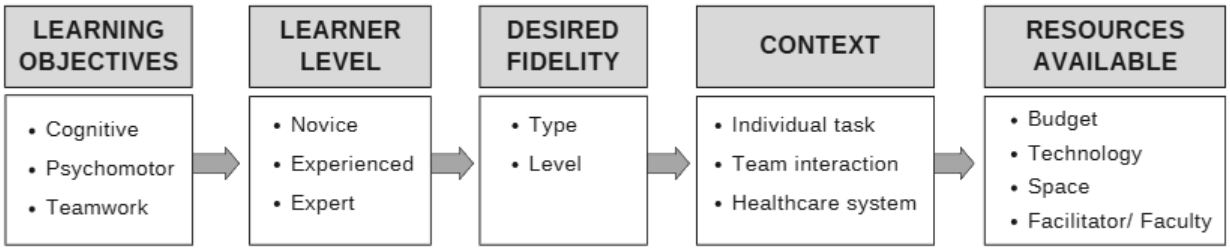
Within this implementation roadmap, ATCS applies a practical decision-making principle of "right modality, right objective, right learner" (Carey & Rossler, 2025) to guide the selection of simulation methods. This approach ensures alignment between learning goals, learner level, and available resources while maintaining cost-effectiveness.

Standardized patients (SPs) serve as the primary modality for communication skills, professionalism, and clinical reasoning training. Task trainers and low-to-mid fidelity simulators are used for procedural skill development when psychomotor performance is the primary objective. High-fidelity mannequins and virtual simulation are reserved for advanced learners and complex clinical scenarios requiring team coordination, crisis management, or integrated clinical decision-making.

Modality selection is determined during the instructional design phase using a structured planning checklist. This checklist incorporates key domains, including learning objectives, learner readiness, faculty availability, equipment requirements, and operational feasibility, as illustrated in Figure 3.

Figure 3

Key Factors for Selecting Simulation Modality



Note. The figure illustrates a structured and sequential decision-making process for selecting simulation modalities. The process begins with defining learning objectives, followed by consideration of learner level and required fidelity. Contextual factors and available resources are subsequently evaluated to ensure feasibility. This stepwise approach facilitates alignment between educational goals and the selected simulation modality.

By prioritizing educational outcomes over technology-driven implementation, ATCS ensures efficient resource utilization - an approach particularly relevant for simulation centers operating in resource-limited settings.

LEARNER ORIENTATION AND PSYCHOLOGICAL SAFETY

All simulation sessions begin with a structured orientation and pre-briefing to establish expectations, clarify learning objectives, and reinforce principles of psychological safety. Standardized ground rules are reviewed at the beginning of each session, emphasizing confidentiality, mutual respect, and a non-judgmental learning environment.

Facilitators explicitly normalize errors as a natural part of the learning process and encourage learners to engage openly in discussion and reflection. During debriefing, faculty apply the PEARLS framework to guide structured reflection, explore learners' clinical reasoning, and maintain a supportive and constructive tone aimed at helping students develop actionable plans to improve their clinical performance. To ensure consistency, orientation scripts and debriefing prompts are embedded within facilitator guides. This standardized approach reduces performance anxiety, promotes honest participation, and strengthens learner engagement across programs.

By integrating psychological safety into routine operational practice rather than treating it as a theoretical concept, ATCS fosters a safe and effective learning environment while maintaining structured educational rigor.

FACULTY AND STAFF DEVELOPMENT

Faculty and staff development are integrated into ATCS operational systems to ensure instructional quality and long-term sustainability. Since 2017, core faculty have participated in structured training in simulation center operations and SBE through a memorandum of understanding with TTUHSC El Paso.

This collaboration was operationalized through the Collaborative Educational Program, a longitudinal faculty development program comprising core modules in competency-based medical education, teaching and assessment, medical education research (including Objective Structured Clinical Examination (OSCE) and standardized patient methodologies), simulation-based clinical training, and leadership development. Training was delivered through a combination of on-site workshops, hands-on simulation sessions, and longitudinal mentorship across multiple cohorts. By 2022, more than 220 faculty members had participated in these collaborative programs, contributing to institutional capacity building and supporting the standardization of simulation-based education practices. Selected faculty also completed short-term intensive training at the simulation center in El Paso, focusing on OSCE implementation, simulation technologies, and standardized patient programs. These activities collectively strengthened local expertise and contributed to institutional readiness for SSH accreditation.

In addition, ATCS conducts regular internal development sessions focusing on simulation equipment management, scenario facilitation, and structured onboarding for new staff. Faculty are encouraged to engage in simulation-related scholarship to support academic integration. In parallel, in-house workshops organized by the Faculty Development Unit address SBE, OSCE implementation, standard-setting methodologies, and active learning design.

To ensure operational consistency, ATCS maintains a centralized faculty database that tracks expertise, training history, teaching experience, and learner feedback. Faculty assignments are aligned with documented competencies. A structured mentorship model pairs junior faculty with experienced mentors to strengthen facilitation skills, standardize instructional quality, and support ongoing professional development.

TEACHING, ASSESSMENT, AND QUALITY ASSURANCE

Teaching quality and assessment at ATCS are supported by a structured faculty qualification and quality assurance system designed to ensure consistency, reliability, and alignment with accreditation standards. Faculty members are required to complete formal professional development in SBE prior to serving as instructors or examiners, ensuring a standardized baseline of teaching and assessment competency.

Between 2018 and 2021, more than 186 faculty members underwent structured assessment training focused on key principles, including fairness, reliability, feasibility, confidentiality, and psychological safety. This training included calibration exercises and performance benchmarking to ensure consistent scoring practices. Examiners were selected based on both clinical expertise and assessment competence, only receiving formal assignment after achieving acceptable levels of scoring agreement during calibration.

To support continuous quality improvement, ATCS implemented a multi-source evaluation system using standardized tools to assess learners, instructors, and standardized patients (SPs). A routine 360° feedback process was conducted to systematically collect input from learners, peers, SPs, and operational staff. This approach was designed to provide comprehensive insights into instructional effectiveness and to identify areas for targeted improvement.

The OSCE serves as the primary competency-based assessment format. OSCEs are developed using blueprint-driven design to ensure alignment with CBME outcomes and national healthcare priorities. Quality assurance measures include pre-exam calibration sessions, pilot testing of stations, standardized scenarios and checklists, electronic scoring systems, and structured post-exam reviews. Assessment data are systematically analyzed to support CQI initiatives. Video monitoring, examiner debriefings, and targeted recalibration workshops are used to identify variability in scoring and improve inter-rater reliability. In addition, formative OSCE sessions incorporate structured debriefing and video-assisted review to enhance reflective learning and better prepare learners for high-stakes assessments and clinical practice.

RESEARCH

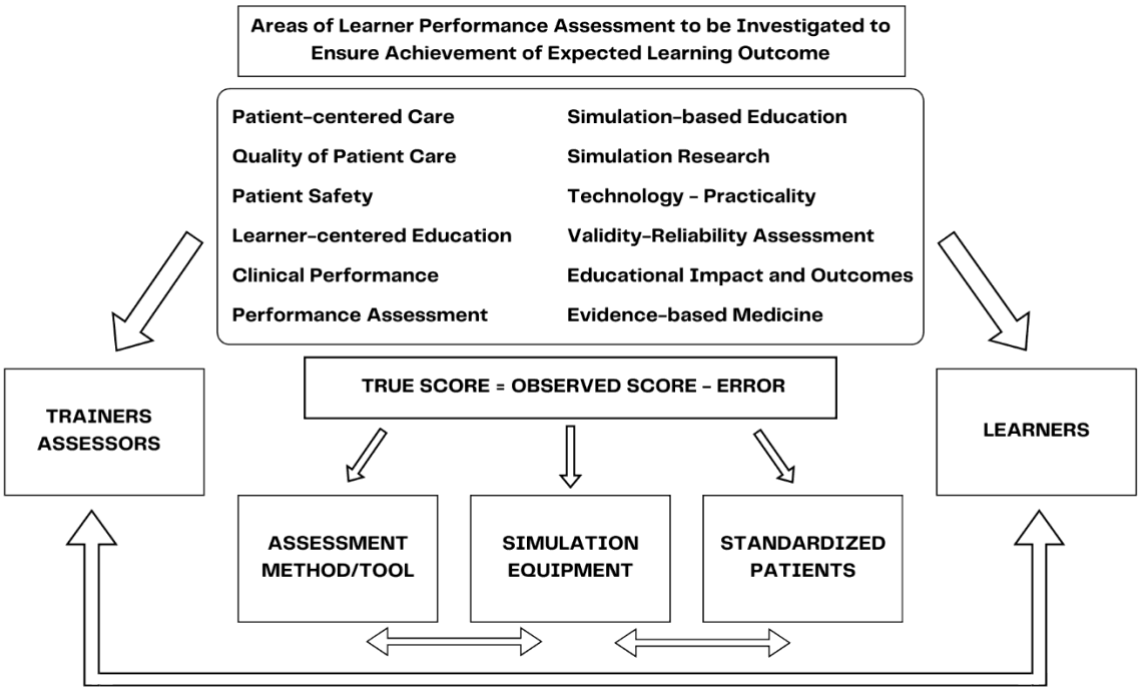
In alignment with ATCS's mission, ATCS established a Simulation Research Framework (Figure 4) to support study oversight, monitor assessment processes, and identify potential sources of variability in competency evaluation (e.g., examiners, assessment tools, equipment, and standardized patients).

Operational guidelines were developed for UMP faculty and staff conducting simulation-based research. These include requirements for protocol review, ethical approval, and internal methodological oversight. Research proposals undergo internal review to ensure alignment with institutional priorities and quality standards before implementation. Research findings are shared through conferences, peer-reviewed publications, and institutional quality improvement meetings. Key insights are incorporated into faculty development activities, assessment recalibration, and program redesign to strengthen operational effectiveness. Moving forward, ATCS will prioritize three applied research domains:

- Strengthening the validity and reliability of assessment tools
- Evaluating the impact of simulation on clinical performance
- Integrating evidence-based medicine and interprofessional collaboration into simulation training

Figure 4

ATCS's Conceptual Framework for Simulation Research in Healthcare



Note. This figure presents key domains to be examined to ensure achievement of expected learning outcomes and highlights the psychometric principle that True score = observed score – error (Cappelleri, 2014). It illustrates the dynamic interaction among assessors, learners, assessment tools, simulation equipment, and standardized patients within a continuous quality improvement framework.

DISCUSSION

The development of ATCS demonstrates that SSH accreditation can be effectively operationalized in resource-limited settings when governance systems, standardized procedures, and CQI are embedded into routine operations. This experience can be conceptualized as a practical implementation roadmap, consisting of phased development, governance structuring, standardized instructional processes, and embedded CQI systems. These elements provide transferable strategies that can be adapted by other simulation centers operating in resource-limited settings. Rather than viewing accreditation as a one-time achievement, ATCS approached it as an operational framework that guides decision-making, documentation standardization, and performance monitoring.

Initial challenges included financial constraints, variability in faculty preparedness, and limited familiarity with accreditation requirements. Instead of prioritizing high-cost technology investments, ATCS first focused on establishing governance structures, clearly defining roles and reporting lines, and standardizing operational processes. This ensured operational continuity during staff transitions and reduced variability in program implementation.

A structured CQI system played a central role. By integrating PDSA cycles into daily workflows, performance indicators were reviewed regularly rather than only during accreditation preparation. This approach enabled small but continuous adjustments in scheduling, scenario design, faculty calibration, and assessment processes. As a result, accreditation readiness became an ongoing operational condition rather than a periodic activity.

Alignment among instructional design, faculty development, and assessment systems strengthened institutional credibility and reliability. Blueprint-driven OSCE implementation, structured examiner calibration processes, and centralized data management ensured consistency and defensibility of assessment outcomes. In resource-limited contexts, these structures are particularly important for balancing efficiency with accountability.

The establishment of a formal partnership with TTUHSC El Paso in 2017 represented a pivotal turning point in our accreditation journey. In contrast to isolated internal efforts, this structured international collaboration enabled a more systematic and guided approach to aligning with SSH standards. Findings from our experience suggest that such partnerships can play a critical role in addressing common barriers in resource-limited settings, particularly in relation to faculty development, standardization of processes, and access to educational resources. A key contribution of this collaboration was the provision of external expertise, which facilitated not only the development but also the critical appraisal of institutional policies and procedures. This external perspective was instrumental in identifying gaps that may not have been apparent through internal review alone, thereby strengthening the overall quality and consistency of implementation. In addition, the iterative nature of mentorship, combined with mock accreditation activities and continuous feedback, supported a cycle of ongoing refinement consistent with the principles of continuous quality improvement.

Furthermore, access to structured training programs, simulation equipment, and digital resources through the partnership significantly enhanced local capacity, allowing for more rapid and effective adoption of competency-based and learner-centered educational approaches. These findings align with previous literature (Robinson et al., 2024) emphasizing the importance of collaborative networks in advancing simulation-based education, particularly in low- and middle-income countries.

Collectively, our experience suggests that strategic international collaboration should not be viewed merely as supplementary support, but rather as a core component of successful accreditation efforts in resource-constrained contexts. Such partnerships offer a scalable and potentially replicable model for other institutions seeking to bridge resource gaps while maintaining alignment with international standards. For simulation operations specialists, this experience highlights the following practical considerations:

- Governance should be established before expanding technology investments.
- Written policies and standardized workflows reduce operational variability.
- CQI processes should be embedded into routine operations, not reserved for accreditation cycles.
- Faculty calibration and assessment oversight are essential for maintaining quality.
- Documentation and data management systems are foundational for sustainability and scalability.

When operationalized through clear policies, standardized procedures, and continuous monitoring, accreditation can function as a strategic management tool that strengthens simulation systems in resource-limited environments.

