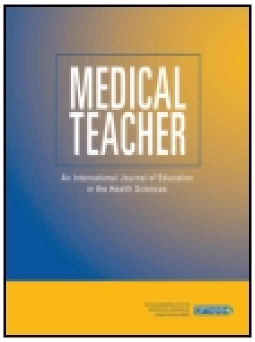

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WEB PAPER
AMEE GUIDE

Simulation in healthcare education: A best evidence practical guide. AMEE Guide No. 82

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Abstract

Over the past two decades, there has been an exponential and enthusiastic adoption of simulation in healthcare education internationally. Medicine has learned much from professions that have established programs in simulation for training, such as aviation, the military and space exploration. Increased demands on training hours, limited patient encounters, and a focus on patient safety have led to a new paradigm of education in healthcare that increasingly involves technology and innovative ways to provide a standardized curriculum. A robust body of literature is growing, seeking to answer the question of how best to use simulation in healthcare education. Building on the groundwork of the Best Evidence in Medical Education (BEME) Guide on the features of simulators that lead to effective learning, this current Guide provides practical guidance to aid educators in effectively using simulation for training. It is a selective review to describe best practices and illustrative case studies. This Guide is the second part of a two-part AMEE Guide on simulation in healthcare education. The first Guide focuses on building a simulation program, and discusses more operational topics such as types of simulators, simulation center structure and set-up, fidelity management, and scenario engineering, as well as faculty preparation. This Guide will focus on the educational principles that lead to effective learning, and include topics such as feedback and debriefing, deliberate practice, and curriculum integration – all central to simulation efficacy. The important subjects of mastery learning, range of difficulty, capturing clinical variation, and individualized learning are also examined. Finally, we discuss approaches to team training and suggest future directions. Each section follows a framework of background and definition, its importance to effective use of simulation, practical points with examples, and challenges generally encountered. Simulation-based healthcare education has great potential for use throughout the healthcare education continuum, from undergraduate to continuing education. It can also be used to train a variety of healthcare providers in different disciplines from novices to experts. This Guide aims to equip healthcare educators with the tools to use this learning modality to its full capability.

Introduction and background

A confluence of recent events has led to increased growth in the use of clinical simulation across the healthcare education continuum. These factors include an increased focus on patient safety, the call for a new training model not based solely on apprenticeship, a desire for standardized educational opportunities that are available on-demand, and a need to practice and hone skills in a controlled environment. In addition, the benefits of clinical simulation are increasingly reported in the literature, adding further validity to its use in healthcare education (Issenberg et al. 2005; McGaghie et al. 2010a). The effectiveness of simulation, like all educational modalities, depends on how well it is used. Simulation should be utilized as an adjunct to patient care experiences, and its integration into the curriculum should be well-planned and outcome driven.

Purpose/Guide overview

This Guide is meant to be a practical handbook for educators about the effective use of simulation for healthcare education. The goal is to discuss, in an evidence-based manner, the

Practice points

- Simulation is increasingly being used in healthcare education to teach cognitive, psychomotor, and affective skills to individuals and teams.
- It is important to first determine the outcomes of using simulation and utilize these to guide its integration into the curriculum.
- Feedback is critical to effective learning using simulation, and should be guided by individual learning needs.
- Simulation allows for training in a controlled environment, with opportunities for deliberate practice and assessment.
- Simulation-based mastery learning, or SBML, significantly improves skills for all participants, and also leads to skill retention.
- Further research is needed in the areas of instructional design, outcomes measurement, and translational and implementation sciences in the context of simulation.

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features of high-fidelity simulation that lead to effective learning, and how best to implement them in a simulation program. As such, our point of departure is the Best Evidence Medical Education (BEME) systematic review published in 2005 (Issenberg et al. 2005), where the authors identified the top ten features of high-fidelity simulations that facilitate learning. The approach is that of a selective, not exhaustive, review to determine best practices and examples that will aid faculty in implementation of simulation. Additional components to assist healthcare educators in launching a successful simulation program, including concepts of operations, logistics, and faculty development, are covered in the complementary Guide on building a simulation program (Khan et al. 2010).

Each section in the Guide discusses the topic's background and importance to simulation, practical implementation points, including examples, and identifies common challenges encountered. Examples are derived from the literature and our own experiences using simulation.

Curriculum integration

Definition and background

When a simulation program is implemented, it usually complements an existing curriculum. Simulation is one of several teaching strategies available to healthcare educators. Others include lectures, problem-based learning, hospital, ambulatory and community-based clinical experience, peer-assisted learning, and multimedia computer-based learning. Incorporating simulation into the curriculum by first determining where it will best be used leads to a more effective use of the modality. The simulation experience must be planned, scheduled, implemented and evaluated in the context of a broader medical curriculum. Integration of simulation can occur at the course level or on a larger scale across an entire curriculum. The general concepts and principles are the same for both approaches.

Importance of curriculum integration in simulation-based healthcare education