CONCLUSION

The seven-year development of ATCS demonstrates that simulation centers in resource-limited settings can establish and sustain structured simulation programs aligned with international standards through phased planning, strong governance, and sustained faculty development. Beyond accreditation, this process strengthened assessment systems, faculty capability, operational consistency, and a culture of patient safety and continuous quality improvement. The ATCS model offers a practical and transferable implementation roadmap for institutions in low- and middle-income

countries seeking to build, scale, and sustain SBE while remaining responsive to local resource constraints.

Conflict of interest statement: The authors have no conflicts of interest to declare.

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Advancing Simulation Equipment Maintenance Through Workflow Automation

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SUMMARY

This paper presents a quality improvement project developed within the British Columbia Institute of Technology (BCIT) School of Health Sciences Simulation Program. Using the Plan-Do-Study-Act (PDSA) framework – widely implemented in healthcare for iterative, evidence-informed process improvement (Leis & Shojania, 2017) – the project identified an operational problem and designed a targeted intervention to address it. Specifically, this paper explores BCIT's design, implementation, and impact of a Quick Response (QR) based workflow automation system using Microsoft SharePoint, Forms, and Power Automate. Power Automate workflows were created to address persistent operational challenges, many of which are commonly found throughout healthcare simulation centers (Krishna Debbadi & Boateng, 2025; Zayas-Cabán et al., 2021). In this paper, we outline the potential for low-code automation and standardized digital reporting to reduce cognitive load, eliminate undocumented equipment issues, improve maintenance accountability, and enhance communication between faculty and simulation operations teams. Digital transformation and Artificial Intelligence (AI) supported workflows are positioned as a scalable and cost-effective model for simulation centers seeking to modernize operations.

INTRODUCTION

Healthcare simulation centers are specialized educational environments designed to replicate clinical scenarios for the training and assessment of health sciences students and professionals (Dleikan et al., 2020). By providing a controlled, risk-free setting in which learners can practice clinical skills, respond to emergencies, and develop clinical decision-making, simulation centers serve a critical role in preparing the healthcare workforce (Saleem & Khan, 2023). The effectiveness of these environments depends not only on the quality of the educational programming but also on the reliability and readiness of the equipment and technology that supports it (Mitchell & Ivimey-Cook, 2023).

Central to the daily function of a simulation center is the simulation technologist, a role with responsibilities that include equipment setup and teardown, manikin programming, audiovisual system management, scheduling support, and technical troubleshooting (Tellefson et al., 2025). Unlike clinical departments with long-established administrative infrastructures, simulation teams are typically small and specialized, meaning each technologist carries a broad scope of responsibility (Bailey et al., 2015). This makes efficient workflow organization and reliable communication systems essential to maintaining a functional simulation environment.

Inconsistent and informal reporting processes can be detrimental to the effectiveness and efficiency of simulation centers, as they lead to undocumented issues and delayed maintenance or repair of equipment (Mwanza et al., 2023). Functioning equipment is a necessity within simulation centers, and damaged or malfunctioning equipment can disrupt or even prevent the facilitation of simulations (Schram et al., 2024). As a result, simulation technologists may be required to repair equipment in the middle of active simulations. This is a problem that can negatively impact simulation

centers by making inefficient use of simulation technologists' time and compromising the educational value of simulations.

This paper presents a quality improvement initiative developed at the BCIT School of Health Sciences Simulation Program to address these challenges through the implementation of a QR-based workflow automation system using Microsoft SharePoint, Forms, and Power Automate. This workflow aimed to replace informal, verbal reporting with a standardized, automated process that ensures every equipment issue is captured, routed, and resolved in a timely and accountable manner.

BACKGROUND

Before turning to a more automated workflow system, the BCIT simulation center faced recurring operational issues involving equipment maintenance. Faculty reported equipment issues informally and inconsistently, often relying on incidental contact with available simulation technologists rather than a standardized reporting process, leading to problems going undocumented. Intermittent malfunctions were particularly susceptible to this gap, as some issues would go unreported and unresolved until the next academic term. Meanwhile, maintenance history for high-fidelity equipment such as IV pumps, ventilators, defibrillators, and manikins, all of which require timely and accurate troubleshooting, was fragmented across email threads, handwritten notes, and individual memory. Simulation technologists overseeing maintenance could only respond to issues they were made aware of, and without a formal logging system. Many problems repeatedly resurfaced because they had never been properly documented or resolved.

The absence of a standardized reporting system created blind spots in the daily operations of the simulation center, leading to delays, inconsistent documentation, and safety concerns. The need to incorporate workflow automation into healthcare settings has been discussed in previous research, as its success in other industries has made its benefits apparent (Mwanza et al., 2023; Zayas-Cabán et al., 2021). However, many commercial software solutions fail to fully address the unique operational challenges of facilities such as simulation centers, making it necessary to redesign or build new automated workflows (Zayas-Cabán et al., 2021; Zayas-Cabán et al., 2023).

Incident reporting systems in healthcare have a well-established role in identifying and resolving operational gaps (Archer et al., 2017). Structured reporting mechanisms create accountability, enable trend analysis, and support evidence-based decision-making (Zayas-Cabán et al., 2021). When applied to simulation operations, these principles translate directly to a system that captures every equipment issue at the point of occurrence, routes it to the appropriate person, and tracks its resolution, addressing the core failures that characterized the previous informal approach.

Microsoft Power Automate has emerged as a practical platform for building these kinds of automated workflows within institutional environments. Its low-code design allows users to create custom workflows, notifications, and data collection tools without requiring a dedicated software engineer or advanced programming expertise (Pearson et al., 2020). The program operates as a rule-based intelligent automation platform, where user-defined logic drives execution. When a condition is met, such as a form submission, a predefined sequence of actions is triggered: routing notifications, logging data, and updating records. This is fundamentally different from deep learning AI, which trains on data to make independent predictions (Jakhar & Kaur, 2020).

Power Automate operates seamlessly within the Microsoft 365 ecosystem, enabling integration with SharePoint for data storage, Forms for standardized data collection, and Outlook for automated notifications. The program enables seamless integration with large corporate-level systems, making it well suited for complex institutional environments (Krishna Debbadi & Boateng, 2025; Pearson et al., 2020). As highlighted in recent case studies, organizations across different sectors have used Power Automate to move away from outdated processes, eliminate manual inefficiencies, and modernize data-driven reporting structures (Zayas-Cabán et al., 2021). These examples demonstrate how this style of automation can transform operational strategies by improving consistency, accountability, and response time.

Existing literature on AI-constructed automation shows that it has the potential to improve decision-making, reduce administrative burden, improve data accuracy, and allow workers such as simulation technologists to focus on high-value tasks (Oyangoren & Camilo, 2025).

Objectives

The objective of this quality improvement project was to design and implement a QR-based workflow automation system for equipment issue reporting and maintenance tracking within the BCIT School of Health Sciences Simulation Program. The system was developed to address persistent operational inefficiencies, specifically the reliance on informal, undocumented communication channels. Using Microsoft SharePoint, Forms, and Power Automate, the goal was to replace these ad hoc processes with a standardized, automated reporting workflow accessible to all faculty and staff via personal smartphones.

METHODS

The PDSA (Plan-Do-Study-Act) framework (Leis & Shojania, 2017) was used to structure the improvement process, beginning with a clear identification of the operational problem in the Plan phase, followed by the implementation of the automated workflow in the Do phase, observation of its effects in the Study phase, and ongoing refinements based on team feedback in the Act phase. This iterative approach ensured that decisions were grounded in observed outcomes and allowed the team to make incremental adjustments as the system was adopted across the simulation center.

Our Simulation Operations Lead, co-author (SD), designed and tested several workflows where major pieces of equipment at our simulation center, including patient simulators, IV pumps, defibrillators, ventilators, and patient monitors, were each assigned a unique identifier. For example, our SimMan3G high-fidelity patient simulators were given unique identifiers such as S01, S02, S03, etc. These identifiers enabled Power Automate to accurately track each asset and dynamically update the inventory database within SharePoint. Furthermore, each physical inventory item was fitted with a QR code sticker, allowing staff to quickly scan equipment at the point of use.

Each QR code provides immediate access to a Microsoft Form (Figure 1), allowing faculty and staff to report issues quickly and consistently using their personal smartphones without requiring additional software or login credentials. Each form takes a matter of seconds to report any issues, which then triggers an email alert to our simulation technologists.

Figure 1

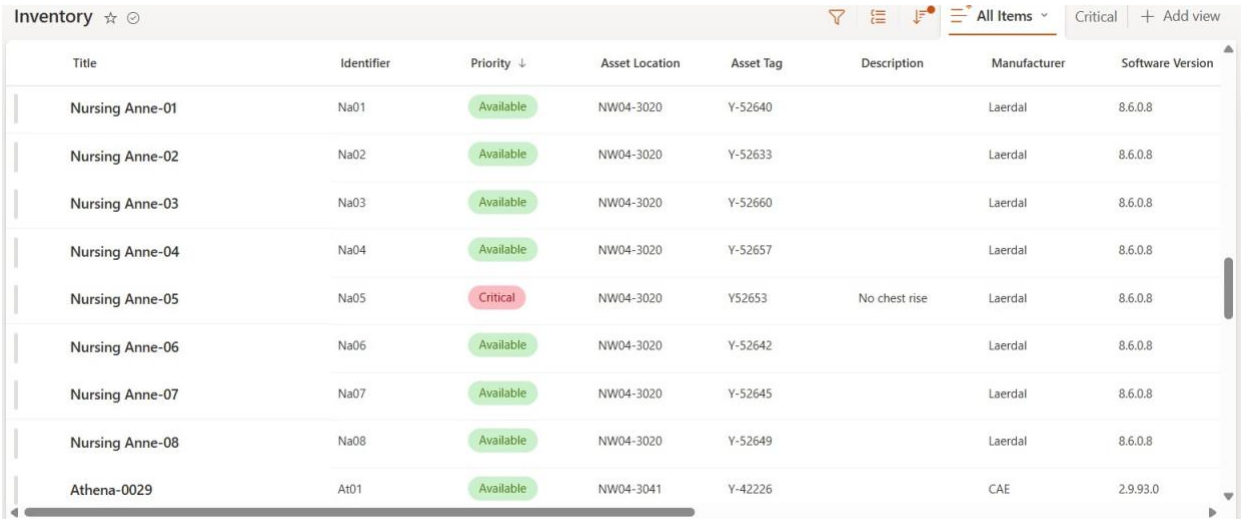
Microsoft Forms Connected to QR/SharePoint

When an issue occurs, the user scans the QR code attached to the equipment. This action opens a standardized form prompting the user to identify the equipment using the unique identifier, select whether it is low or critical priority, and briefly describe the issue. Upon submission, Microsoft Power Automate triggers an automated workflow that sends a notification email to the appropriate simulation technologists and simultaneously logs the issue into a centralized SharePoint tracking list (Figure 2). This SharePoint tracking list serves as the centralized database populated by each form submission.

Each row in the tracking list corresponds to a single piece of equipment, with columns reflecting the form fields completed by the user, including the equipment identifier, issue description, priority, and submission timestamp. Additional fields visible in the tracking list, such as status and resolution notes, are completed manually by the simulation technologist after the issue has been reviewed and addressed, allowing the team to monitor each report to completion. Aggregated data from the tracking list can be exported for accreditation reporting, equipment lifecycle management, budget forecasting, and incident trend analysis. This structured workflow ensures accountability and prevents issues from being overlooked, which is often an ongoing challenge in simulation programs. Our current use of Power Automate is not just a single-use tool but rather can be a part of a progressive digital transformation pathway. For our site at BCIT, we find that this ensures no reported issue disappears, solving a problem that our team used to frequently encounter.

Figure 2

SharePoint Equipment Tracking Site



Simulation centers interested in replicating this workflow can do so using tools already available within the Microsoft 365 ecosystem, specifically Microsoft Forms, Power Automate, and SharePoint. The following steps outline the process in the order they should be completed.

Step 1: Create Your SharePoint Tracking List

Begin by setting up a SharePoint site that will serve as the central repository for all equipment issue reports. Within that site, create a list with columns corresponding to the information you want to capture for each report. Recommended fields include Equipment ID, Equipment Type, Issue Description, Location, Date Submitted, Status (e.g., Open, In Progress, Resolved), and any additional notes from the operations team. This list will become the live database that your team monitors and

updates as issues are reported and resolved. Establishing SharePoint first is important because it will be the destination that both the form and automation workflow will connect to.

Step 2: Assign Unique Identifiers to All Equipment

Before building the form, assign a unique alphanumeric identifier to every major piece of equipment in your simulation center. A simple, consistent naming convention works best. For example, SimMan3G units can be labeled S01, S02, and S03, while IV pumps might follow a separate sequence such as IV01, IV02, and so on. These identifiers serve as the critical link between the physical equipment and the digital tracking system, allowing Power Automate to correctly log and route each report to the appropriate entry in SharePoint. Once identifiers are assigned, create a corresponding master inventory list in SharePoint that maps each ID to its equipment type, location, and any relevant lifecycle information.

Step 3: Build Your Microsoft Form

With your SharePoint list established and your equipment identifiers defined, the next step is to create the reporting form in Microsoft Forms. Navigate to Microsoft Forms through your Microsoft 365 account and create a new form. Design the form to collect the essential information needed for each report: the equipment's unique identifier, a description of the issue, and the location of the equipment. Keep the form as concise as possible. The goal is for faculty or staff to be able to complete and submit it in under a minute. Once the form is complete, copy the shareable link, as this will be embedded in your QR codes in the next step.

Step 4: Generate and Print QR Codes

In Microsoft Forms, open your form, click the share button, and select "QR code" to download a scannable image that links directly to your form. If you have created separate forms for different equipment categories, generate a corresponding code for each. Print the QR codes as durable sticker labels and affix them directly to each piece of equipment in a visible, accessible location. When scanned with a smartphone, the QR code should open the form immediately, without requiring the user to log in or download any application. At this stage, it is also helpful to include the equipment's unique identifier on the same label as the QR code so users can easily reference it when completing the form.

Step 5: Build Your Power Automate Workflow

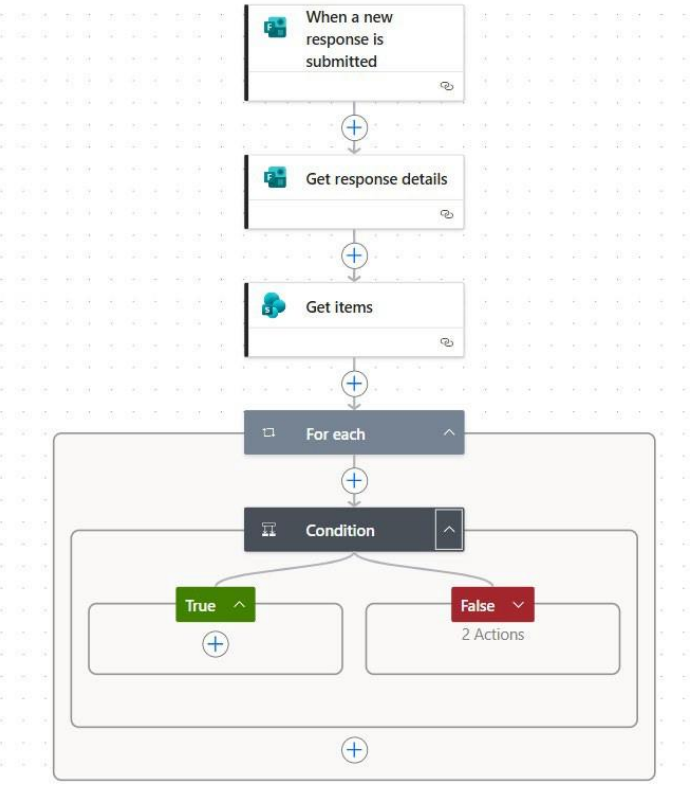
Microsoft Power Automate acts as the engine that connects your Microsoft Form to your SharePoint list and triggers notifications to your team. To begin, create a new automated cloud flow and select the trigger "When a new response is submitted", linking it to your Microsoft Form. Next, add "Get response details" to extract the individual answers from the submission. Then, use "Get items" to retrieve records from your SharePoint list. The flow then uses a "For each" loop to go through the returned items, followed by a Condition that compares a value from the form response to a value in the SharePoint list. This effectively asks: does this existing SharePoint record already match the submitted form response?

If the condition evaluates to “True”, the item is already accounted for, and the flow skips it, continuing to check the remaining records. If it evaluates to “False”, no matching record exists, so the flow performs two actions: updating the SharePoint list with the new submission and sending a notification email. This ensures that only unmatched responses trigger an update, preventing duplicate entries from being created in the list. Finally, add an email notification action, such as "Send an email (V2)" via Outlook, configured to alert your simulation operations team whenever a new report

is submitted. The email can be customized to include the equipment ID, issue description, and a direct link to the SharePoint entry for immediate review. Save and test the flow by submitting a sample form response to confirm that the SharePoint list populates correctly and the notification email is received (Figure 3).

Figure 3

Power Automate Workflow



Step 6: Train Your Team and Launch

Before going live, brief both faculty and simulation operations staff on how the system works. Faculty need only understand one thing: scan the QR code on the equipment and complete the form. Operations staff should be oriented to the SharePoint tracking list, specifically how to update the status of each issue as it moves from “open” to “in progress” to “resolved”, and how to add internal notes as maintenance is carried out. Establishing a clear expectation that all issues must be logged through the system, rather than communicated verbally, is essential to the workflow's effectiveness. A short demonstration at a team meeting or via a brief instructional video attached to each QR code station is sufficient for onboarding most users.

Step 7: Monitor, Export, and Iterate

Once the system is live, your SharePoint tracking list becomes a living record of all equipment issues across your simulation center. Over time, patterns may emerge, such as recurring issues with specific equipment, seasonal spikes in maintenance requests, or gaps in resolution times, all of which can inform purchasing decisions and preventive maintenance strategies. Teams are encouraged to

revisit the form design and workflow periodically to ensure the system continues to meet operational needs as the simulation center grows.

RESULTS

Success was defined by the system's ability to ensure that every submitted equipment report was automatically logged, routed to the appropriate simulation technologist, and tracked through to resolution, reducing the possibility of issues being lost or forgotten. Secondary indicators of success included positive feedback from faculty and simulation technologists regarding ease of use, reduced administrative burden, and improved confidence that reported issues would be addressed systematically.

It is worth noting that this manuscript is a quality improvement project rather than a formal research study, and as such, feedback was not collected through structured research methods such as surveys or controlled observation. Rather, the outcomes described here reflect the experiential findings of our team following the rollout of the system.

With that context in mind, the system was found to meet each of the core objectives it was designed to address. Standardized reporting was achieved through the QR code and Microsoft Forms workflow, which replaced all informal verbal and email-based communication with a consistent, accessible submission process. Tracking and documentation were established through the centralized SharePoint list, which captures every submission with a timestamp, equipment identifier, issue description, and resolution status. Timely issue resolution was supported through automated email notifications to simulation technologists, ensuring that no submitted report goes unacknowledged.

Faculty noted several positive changes since implementation, including more efficient reporting using QR codes, reduced uncertainty about who to contact when an issue arises, and greater trust that reported problems would be addressed. Simulation technologists observed that fewer repeated problems were encountered during setup, day-to-day organization had improved, and the timestamp and categorization features of the tracking list allowed them to prioritize their workload more effectively.

Perhaps most practically, the aggregated data generated by the system has begun to provide evidence-based justification when making the case for repair budgets and equipment replacements, a persistent challenge in simulation operations that has historically relied on anecdotal reporting. As Boppana (2023) notes, automation is not merely a convenience; it is a strategic advancement that allows institutions to work smarter, reduce risk, and deliver a consistently high-quality experiential learning experience.

Ultimately, the system successfully replaced an informal, undocumented reporting culture with a structured, automated workflow that aligns with the objectives established in the Plan phase of the PDSA cycle. The ongoing Study and Act phases continue through periodic review of submission trends, faculty feedback, and incremental refinements to the workflow as the simulation center grows.

DISCUSSION

The BCIT Simulation Operations Team’s implementation of a QR-based workflow automation system using Microsoft SharePoint, Forms, and Power Automate enhanced operational efficiency within our simulation center. We find that the workflow developed in this study moves beyond current literature on digital transformation, AI-supported automation, and healthcare operations by providing a practical real-world application that is tailored to the operation of a simulation center.

Beyond its immediate operational benefits, this project demonstrates a scalable model that can be adopted by simulation centers of varying sizes and resource levels. Because the system is built using widely available Microsoft enterprise tools and a low-code approach, it is both cost-effective and accessible, which makes it particularly attractive for institutions with limited IT support or budgets. With minimal customization, the workflow could be replicated across academic institutions,

healthcare training centers, and hospital-based simulation programs to standardize equipment reporting and maintenance practices.

As automation and artificial intelligence continue to advance, this system provides a strong foundation for future growth. Potential expansions include predictive maintenance, intelligent issue classification, and integrated analytics to inform purchasing decisions, lifecycle planning, and risk mitigation. Ultimately, this project highlights how thoughtful adaptation of digital tools can empower simulation teams, improve learner experiences, and contribute to a safer and more reliable educational environment.

Conflict of interest statement: The authors have no conflicts of interest to declare.

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A Low-Cost 3D-Printed Task Trainer for Pediatric Otic & Nasal Foreign Body Removal

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SUMMARY

Introduction: Nasal and otic foreign bodies are common in pediatric practice, but most trainees have limited procedural experience because of inconsistent patient availability and safety concerns. Commercial task trainers are often expensive or lack pediatric anatomical realism. Low-cost 3D printing offers an accessible alternative; however, there are few published models that address foreign body removal. This activity used a 3D-printed pediatric head to determine whether a low-cost task trainer could improve learner comfort and knowledge with foreign body removal.

Methods: Participants included 28 incoming pediatric interns at a large academic medical center. Learners completed a pre-simulation survey that gauged experience, comfort, and procedural knowledge. Trained pediatric residents facilitated learners through otic and nasal foreign body removal using otoscopes, alligator forceps, hooks, and Katz extractors on a 3D-printed task trainer. After practice, participants completed a post-simulation survey assessing comfort and knowledge. Knowledge improvement was measured using a multiple-choice quiz; comfort was measured using a Likert scale. Paired t-tests were used to determine significance between pre- and post-simulation knowledge scores and comfort.

Results: At baseline, 64% of participants reported no prior exposure to foreign body removal, and 60% indicating they were "not comfortable at all." Knowledge scores improved from 48% pre-simulation to 95% post-simulation ($p < 0.001$). Similarly, comfort improved significantly, with 65% of participants reporting readiness to perform the procedure with minimal assistance ($p < 0.01$).

Conclusion: This low-cost 3D-printed task trainer is an effective method of enhancing learner confidence and procedural knowledge. Its affordability and reproducibility support broad implementation, particularly in resource-limited educational settings.

INTRODUCTION

Foreign body insertion into the ears and nose is a common occurrence in pediatric populations, frequently leading to evaluations, either outpatient or in the emergency department (DiMuzio & Deschler, 2002; Heim & Maughan, 2007). While most foreign bodies can be safely removed in minimally resourced clinical settings, unsuccessful attempts may result in complications such as mucosal injury, bleeding, infection, or aspiration (Schulze et al., 2002). Early and effective management is, therefore, essential. As per the procedures list in the ACGME Entrustable Professional Activities 1: "All pediatricians must be familiar with appropriate simple foreign body removal techniques and instrumentation prior to graduation" (The American Board of Pediatrics, 2021).

Despite the frequency of these cases, many pediatric trainees receive limited hands-on experience with foreign body removal prior to encountering it in clinical practice. Traditional opportunities for procedural education in this area are often inconsistent, dependent on patient

availability, and constrained by patient safety concerns (Barsuk et al., 2012). Simulation-based education offers a valuable alternative by providing trainees with a safe and controlled environment without feeling the constraints of patient fear, parental anxiety, or timing. This encourages learners to explore, reflect, and develop procedural confidence before performing these skills on patients (Okuda et al., 2009).

Although several task trainers for ear and nasal foreign body removal exist, commercially available models are often expensive, lack anatomical accuracy, or do not allow for repeated use (Sawyer et al., 2015). Advances in three-dimensional (3D) printing technology have created opportunities for low-cost, customizable, and reproducible simulation tools that can enhance procedural training in resource-limited environments (Weinstock et al., 2017).

In this study, we describe the design and implementation of a low-cost, 3D-printed pediatric task trainer for otic and nasal foreign body removal. We also evaluate its educational value through pre- and post-simulation assessments of trainee comfort and knowledge. Our goal is to provide an accessible, reproducible model that can be used to improve pediatric procedural education in diverse training settings.

METHODS

Manufacturing of Head

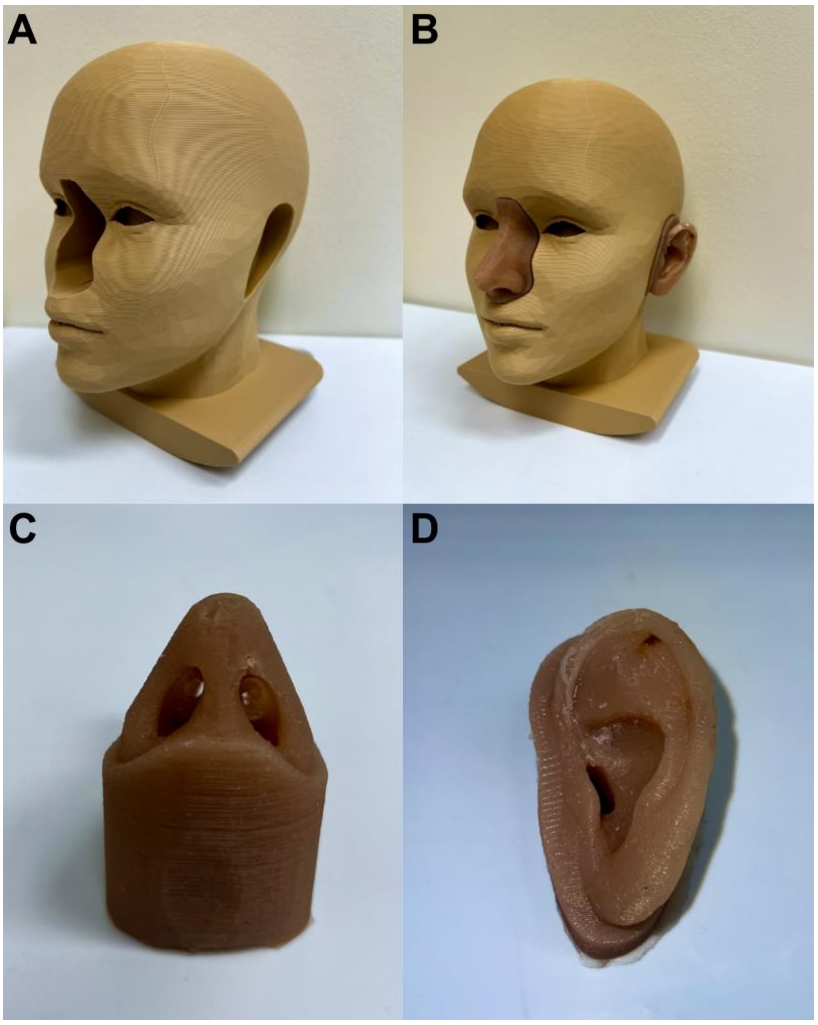
A 3D model of a pediatric head was obtained from an open-access online design database (*Head*, 2015). Fusion 360 design software (v.2605.0.97; Autodesk Fusion, 2025) was then used to modify the design, including sizing the model according to average dimensions of a 5-year-old child, adding a tiltable base, and incorporating removable ear and nose pieces (World Health Organization, n.d.). The base was adjusted to achieve a balance of stability and maneuverability in the horizontal axis based on feedback from users. The ears were designed to simulate a 5-year-old child's ear by incorporating a hole behind the tragus in the shape of an ellipse with a major axis of 10mm, a minor axis of 5mm, and a depth of 15mm (Voss et al., 2025). Similarly, the nose was designed to simulate bilateral nares connecting at the nasopharynx by including two elliptical openings with a major axis of 10mm, a minor axis of 6.5mm, and a total depth of 50mm (*3D-Printed Task Trainer for Pediatric Otic & Nasal Foreign Body Removal*, 2025; Zalzal et al., 2018).

The head and base design (which did not include the ears and nose) was sliced using Bambu Slicer software (v2.0.3; Bambu Studio, 2025). It was printed on a Bambu P1S printer with a 0.6 mm nozzle using light brown matte PLA filament. Standard print settings were used, except for a layer height of 0.38 mm, 3 wall loops, 10% infill, and tree support. The total print time was 15 hours and 30 minutes, and it required 703 grams of PLA filament.

The ears and nose were made using molds formed from 3D-printed negative models of the ears and nose/nostrils. The STL files are available for download (*3D-Printed Task Trainer for Pediatric Otic & Nasal Foreign Body Removal*, 2025). Both the molds and negative models were sprayed with a release agent to prevent adhesion to the mold. Ecoflex 00-30 silicone was measured, pigmented, mixed, and poured into the molds to cover the negative models. After curing for 4 hours, the silicone components were removed from the molds. For the nasal pieces, the 3D-printed nostril inserts remained embedded in the silicone. A small incision was made at the superior anatomical aspect of the nose model to allow removal of the internal negative insert. Excess silicone was carefully trimmed from the model. The ear and nose models snap into the head model without the use of any adhesives (Figure 1).

Figure 1

3D-printed Task Trainer



Note. A. 3D-printed head with tiltable base. B. 3D-printed head with silicone ears and nose in place. C. Stand-alone silicone nose. D. Stand-alone silicone ear.

Task Trainer Facilitation Protocol and Survey Questions

Incoming pediatric interns at the University of Texas Southwestern, a large academic graduate medical program, participated in a multi-station procedural and simulation bootcamp. One station focused on pediatric foreign body removal, using the above task trainer. The simulation was facilitated by trained pediatric residents, chosen by a board-certified pediatrician. Facilitators utilized a standardized script that discussed the prevalence of ear and nose foreign bodies in the pediatric setting, highlighted methods for removal of various types of foreign bodies, including organic, inorganic, and insects, as well as indications for subspecialty consultation (Appendix A).

After a brief explanation of the purpose of the station, participants were asked to complete a pre-simulation survey, which assessed comfort, knowledge, and previous experience with foreign body removal (Appendix B). Participants first practiced the removal of inorganic foreign bodies (beads) from the silicone ears using an otoscope, alligator hook, and forceps. They were then able to complete hands-on practice with the nose model to remove foreign bodies using a Katz extractor. The

procedural facilitator assisted with the simulation, ensured critical actions were performed, and was available to answer questions. The participants were given about five minutes at the station to practice foreign body removal.

After completing the simulation, all participants were given a post-simulation survey (Appendix B) to assess their confidence and knowledge related to foreign body removal. A knowledge-based quiz was developed from the procedure's critical actions and aligned with the stated learning objectives. The content was reviewed and approved by a separate team of procedural experts. The quiz consisted of multiple-choice questions addressing key steps and management strategies for the removal of different types of foreign bodies (bead, popcorn, and insect).

Data Analysis

Survey results were compiled and organized in Microsoft 365 Excel (version 16.0). Paired t-tests were used to compare pre- and post-simulation comfort scores and percentage of correct responses on the knowledge assessment. P-values less than < 0.05 were considered statistically significant.

RESULTS

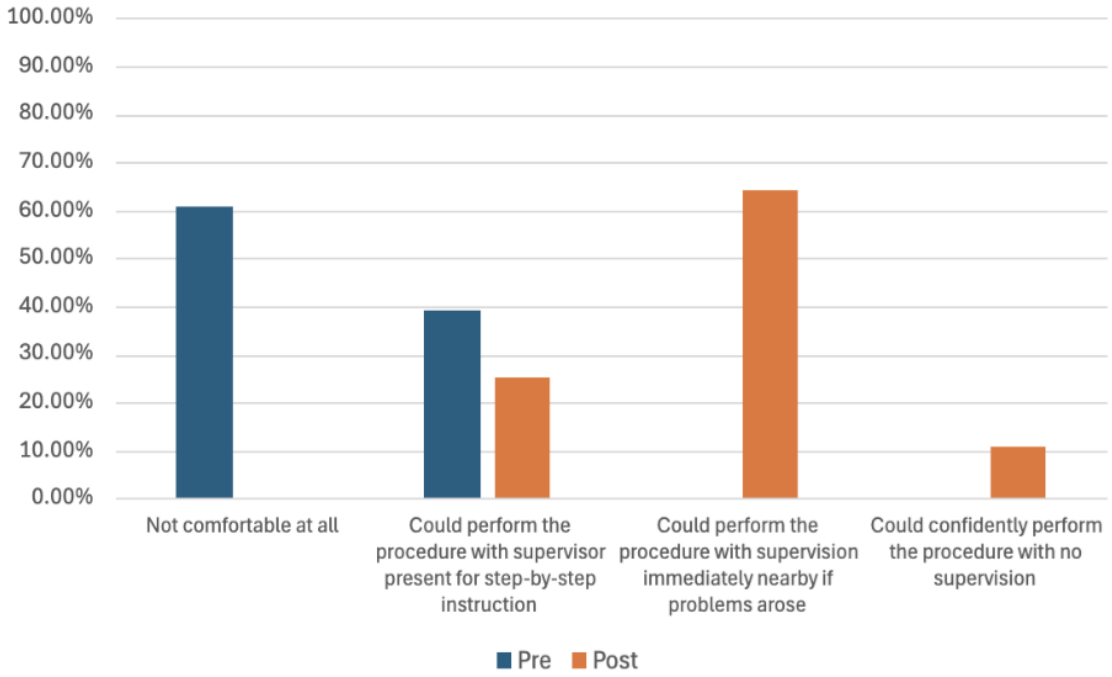
Twenty-eight pediatric interns participated in the foreign body removal using the task trainer and completed both the pre- and post-simulation surveys. The majority of participants (64%) had no previous experience observing or performing foreign body removal, 29% of participants reported observing the procedure, and only 7% of respondents reported any hands-on experience with the procedure (Figure 2).

On the pre-simulation survey, 60% of participants indicated that they were not comfortable at all with foreign body removal and would prefer to watch someone demonstrate the entire procedure for them before attempting it with a real patient. After completing the station, 65% of participants felt they could complete the procedure, as long as help was nearby if problems arose (Figure 2). Similarly, participants felt significantly more comfortable with the procedure when comparing self-reported comfort on the pre-simulation survey ($M = 1.39$, $SD = 0.50$) to the post-simulation survey ($M = 2.86$, $SD = 0.59$, $p < 0.001$). For knowledge, participants scored significantly higher on the post-simulation assessment ($M = 2.86$, $SD = 0.36$, $p < 0.001$) than on the pre-simulation assessment ($M = 1.46$, $SD = 0.64$).

(continued on next page)

Figure 2

Self-reported Comfort Before and After Simulation



Note. Percentage of participants (n = 28) reporting each level of comfort with foreign body removal on pre- and post-simulation surveys. Paired t-test of pre- and post-simulation comfort showed significantly higher self-reported comfort after the simulation ($p < 0.001$).

DISCUSSION

These results suggest that our low-cost, 3D-printed task trainer for otic and nasal foreign body removal is an effective educational tool to improve both trainee comfort and knowledge. Our subjects, a cohort of incoming pediatric interns, had a critically low baseline level of experience, with less than 10% having prior hands-on exposure to foreign body removal. This reinforces existing literature, which highlights inconsistency in traditional, patient-dependent procedural training. After a standardized simulation session, self-reported comfort levels and objective knowledge both improved significantly, with the average knowledge assessment score rising from 48% to over 95%. These results align with the use of simulation-based education in medicine, which creates a safe and repeatable environment necessary to build procedural competence and confidence (Okuda et al., 2009).

A key strength of this task trainer is its use of 3D printing technology to develop an accessible and reproducible model. Commercial simulation models are often very expensive, creating a significant barrier in resource-limited or global health contexts (Weinstock et al., 2017). For example, an ear examination simulator, with a similar design to our 3D printed task trainer, costs over $1,300 (*Ear Examination Simulator*, n.d.).

Multiple iterations of the task trainer were attempted and revised based on user feedback to make the most user-friendly and realistic version possible. The two main adjustments to the initial prototypes were the tiltable base and the material for the ears and nose. The base was initially larger and gave less opportunity to tilt, but this was improved in the current design. Initially, the ears and nose were 3D printed with flexible TPU material, but user feedback indicated that it was not flexible enough. As a result, we switched to silicone casting. We used open-source digital models and inexpensive PLA filament and silicone to create a trainer with a materials cost under $25 using a

commercial 3D printer. The task trainer has also proven to be durable, with no signs of wear on the ears or nose after more than 50 users. When damage does occur, the ears and nose can be replaced for about $3 (Table 1). This approach aligns with the increased use of additive manufacturing in medical education to create customizable for procedural practice (Weinstock et al., 2017). Additionally, the low production cost makes this model feasible for mass distribution and helps address challenges in procedural skill development in underserved areas (Olatunji et al., 2023).

Table 1

Materials and Cost

Part	Material	Cost
3D Printed Head	703g Overture, Light Brown, Matte PLA 3D Printer Filament	$10.12
3D Printed Molds	180g Overture, Light Brown, Matte PLA 3D Printer Filament	$2.59
Silicone Ear x2	130g Ecoflex 00-30 Silicone	$6.05
Silicone Nose x1	70g Ecoflex 00-30 Silicone	$3.26
Silicone pigment	5 Drops Skin Rubber Pigment	$0.05

Limitations

Future research is needed to validate the clinical utility of this model and test participants' ability to apply the skills learned to actual patient care. This study had several limitations, including that it was performed at a single academic center with a small cohort of participants, which may limit the generalizability of our findings. Additionally, participant comfort was self-reported and a subjective assessment. More importantly, this study only accounted for immediate post-simulation of knowledge and comfort, and it did not test knowledge retention over time.

Future Research

Future developments in this space could include designing a comprehensive line of 3D printable, open-source task trainers to support a simulation curriculum in under-resourced areas, making simulation accessible to trainees worldwide. Although our study has laid out the framework for designing, manufacturing, and using 3D printable task trainers, additional, larger-scale and longitudinal studies are needed to make 3D printable simulation models a standard part of medical education.

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Appendix A

Foreign Body Removal Facilitator Guide

Complete Pre-Simulation Survey

General Intro

- Discuss prevalence of procedure: 45,000 ER visits annually for just ear foreign bodies.
- Discuss importance of training: Removal success highest on first attempt

Ear Canal

- Always perform otoscopy first to evaluate the foreign body and the tympanic membrane (What is the object? Is the TM intact?)
- Discuss positioning: sitting or semi-reclined, consider need for restraints (wrap arms / legs), distraction (child life, tablet), sedation needed?
- Irrigation is good first step for small inorganic objects
    - Fill a 30- to 60-mL syringe with sterile water warmed to body temperature.
    - Inject a stream of water into the superior aspect of the external canal behind the foreign object using moderate pressure, with a kidney basin under the ear to catch water.
    - Do NOT use irrigation if:
        - Object is soft or might swell if water added (i.e. bean, popcorn, seed)
        - Object is button battery or magnet, as water may accelerate damage
        - Known or suspected perforation of tympanic membrane for FB in the ear
- Manual instrumentation is good for wide variety of objects such as cotton tips, button batteries, and large beads
    - Insert a right-angle hook or loop and insert the instrument to the edge of the object under direct visualization.
    - Slip the instrument behind the object and gently pull it out of the canal

Nostril

- Katz extractor is often the best first option.
- Insert the extractor past the object. Inflate with 1 mL of air using the attached syringe. Remove the extractor and the foreign body from the canal with balloon inflated.
- Can also attempt positive pressure by keeping opposite nostril occluded and having patient blow forcefully. Not always possible based on age / cooperation level.

Special Considerations (discuss if time permits)

- For living foreign bodies (i.e. insects):
    - Tilt the affected ear upward. Use a dropper to fill the ear canal with warm mineral oil or lidocaine solution. Wait 1-2 minutes to kill the insect and numb the canal.
    - Gently grasp the body, wing, or leg of the insect with alligator forceps and gently pull the entire insect out of the ear.
- Consult ENT for:
    - Posterior nasal foreign bodies (cannot see from looking into nares anteriorly)
    - Impacted foreign bodies with marked inflammation or penetrating FB
    - Evidence of vestibular symptoms (nausea, vomiting, nystagmus, vertigo, or ataxia)

Appendix B

Foreign Body Removal Learning Objectives

By the end of this session, learners will be able to:

1. Identify appropriate tools (e.g., suction, forceps, hooks) based on foreign body type and location (ear canal vs. nostril)
2. Practice safe foreign body extraction with minimal damage in a simulated environment
3. Adapt techniques for common scenarios: organic materials (e.g., food) vs. inorganic objects (e.g., beads, batteries) vs. living specimens (e.g., insects)
4. Demonstrate knowledge and perceived comfort level via post-simulation surveys

Foreign Body Removal Pre-Simulation Survey

1) Have you previously observed or performed a foreign body removal?
    a. Yes, observed only
    b. Yes, performed with supervision
    c. Yes, performed independently
    d. No experience

2) How comfortable do you feel removing any foreign body from a pediatric patient's ear or nose?
    a. Not comfortable at all, I would prefer to watch someone demonstrate the entire procedure for me.
    b. I could perform the procedure if a supervisor were present to give hands-on, step-by-step instruction.
    c. I could perform the procedure with supervision immediately nearby (i.e. available outside the room or down the hallway) if problems arose.
    d. I could confidently perform the procedure independently with no supervision.

3) Which of the following is the most appropriate method to remove a firm, inorganic foreign body (e.g. a plastic bead) from a child's ear?
    a. Use water irrigation, a Katz extractor, or a right-angle hook, based on the object's characteristics.
    b. Instill mineral oil and wait for the object to soften or dissolve.
    c. Instruct the patient to blow their nose while occluding the opposite nostril.
    d. Insert a balloon syringe-catheter (Katz extractor) without visualizing the full extent of the object.

4) How would you remove an organic foreign body (i.e. a piece of popcorn) from a nostril?
    a. Use a Katz extractor or a right-angle hook, based on the object's characteristics.
    b. Use water irrigation with a syringe and sterile saline to flush the object out of the nostril.
    c. Apply tissue adhesive to a cotton swab and stick it to the object before slowly removing it.
    d. Instill mineral oil and wait for the object to soften or dissolve before attempting removal.

5) What would be your first step in removing a living foreign body (i.e. a bug) from an ear?
    a. Instill mineral oil into the ear canal before removal to immobilize the insect.
    b. Immediately attempt to remove with forceps to ensure quickest removal of the insect.
    c. Use water irrigation to flush the insect out of the ear canal.
    d. Ask the patient to blow their nose forcefully while occluding the opposite nostril.

Foreign Body Removal Post-Simulation Survey

1) After participating in the foreign body removal procedural station, how comfortable do you feel removing a foreign body from a pediatric patient's ear or nose?
    a. Not comfortable at all, I would prefer to watch someone demonstrate the entire procedure for me.
    b. I could perform the procedure if a supervisor were present to give hands-on, step-by-step instruction.
    c. I could perform the procedure with supervision immediately nearby (i.e. available outside the room or down the hallway) if problems arose.
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    c. Use water irrigation to flush the insect out of the ear canal.
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5) What feedback do you have for this task-trainer and/or procedure station?

Revolutionizing New Hire Education in Critical Care: The Power and Cost-Savings of Multimodal Simulation

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SUMMARY

The transition to critical care practice requires structured education to support clinical readiness among new graduate nurses. To standardize orientation across multiple Intensive Care Units (ICUs) and strengthen nurse competence, we developed and evaluated a multimodal, simulation-based ICU Core Curriculum utilizing scaffolded learning, didactic instruction, task training, and scenario-based simulation to promote critical thinking, skill acquisition, and interprofessional collaboration. The curriculum demonstrated an improvement in learner engagement, confidence, and knowledge in high-risk domains such as respiratory management and Code Blue response, while supporting adoption of evidence-based practices. Ongoing refinement through Plan-Do-Study-Act cycles and learner feedback, combined with consolidating orientation across multiple units and strategic use of simulation resources, resulted in significant cost savings, and demonstrated the value of a simulation-centered onboarding model.

BACKGROUND

Intensive Care Units (ICUs) are high-acuity environments requiring rapid clinical decision-making, advanced technical proficiency, and effective interprofessional collaboration. The evolving landscape of ICU nursing, shaped by increasingly complex patients, rapid technological advancement, and persistent staffing challenges, has amplified the urgency for effective onboarding strategies (American Association of Critical-Care Nurses, 2022). The ongoing shortage of experienced ICU nurses, compounded by retirement and turnover, has led to an experience-complexity gap, in which there is a disconnect between ICU patient acuity and readiness of novice nurses to safely manage their care. This places significant pressure on nurse educators and preceptors to bridge this gap and ensure safe, high-quality care. There is substantial financial pressure on healthcare organizations to onboard and retain critical care nurses. Estimates suggest the cost of onboarding a new graduate nurse can exceed $100,000 (Jones, 2021). More recent workforce analyses estimate the average cost of nurse turnover to be approximately $60,090 per nurse, with national nursing turnover rates averaging 17.6%, and turnover rates in ICU settings are reported to be even higher, averaging approximately 27% (Gamble, 2026).

In this context, simulation-based education emerges as a strategic solution to address the experience-complexity gap. Simulation training can significantly enhance learning and confidence for novice nurses transitioning into high-risk clinical settings (Rutherford-Hemming et al., 2022). A multimodal approach integrating instructional methods such as high-fidelity manikins, virtual reality, case-based discussions, and interprofessional team training can enhance learner engagement, promote critical thinking, and better prepare students for the complexities of clinical practice (Schwengel et al., 2025).

Our large Midwestern freestanding pediatric hospital has 72 ICU beds across three pediatric ICU's: trauma, respiratory, cardiothoracic. Historically, each unit maintained separate orientation programs, resulting in inconsistent onboarding and inefficient resource utilization. To standardize competency development and orientation for newly hired nurses, ICU nurse educators collaborated with the hospital's Simulation Center to develop and implement the ICU Core Curriculum, a multimodal, simulation-based program designed to provide consistent, evidence-based training across all ICU settings.

ICU Core Curriculum Development

The ICU Core Curriculum is a comprehensive approach to new-hire orientation in the ICU. A primary driver was the need to equip nurses with the requisite skills to deliver safe, coordinated, high-quality care regardless of unit assignment. To address knowledge and performance gaps identified by ICU nurse educators, existing orientation lectures were supplemented with hands-on learning experiences, developed in collaboration with an interprofessional simulation team. The collaboration focused on enhancing learning strategies, improving educational delivery, and standardizing the onboarding process across units.

Our Simulation Center, accredited by the Society of Simulation in Healthcare (SSH), features diverse simulation modalities and immersive learning environments designed to replicate clinical practice. Simulation best practices are applied in curriculum design by Certified Healthcare Simulation Educators (CHSE), ensuring that scenarios align with international standards (International Nursing Association for Clinical Simulation and Learning [INACSL], 2021a). Learners participate in small groups (≤ 7 per session) to maximize engagement, with each experience structured to include a formal prebrief, realistic simulation encounter, and debrief (INACSL, 2021a). Facilitators are trained in evidence-based debriefing methods and utilize Debriefing Assessment for Simulation in Healthcare scoring to promote reflection and skill integration (Al-Khayat et al., 2024).

We applied scaffold learning theory (INASCL, 2021a) to develop a week-long, progressive, multi-modal educational approach. Nurses attend the ICU Core Curriculum between weeks 10 and 12 of their 20-week orientation. Each day of the curriculum focuses on a specific area of patient care, such as respiratory or cardiovascular (Palmer et al., 2025). The morning didactic session includes interactive presentations with embedded polls and videos, open discussion using the Socratic method of teaching, and educational games. The afternoon session uses various simulation modalities to complement the didactic content. Examples include task training procedures, demonstrations with open discussion and return demonstration, scenario walkthroughs, low- and high-fidelity simulation cases, and escape rooms.

Based on the cognitive load associated with a week-long curriculum, careful consideration was placed on maintaining variety and balancing difficulty level to maintain learner engagement and transfer working memory to long-term memory. Additionally, the principles of Bloom's Taxonomy (1956) were used to ensure learners were progressing in their level of learning from remembering to understanding, applying, and analyzing new knowledge (INASCL, 2021b). Careful consideration was given to a newer generation of adult learners who have unique educational learning needs and respond better to experiential learning (Masso et al., 2022). The ICU Core Curriculum agenda is provided below (Figure 1).

Figure 1

Curriculum Agenda

Monday: Respiratory	Tuesday: Respiratory/Neurologic	Wednesday: Cardiovascular	Thursday: Shock & Kidney	Friday : Integration Day
❖ **Comfort level in key ICU domains survey & knowledge check test** - Respiratory mindfulness - Upper airway & assessment - Lower airway & asthma - Rescue breathing task training: Infant, child, & adult torsos. - Intubation path: RN perspective - Mechanical ventilation	- Neuro assessment, seizure, head bleed, stroke - Advanced illness management team - Wound team	- Cardiac rhythms - Congenital heart disease - Hemodynamic monitoring/arterial blood gases - Gastrointestinal & necrotizing enterocolitis - Peripheral intravenous lines & extravasations	- Diabetic ketoacidosis - Shock - Pain team - Acute kidney injury & dialysis - Lifeline of Ohio organ procurement	- Cardiopulmonary resuscitation feedback & bagging - Interactive crash cart - Pediatric cardiac arrest
Lunch: 30 mins	Lunch: 30 mins	Lunch: 30 mins	Lunch: 30 mins	Lunch: During downtime
Simulation + Skills: Task trainers, airway heads, low-fidelity 45-minute Stations: - Unit ventilator tour/other vents scavenger hunt - Oscillator, inhaled nitric oxide, manual breath bagging - Noninvasive ventilation - Tracheostomies, masks, aerosols, skin padding ❖ Daily post simulation survey	**Simulations + Skills**: Task trainers, high fidelity & low fidelity 60-Minute Stations: - External ventricular drain scenario, sedation meds - Wound vacs, proning, code meds - Respiratory distress simulation - DOPE (Airway: dislodgement, obstruction, pneumothorax, equipment) simulation ❖ Daily post simulation survey	**Simulations + Skills**: Part task trainers, high fidelity, & low fidelity 45-Minute Stations: - Chest tubes, intra-abdominal pressure, & nasogastric tube simulation - Cardiopulmonary resuscitation feedback & rhythm simulation - Arterial line & Central venous pressure line set up - Peripheral intravenous line insert/assessment ❖ Daily post simulation survey	**Simulation + Skills**: task trainers, low-fidelity 60-Minute Stations: - Shock escape room - Insulin pens, temp management - Push-pull set up & rapid infuser ❖ Daily post simulation survey	**Simulations + Skills**: Part task trainers, low fidelity, high fidelity, & standardized participants 60-Minute Stations: - Skills check off escape room 1 - Skills check off escape room 2, knowledge review game - Code blue simulation - Difficult communication end of life simulation ❖ Daily post simulation survey ❖ **End of program comfort level in key ICU domains survey & knowledge check test.**

The agenda is one example of how the team incorporates Bloom's Taxonomy (1956) and scaffolding learning in the objectives, simulation design, and strategic use of multimodal simulation (INASCL, 2021b). Day one is focused on respiratory education and exposure to various modes of simulation. Respiratory lectures define and describe assessments, blood gases, and mechanical support in preparation for the afternoon application stations and interactive ventilator escape room. In these breakouts, novice learners build on their understanding with faculty-supported hands-on application of devices, such as bilevel positive airway pressure (BiPAP), including setup, skin protection procedures, blood gas analysis, and device setting management. Airway heads and low-fidelity manikins are utilized to accomplish these learning objectives. The next afternoon, learners apply their respiratory knowledge during a respiratory distress simulation with a high-fidelity simulator. During the simulation, learners interpret blood gases and advocate escalating care, transitioning from nasal cannula to BiPAP. Each day of the curriculum follows this general simulation design.

The final training day is called Integration Day. It allows learners to synthesize the skills and knowledge refined throughout the week. Participants demonstrate their learning by rotating through several stations, including a knowledge check escape room, which encompasses the performance of skills practiced during the week.

PROGRAM EVALUATION

We assessed the program's effectiveness using surveys, tests, and cost analysis. Participant comfort in key ICU domains was assessed with a survey organized by body system (respiratory, cardiovascular, neurologic, hemodynamics) consistent with nursing professional development frameworks used in pediatric ICU onboarding (Palmer et al., 2025). Knowledge was assessed by an 11-item pre- and post-program test. Daily feedback was gathered utilizing the Simulation Center's five-point Likert Scale and open-text simulation program survey to gauge skill improvement, likelihood of changing practice, and to provide feedback on the facilitator. Survey and test data were analyzed with descriptive statistics. Pre- and post-program data were compared using Mann-Whitney's test for the comfort scores and Fisher's exact test for knowledge scores. The cost analysis was conducted

through a retrospective review of training logistics and resource allocation prior to and following implementation of the ICU Core Curriculum.

The current ICU Core Curriculum is the result of continual improvements through Plan-Do-Study-Act (Zann, 2021) cycles of seven cohorts from 2023-2025. Changes were implemented based on participant program evaluation tests and surveys, faculty observations, and monthly standing educator meetings. Following the weekly implementation of the curriculum, the instructional team engaged in structured debriefing sessions. To critically examine the week's teaching and learning experiences, these reflective meetings occurred promptly, while observations, student interactions, instructional outcomes, and survey results were still fresh in memory.

This process supported iterative improvements to both curriculum content and educational strategies, aligning with best practices in responsive and reflective teaching (Zann, 2021). Examples of iterative changes included adjusting the pacing and sequencing of respiratory content, increasing hands-on breakout time, refining simulation complexity, and standardizing facilitator prebriefing approaches. These modifications contributed to consistently high learner engagement, psychological safety, and perceived clinical preparedness across cohorts.

RESULTS

Between September 2023 and January 2025, 106 new-hire nurses participated in the ICU Core Curriculum.

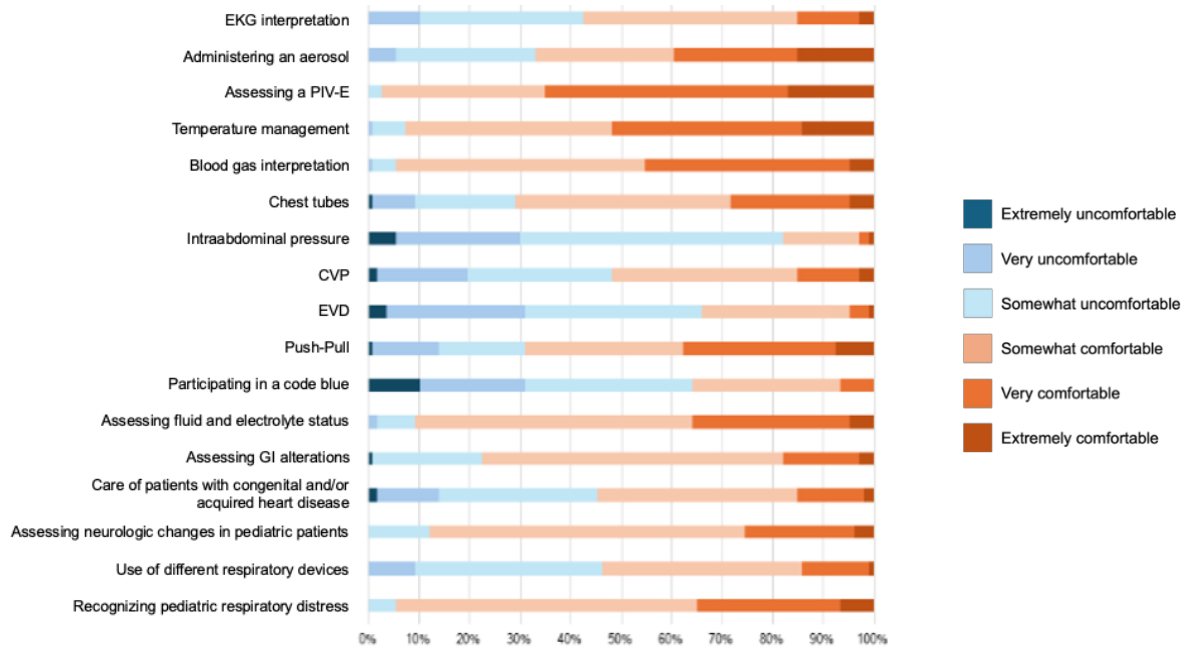
Participant Comfort and Knowledge

Pre- and post-program surveys assessing comfort (Figure 2) and knowledge (Figure 3) were completed by 106 and 105 participants, respectively. Comfort levels improved in all items (Figure 2), with more participants rating themselves as "very comfortable" or "extremely comfortable". The items that had the largest increases in comfort levels included "recognizing pediatric respiratory distress," rising from 35% to 79% ($p<0.001$), and "participating in a Code Blue," which increased from 7% to 50% ($p<0.001$). Participant knowledge increased in 9 of the 11 knowledge areas (Figure 3). The largest improvements were noted in "recognition of appropriate respiratory support" (31% vs. 55%, $p=0.001$), "Code Blue medications" (58% vs. 100%, $p<0.001$), and "cardiac rhythm (EKG) interpretation" (68% vs. 91%, $p<0.001$). Despite these improvements, fewer than half of the participants correctly answered questions related to necrotizing enterocolitis and pulmonary hypertension crisis in the post-program test.

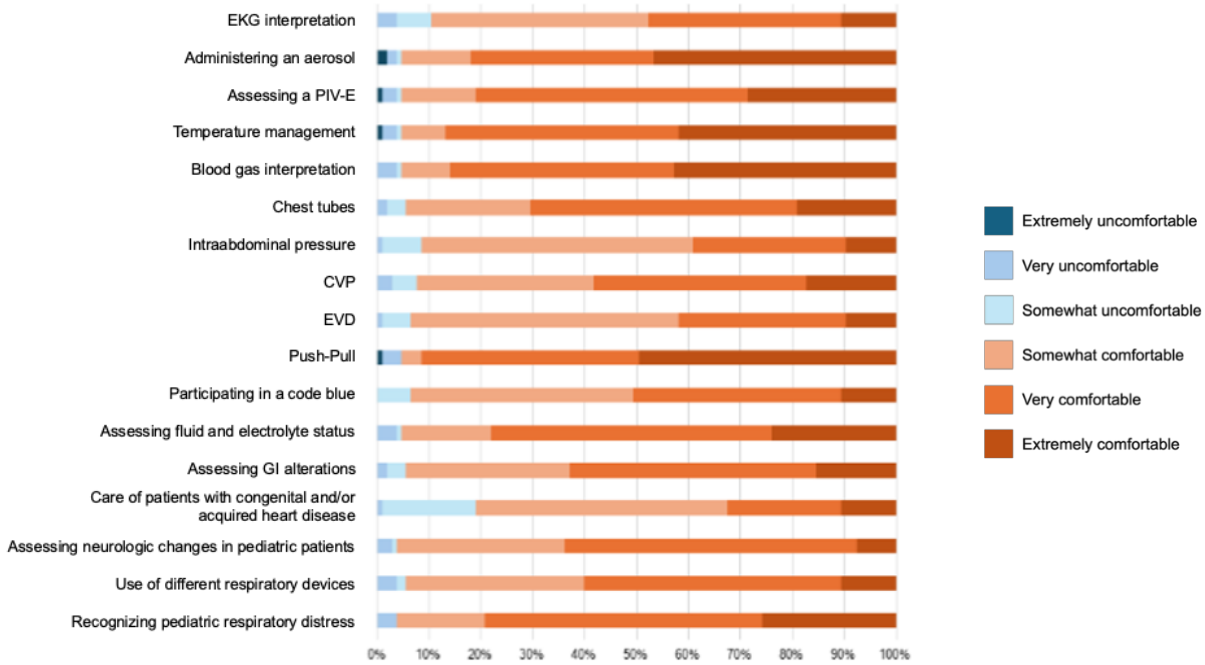
(continued on next page)

Figure 2

A. Pre-Program Perceived Comfort (n = 106)



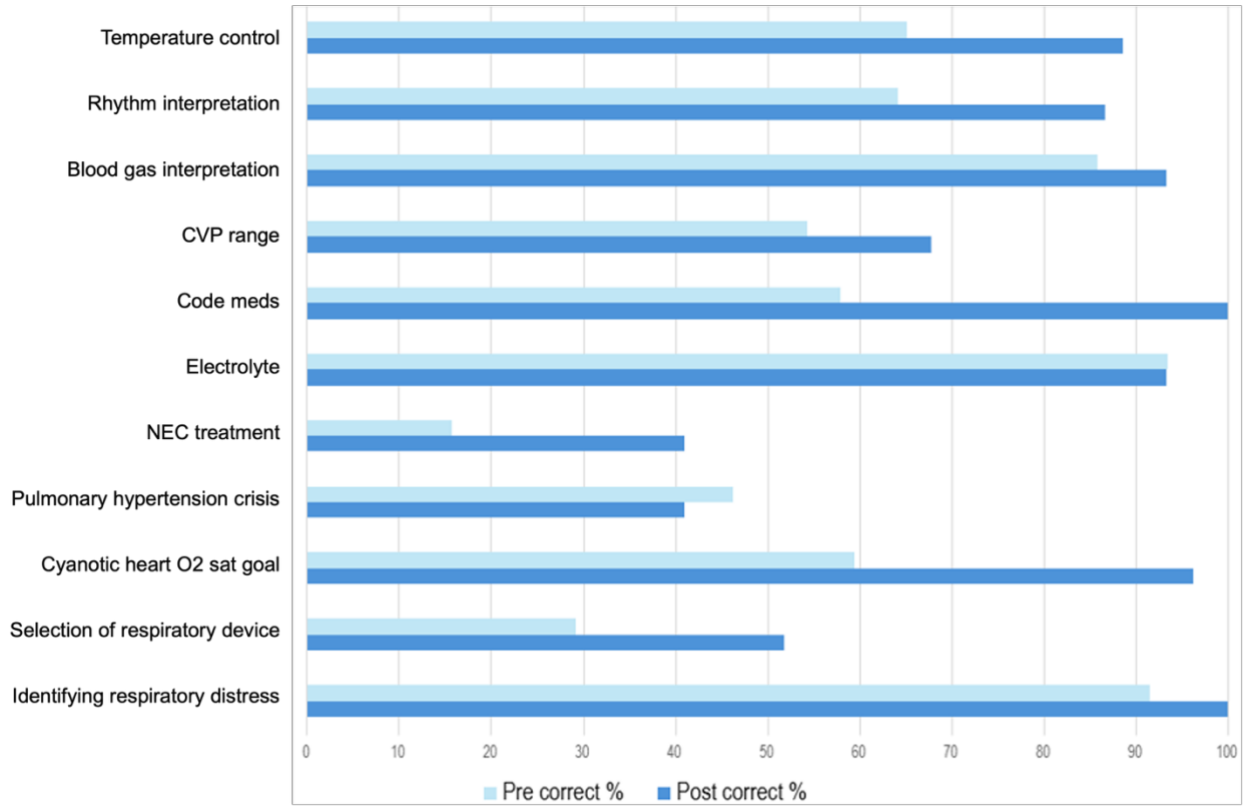
B. Post-Program Perceived Comfort (n = 105)



Note. PIV-E: peripheral IV extravasation event; CVP: central venous pressure; EVD: external ventricular drain.

Figure 3

Percent Correct on Knowledge Assessment Pre- and Post-Program (n = 106)



Note. For normal CVP range, code meds, NEC treatment, n = 56 due to question item changes from April 2024. CVP: central venous pressure; NEC: necrotizing enterocolitis.

Participant Simulation Feedback

Nurses rated the sessions as highly effective in meeting learning objectives (mean rating 4.8 out of 5, SD=0.5), improving teamwork and communication (4.8, 0.5), and enhancing clinical skills (4.7, 0.5). Participants overwhelmingly felt the simulations provided a psychologically safe learning environment (4.8, 0.4) and that the facilitator enhanced learning (4.8, 0.4). The debriefing was perceived as extremely valuable (4.8, 0.5). Notably, nurses reported a strong likelihood of changing their clinical practice because of the simulations (4.7, 0.5). Survey comments highlighted strong appreciation for the comprehensive and practical nature of simulation exercises (Figure 4).

Figure 4

Example Participant Feedback

"This is just my overall thoughts of the week. I have done a ridiculous amount of orientation classes, and this is my fourth ICU core class that I have completed. Out of all of them, and all of the hospitals, this has been by far one of the most robust and easy to digest learning experiences that I have ever been a part of. I feel like it really rounded out all of my corners and has made me a much better nurse." - Participant A

"This was a really important sim to have, and I really appreciated having this opportunity. Thank you! I don't think I would change anything—just keep doing this please!" - Participant B

"This was super helpful to have the space to put it all together after the learnings this week. Prior to this week, I felt super uncomfortable about what my role would be in a code situation and now I feel like I have a better grasp of where I could jump in or at least how to start while waiting for more help." - Participant C

"All of this has been relevant, useful, and easily digestible so far!" - Participant D

Cost Analysis

Implementing a structured ICU Core Curriculum training program offers significant cost-saving opportunities by improving resource utilization and reducing inefficiencies. If each of our ICUs conducted its own training separately, the cost is estimated to be $219,300 annually across the three units. In contrast, a combined approach with the ICU Core Curriculum has fewer sessions per year, leading to an estimated annual cost of $177,375. This resulted in total estimated savings of $41,925 per year of ICU Core Curriculum implementation.

Table 1

Cost Analysis

Budget item	Annual cost of unit-specific ICU orientation (estimated)	Annual cost of ICU Core Curriculum (2023)
Sessions per year	9	3
Hours of planning and facilitation per session	50	25
Hours of education per session	40	40
Educators per session	2	5
Educator hourly rate with fringe benefits	65	65
Educator cost	**$105,300**	**$63,375**
Learners per year	57	57
Learners hourly rate with fringe benefits	50	50
Learner cost	**$114,000**	**$114,000**
Estimated annual cost	**$219,300**	**$177,375**
Estimated cost savings		**$41,925**

Note. Educator cost = no. of sessions × (planning + education hrs.) × no. of educators × hourly rate. Learner cost = education hrs. × hourly rate × no. of learners. Estimated annual cost = educator cost + learner cost.

DISCUSSION

The implementation of the ICU Core Curriculum has shown early promise in addressing the experience-complexity gap and improving the transition of new ICU nurses into high-acuity clinical environments. Through standardization, simulation-based learning, and alignment with evidence-based educational frameworks, this program increased learner comfort and promoted consistent

clinical expectations across ICUs. The observed improvements align with existing literature emphasizing simulation's effectiveness for novice nurses transitioning into practice (Rutherford-Hemming et al., 2022; Campbell et al., 2022). Our results are similar to those of quasi-experimental ICU simulation studies showing improvement in patient safety knowledge and communication among new ICU nurses (Jung et al., 2023). These results also align with pediatric ICU work demonstrating improved knowledge, teamwork, and confidence via deliberate practice (Karageorge et al., 2020). The ICU Core Curriculum extends this by delivering a weeklong, CHSE/DASH-evaluated onboarding across three PICUs.

Survey and test results demonstrate that the ICU Core Curriculum effectively increased both participants' comfort and knowledge in managing multiple critical care scenarios. The greatest improvements in participant comfort were seen in using push-pull for fluid administration, Code Blue participation, knowledge of Code Blue medications, and oxygen saturation goal for children with cyanotic congenital heart disease. Persistent discomfort caring for patients with congenital or acquired heart disease, together with low knowledge-assessment scores on the treatment of necrotizing enterocolitis and pulmonary hypertension crisis, highlights areas for future curriculum improvement.

By streamlining educator hours, leveraging shared simulation resources, and consolidating sessions, we estimate that the ICU Core Curriculum is saving our organization more than $40,000 per year. This estimate does not account for the long-term operational savings that could result from strengthening internal training capabilities and reducing reliance on external education resources, such as vendor-led courses, outsourced simulation programs, and third-party continuing education providers. By leveraging the Simulation Center's resources and expertise, the ICU Core Curriculum ensures consistent, high-quality learning experiences.

Integrating simulation into early clinical training not only fosters knowledge acquisition and enhances clinical confidence but also reduces preceptor workload and promotes a uniform standard of care across the institution's ICUs. This partnership highlights the Simulation Center's vital role in advancing clinical education, patient safety, and professional development throughout the organization. Looking ahead, our priorities include long-term follow-up to evaluate knowledge retention and sustained practice change, introducing behavior-based competency checks, and exploring associations with nurse retention and patient outcomes.

Operational Considerations

A key contributor to the success and sustainability of the ICU Core Curriculum was the collaborative partnership between the institutions' ICU nursing educators and the SSH-accredited Simulation Center. ICU educators led the development, implementation, and ongoing refinement of the curriculum, including educational content design, learner coordination, supply standardization, scheduling workflows, and continuous quality improvement efforts. Simulation educators and CHSOS-certified simulation technicians supported the curriculum through consultation on simulation design, management of simulation equipment and environments, audiovisual support, and facilitation of simulation-based learning experiences. During the initial implementation phase, the curriculum required substantial collaboration and operational support from both educator and simulation teams to establish workflows, develop simulation experiences, and standardize delivery across ICUs. As the program matured, many operational processes became more streamlined and sustainable, allowing simulation involvement to transition to a more focused support and consultation role while ICU educators continued to lead ongoing curricular refinement and routine operational management.

Centralizing portions of the curriculum within the Simulation Center created operational efficiencies by leveraging existing simulation infrastructure, reusable cases, task trainers, and high-fidelity simulation resources while promoting consistency across ICU orientation experiences. The integration of multiple simulation modalities, including task trainers, escape rooms, standardized patients, and high-fidelity simulation, allowed the team to align educational objectives with available institutional resources in a cost-effective manner (Boling & Hardin-Pierce, 2016). This evolution in

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Curriculum Agenda

Monday: Respiratory	Tuesday: Respiratory/Neurologic	Wednesday: Cardiovascular	Thursday: Shock & Kidney	Friday : Integration Day
❖ **Comfort level in key ICU domains survey & knowledge check test** - Respiratory mindfulness - Upper airway & assessment - Lower airway & asthma - Rescue breathing task training: Infant, child, & adult torsos. - Intubation path: RN perspective - Mechanical ventilation	- Neuro assessment, seizure, head bleed, stroke - Advanced illness management team - Wound team	- Cardiac rhythms - Congenital heart disease - Hemodynamic monitoring/arterial blood gases - Gastrointestinal & necrotizing enterocolitis - Peripheral intravenous lines & extravasations	- Diabetic ketoacidosis - Shock - Pain team - Acute kidney injury & dialysis - Lifeline of Ohio organ procurement	- Cardiopulmonary resuscitation feedback & bagging - Interactive crash cart - Pediatric cardiac arrest
Lunch: 30 mins	Lunch: 30 mins	Lunch: 30 mins	Lunch: 30 mins	Lunch: During downtime
Simulation + Skills: Task trainers, airway heads, low-fidelity 45-minute Stations: - Unit ventilator tour/other vents scavenger hunt - Oscillator, inhaled nitric oxide, manual breath bagging - Noninvasive ventilation - Tracheostomies, masks, aerosols, skin padding ❖ Daily post simulation survey	**Simulations + Skills**: Task trainers, high fidelity & low fidelity 60-Minute Stations: - External ventricular drain scenario, sedation meds - Wound vacs, proning, code meds - Respiratory distress simulation - DOPE (Airway: dislodgement, obstruction, pneumothorax, equipment) simulation ❖ Daily post simulation survey	**Simulations + Skills**: Part task trainers, high fidelity, & low fidelity 45-Minute Stations: - Chest tubes, intra-abdominal pressure, & nasogastric tube simulation - Cardiopulmonary resuscitation feedback & rhythm simulation - Arterial line & Central venous pressure line set up - Peripheral intravenous line insert/assessment ❖ Daily post simulation survey	**Simulation + Skills**: task trainers, low-fidelity 60-Minute Stations: - Shock escape room - Insulin pens, temp management - Push-pull set up & rapid infuser ❖ Daily post simulation survey	**Simulations + Skills**: Part task trainers, low fidelity, high fidelity, & standardized participants 60-Minute Stations: - Skills check off escape room 1 - Skills check off escape room 2, knowledge review game - Code blue simulation - Difficult communication end of life simulation ❖ Daily post simulation survey ❖ **End of program comfort level in key ICU domains survey & knowledge check test.**

The agenda is one example of how the team incorporates Bloom's Taxonomy (1956) and scaffolding learning in the objectives, simulation design, and strategic use of multimodal simulation (INASCL, 2021b). Day one is focused on respiratory education and exposure to various modes of simulation. Respiratory lectures define and describe assessments, blood gases, and mechanical support in preparation for the afternoon application stations and interactive ventilator escape room. In these breakouts, novice learners build on their understanding with faculty-supported hands-on application of devices, such as bilevel positive airway pressure (BiPAP), including setup, skin protection procedures, blood gas analysis, and device setting management. Airway heads and low-fidelity manikins are utilized to accomplish these learning objectives. The next afternoon, learners apply their respiratory knowledge during a respiratory distress simulation with a high-fidelity simulator. During the simulation, learners interpret blood gases and advocate escalating care, transitioning from nasal cannula to BiPAP. Each day of the curriculum follows this general simulation design.

The final training day is called Integration Day. It allows learners to synthesize the skills and knowledge refined throughout the week. Participants demonstrate their learning by rotating through several stations, including a knowledge check escape room, which encompasses the performance of skills practiced during the week.

PROGRAM EVALUATION

We assessed the program's effectiveness using surveys, tests, and cost analysis. Participant comfort in key ICU domains was assessed with a survey organized by body system (respiratory, cardiovascular, neurologic, hemodynamics) consistent with nursing professional development frameworks used in pediatric ICU onboarding (Palmer et al., 2025). Knowledge was assessed by an 11-item pre- and post-program test. Daily feedback was gathered utilizing the Simulation Center's five-point Likert Scale and open-text simulation program survey to gauge skill improvement, likelihood

of changing practice, and to provide feedback on the facilitator. Survey and test data were analyzed with descriptive statistics. Pre- and post-program data were compared using Mann-Whitney's test for the comfort scores and Fisher's exact test for knowledge scores. The cost analysis was conducted through a retrospective review of training logistics and resource allocation prior to and following implementation of the ICU Core Curriculum.

The current ICU Core Curriculum is the result of continual improvements through Plan-Do-Study-Act (Zann, 2021) cycles of seven cohorts from 2023-2025. Changes were implemented based on participant program evaluation tests and surveys, faculty observations, and monthly standing educator meetings. Following the weekly implementation of the curriculum, the instructional team engaged in structured debriefing sessions. To critically examine the week's teaching and learning experiences, these reflective meetings occurred promptly, while observations, student interactions, instructional outcomes, and survey results were still fresh in memory.

This process supported iterative improvements to both curriculum content and educational strategies, aligning with best practices in responsive and reflective teaching (Zann, 2021). Examples of iterative changes included adjusting the pacing and sequencing of respiratory content, increasing hands-on breakout time, refining simulation complexity, and standardizing facilitator prebriefing approaches. These modifications contributed to consistently high learner engagement, psychological safety, and perceived clinical preparedness across cohorts.

RESULTS

Between September 2023 and January 2025, 106 new-hire nurses participated in the ICU Core Curriculum.

Participant Comfort and Knowledge

Pre- and post-program surveys assessing comfort (Figure 2) and knowledge (Figure 3) were completed by 106 and 105 participants, respectively. Comfort levels improved in all items (Figure 2), with more participants rating themselves as "very comfortable" or "extremely comfortable". The items that had the largest increases in comfort levels included "recognizing pediatric respiratory distress," rising from 35% to 79% ($p<0.001$), and "participating in a Code Blue," which increased from 7% to 50% ($p<0.001$). Participant knowledge increased in 9 of the 11 knowledge areas (Figure 3). The largest improvements were noted in "recognition of appropriate respiratory support" (31% vs. 55%, $p=0.001$), "Code Blue medications" (58% vs. 100%, $p<0.001$), and "cardiac rhythm (EKG) interpretation" (68% vs. 91%, $p<0.001$). Despite these improvements, fewer than half of the participants correctly answered questions related to necrotizing enterocolitis and pulmonary hypertension crisis in the post-program test.

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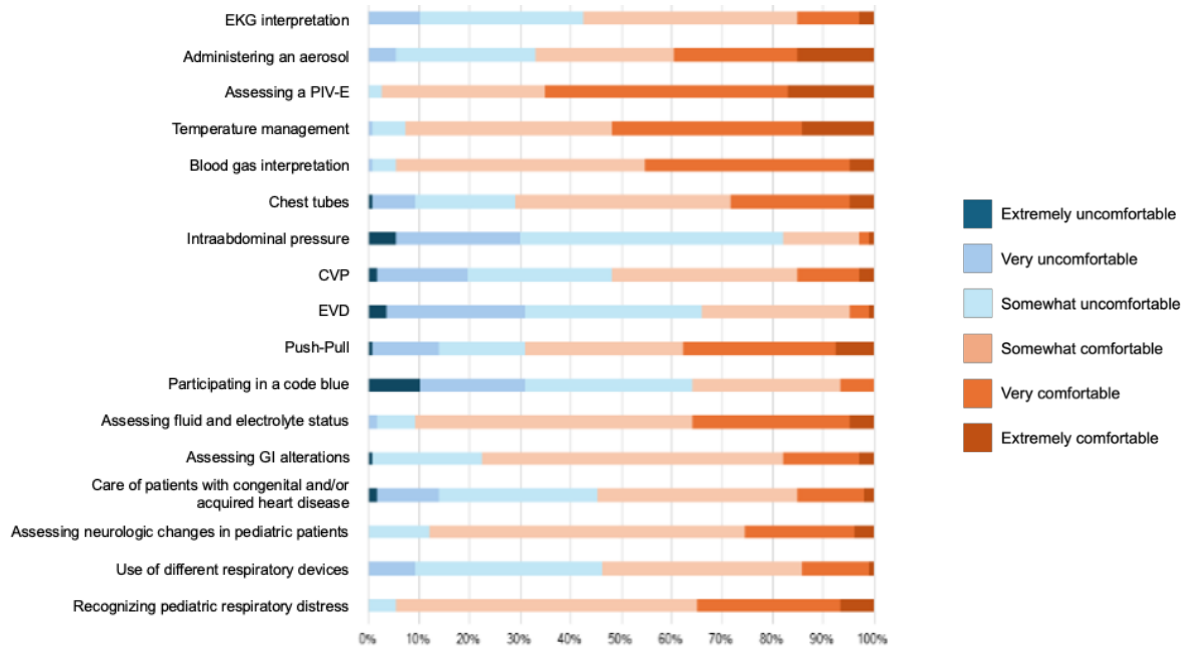
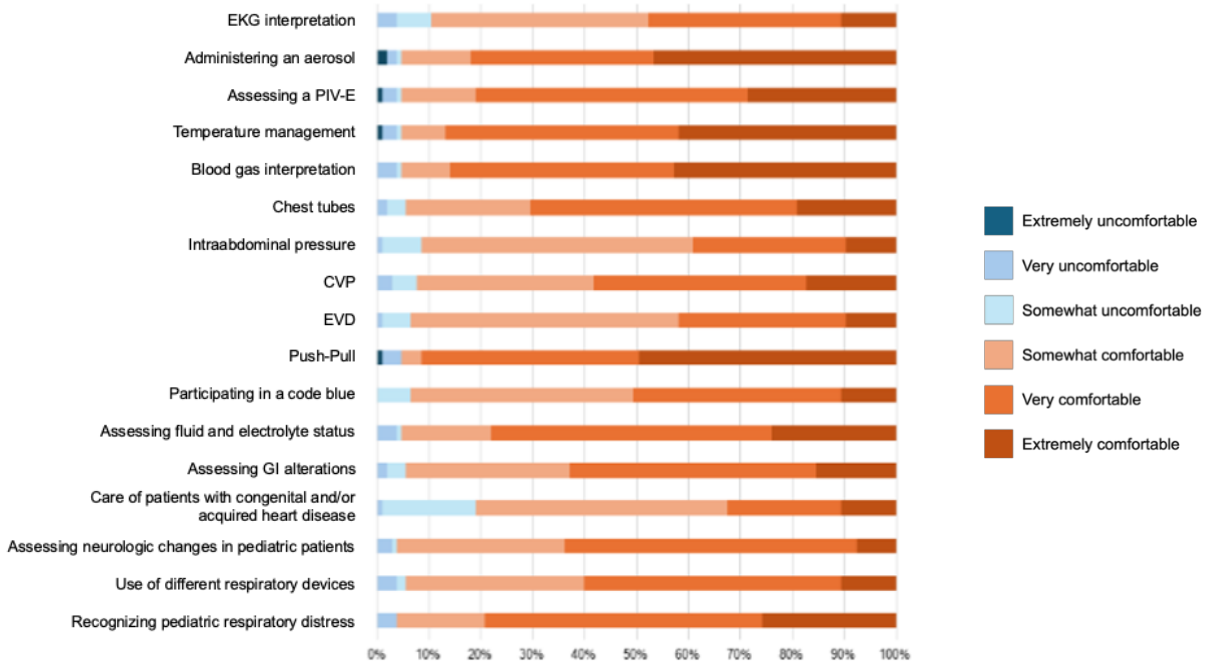
Figure 2

A. Pre-Program Perceived Comfort (n = 106)



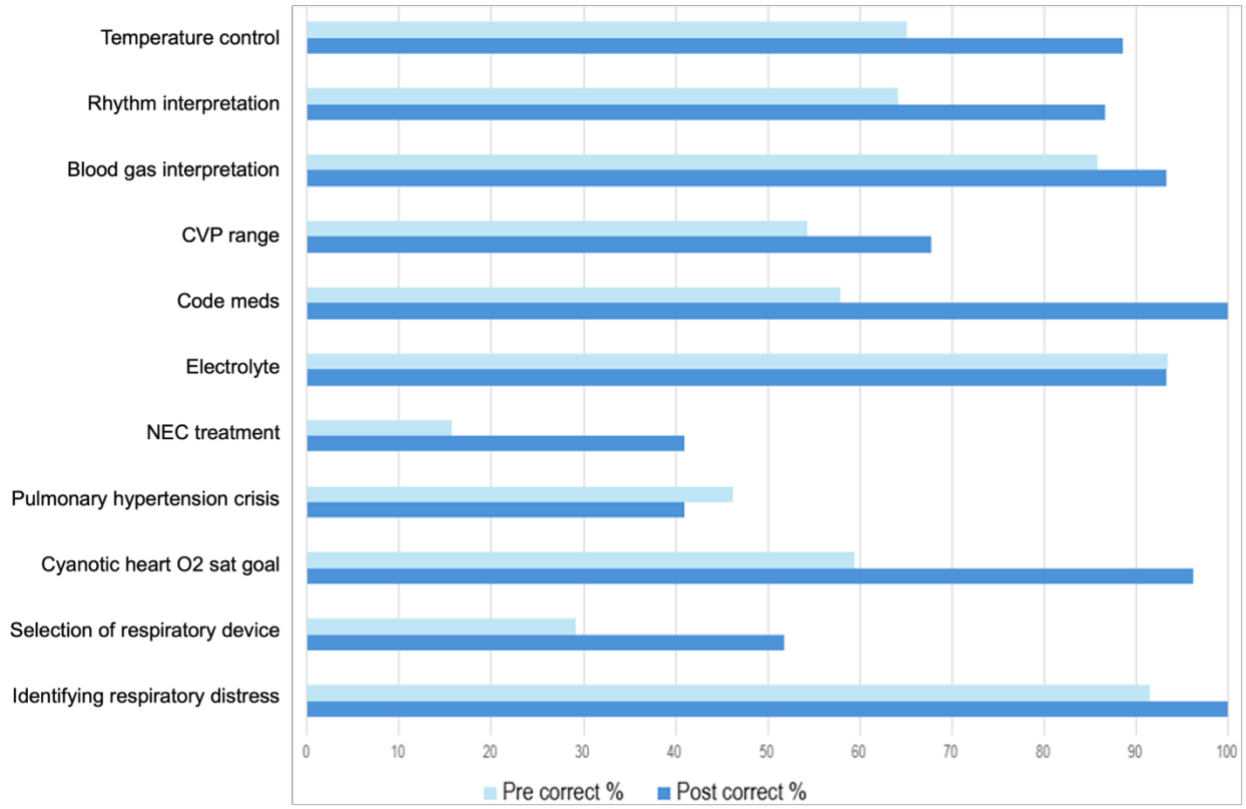
B. Post-Program Perceived Comfort (n = 105)



Note. PIV-E: peripheral IV extravasation event; CVP: central venous pressure; EVD: external ventricular drain.

Figure 3

Percent Correct on Knowledge Assessment Pre- and Post-Program (n = 106)



Note. For normal CVP range, code meds, NEC treatment, n = 56 due to question item changes from April 2024. CVP: central venous pressure; NEC: necrotizing enterocolitis.

Participant Simulation Feedback

Nurses rated the sessions as highly effective in meeting learning objectives (mean rating 4.8 out of 5, SD=0.5), improving teamwork and communication (4.8, 0.5), and enhancing clinical skills (4.7, 0.5). Participants overwhelmingly felt the simulations provided a psychologically safe learning environment (4.8, 0.4) and that the facilitator enhanced learning (4.8, 0.4). The debriefing was perceived as extremely valuable (4.8, 0.5). Notably, nurses reported a strong likelihood of changing their clinical practice because of the simulations (4.7, 0.5). Survey comments highlighted strong appreciation for the comprehensive and practical nature of simulation exercises (Figure 4).

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Figure 4

Example Participant Feedback

"This is just my overall thoughts of the week. I have done a ridiculous amount of orientation classes, and this is my fourth ICU core class that I have completed. Out of all of them, and all of the hospitals, this has been by far one of the most robust and easy to digest learning experiences that I have ever been a part of. I feel like it really rounded out all of my corners and has made me a much better nurse." - Participant A

"This was a really important sim to have, and I really appreciated having this opportunity. Thank you! I don't think I would change anything—just keep doing this please!" - Participant B

"This was super helpful to have the space to put it all together after the learnings this week. Prior to this week, I felt super uncomfortable about what my role would be in a code situation and now I feel like I have a better grasp of where I could jump in or at least how to start while waiting for more help." - Participant C

"All of this has been relevant, useful, and easily digestible so far!" - Participant D

Cost Analysis

Implementing a structured ICU Core Curriculum training program offers significant cost-saving opportunities by improving resource utilization and reducing inefficiencies. If each of our ICUs conducted its own training separately, the cost is estimated to be $219,300 annually across the three units. In contrast, a combined approach with the ICU Core Curriculum has fewer sessions per year, leading to an estimated annual cost of $177,375. This resulted in total estimated savings of $41,925 per year of ICU Core Curriculum implementation.

Table 1

Cost Analysis

Budget item	Annual cost of unit-specific ICU orientation (estimated)	Annual cost of ICU Core curriculum (2023)
Sessions per year	9	3
Hours of planning and facilitation per session	50	25
Hours of education per session	40	40
Educators per session	2	5
Educator hourly rate with fringe benefits	65	65
Educator cost	**$105,300**	**$63,375**
Learners per year	57	57
Learners hourly rate with fringe benefits	50	50
Learner cost	**$114,000**	**$114,000**
Estimated annual cost	**$219,300**	**$177,375**
Estimated cost savings		**$41,925**

Note. Educator cost = no. of sessions × (planning + education hrs.) × no. of educators × hourly rate. Learner cost = education hrs. × hourly rate × no. of learners. Estimated annual cost = educator cost + learner cost.

DISCUSSION

The implementation of the ICU Core Curriculum has shown early promise in addressing the experience-complexity gap and improving the transition of new ICU nurses into high-acuity clinical environments. Through standardization, simulation-based learning, and alignment with evidence-based educational frameworks, this program increased learner comfort and promoted consistent clinical expectations across ICUs. The observed improvements align with existing literature emphasizing simulation's effectiveness for novice nurses transitioning into practice (Rutherford-Hemming et al., 2022; Campbell et al., 2022). Our results are similar to those of quasi-experimental ICU simulation studies showing improvement in patient safety knowledge and communication among new ICU nurses (Jung et al., 2023). These results also align with pediatric ICU work demonstrating improved knowledge, teamwork, and confidence via deliberate practice (Karageorge et al., 2020). The ICU Core Curriculum extends this by delivering a weeklong, CHSE/DASH-evaluated onboarding across three PICUs.

Survey and test results demonstrate that the ICU Core Curriculum effectively increased both participants' comfort and knowledge in managing multiple critical care scenarios. The greatest improvements in participant comfort were seen in using push-pull for fluid administration, Code Blue participation, knowledge of Code Blue medications, and oxygen saturation goal for children with cyanotic congenital heart disease. Persistent discomfort caring for patients with congenital or acquired heart disease, together with low knowledge-assessment scores on the treatment of necrotizing enterocolitis and pulmonary hypertension crisis, highlights areas for future curriculum improvement.

By streamlining educator hours, leveraging shared simulation resources, and consolidating sessions, we estimate that the ICU Core Curriculum is saving our organization more than $40,000 per year. This estimate does not account for the long-term operational savings that could result from strengthening internal training capabilities and reducing reliance on external education resources, such as vendor-led courses, outsourced simulation programs, and third-party continuing education providers. By leveraging the Simulation Center's resources and expertise, the ICU Core Curriculum ensures consistent, high-quality learning experiences.

Integrating simulation into early clinical training not only fosters knowledge acquisition and enhances clinical confidence but also reduces preceptor workload and promotes a uniform standard of care across the institution's ICUs. This partnership highlights the Simulation Center's vital role in advancing clinical education, patient safety, and professional development throughout the organization. Looking ahead, our priorities include long-term follow-up to evaluate knowledge retention and sustained practice change, introducing behavior-based competency checks, and exploring associations with nurse retention and patient outcomes.

Operational Considerations

A key contributor to the success and sustainability of the ICU Core Curriculum was the collaborative partnership between the institutions' ICU nursing educators and the SSH-accredited Simulation Center. ICU educators led the development, implementation, and ongoing refinement of the curriculum, including educational content design, learner coordination, supply standardization, scheduling workflows, and continuous quality improvement efforts. Simulation educators and CHSOS-certified simulation technicians supported the curriculum through consultation on simulation design, management of simulation equipment and environments, audiovisual support, and facilitation of simulation-based learning experiences. During the initial implementation phase, the curriculum required substantial collaboration and operational support from both educator and simulation teams to establish workflows, develop simulation experiences, and standardize delivery across ICUs. As the program matured, many operational processes became more streamlined and sustainable, allowing simulation involvement to transition to a more focused support and consultation role while ICU educators continued to lead ongoing curricular refinement and routine operational management.

Centralizing portions of the curriculum within the Simulation Center created operational efficiencies by leveraging existing simulation infrastructure, reusable cases, task trainers, and high-fidelity simulation resources while promoting consistency across ICU orientation experiences. The integration of multiple simulation modalities, including task trainers, escape rooms, standardized patients, and high-fidelity simulation, allowed the team to align educational objectives with available institutional resources in a cost-effective manner (Boling & Hardin-Pierce, 2016). This evolution in operational support may help organizations considering similar initiatives recognize that, while simulation-based onboarding programs may require significant upfront collaboration and infrastructure development, the ongoing operational demands can become more manageable once workflows, resources, and educational processes are established (Table 2).

Table 2

Operational Contributions of the Simulation Center to ICU Core Curriculum Implementation

Operational support	**Simulation Center contribution (CHSE/CHSOS)**	**Educational impact**	**Operational impact**
Centralized infrastructure	Provided simulation space, equipment, and personnel.	Consistent learning experiences across all ICU orientations.	Reduced duplication of resources and improved efficiency.
Reusable simulation resources	Developed and maintained reusable cases, task trainers, and simulation activities.	Standardized content and learner experience.	Reduced curriculum development time and effort.
Simulation design and modality selection	Assisted ICU educators in aligning simulation methods with learning objectives.	Increased learner engagement, critical thinking, and knowledge application.	Optimized use of institutional resources.
Technical and AV support	Managed simulation technology, environments, and audiovisual systems.	Supported reliable simulation delivery and effective debriefing.	Reduced educator workload and technical disruptions.
Workflow development	Supported scheduling, implementation planning, and resource coordination.	Improved program consistency and learner access.	Established sustainable operational processes requiring less support over time.

Limitations

The following limitations direct our current efforts to further develop and refine the ICU Core Curriculum. Despite intentional scaffolding and progressive escalation of scenario complexity to balance cognitive load, the intensity of a weeklong curriculum may still contribute to cognitive overload and learner fatigue. Participants have indicated in open-text survey feedback that while the training days can be long, they appreciate the opportunity to build on their new knowledge over the course of the week, particularly highlighting the usefulness of bringing everything together during Integration Day. We continue to iteratively adjust and improve the program based on learner feedback to support engagement and knowledge retention.

Although the curriculum incorporates a wide range of simulation modalities, current evaluation efforts have focused primarily on short-term knowledge gains and self-reported comfort. Due to time and resource limitations, individualized assessment of hands-on clinical competencies is currently limited. It remains unclear whether the short-term gains noted immediately following ICU Core translate into long-term knowledge retention or sustained behavior change in clinical practice, or if this improved orientation process is associated with enhanced nurse job satisfaction or nurse retention.

As the program evolved, operational workflows continued to be refined through ongoing collaboration between ICU educators and simulation personnel. Although standardized external training programs, such as the Society of Critical Care Medicine's Fundamentals of Critical Care Support–Pediatrics (FCCS-P) course (2026), provide structured pediatric critical care education, they may not offer the flexibility needed to tailor content, workflows, equipment, and clinical scenarios to institution-specific patient populations and operational practices. Our institution previously utilized FCCS-P as an adjunct within the Graduate Medical Education Residency Program but transitioned to an internally developed curriculum based on learner feedback and the need for a more customized educational approach. Additionally, scalability remains an operational limitation, as delivery of the ICU Core Curriculum requires substantial educator coordination and sustained faculty involvement throughout the weeklong program. Future efforts should explore hybrid educational models incorporating online modules, asynchronous learning, and in-person simulation training to improve scalability while maintaining educational quality, learner engagement, and operational sustainability.

Future Directions

Future iterations of the ICU Core Curriculum should incorporate structured competency checklists and reassessment of key procedural skills (Lim & Song, 2024). To evaluate the long-term effects of the ICU Core Curriculum, we plan to survey participants three months post-training to assess knowledge retention and comfort levels, as well as explore the association between ICU Core participation and new nurse retention at our institution. Future evaluation efforts should include measures of ICU preceptor satisfaction to determine if standardized ICU onboarding reduces preceptor burden.

Although ICU Core was designed to promote safe, consistent bedside practice, this evaluation did not examine patient-level outcomes. Future work should assess whether standardized ICU onboarding is associated with improved clinical outcomes, such as a reduction in unplanned extubation rates, peripheral intravenous line complications, or device-related pressure injuries, and improvements in patient and family satisfaction.

Future operational efforts should evaluate hybrid delivery models incorporating asynchronous pre-learning, virtual simulation, and distributed facilitation strategies to improve scalability and reduce faculty burden. Additional work is needed to identify operational benchmarks for simulation-based onboarding programs, including educator staffing models, simulation technician utilization, equipment lifecycle management, and return-on-investment metrics. Multi-site implementation studies may further clarify how simulation operations infrastructure influences sustainability and reproducibility across institutions with varying resource availability. Addressing these issues will refine the curriculum and ensure that it continues to meet the evolving needs of an increasingly complex patient population as well as new graduate nurses in both the acute and critical care settings.

CONCLUSION

The ICU Core Curriculum demonstrates the potential for a simulation-enhanced, theory-based onboarding program to improve new ICU nurse readiness in a complex healthcare environment. Standardized simulation experiences increased learner knowledge and confidence, with the potential to reduce preceptor burden and promote consistency across ICU units. By consolidating orientations, this program generated an estimated cost savings of $41,925 annually. Guided by scaffolded

learning, INACSL standards, and CHSE/CHSOS-facilitated simulation in an SSH-accredited center, this model shows strong potential for expansion to other nursing specialties.

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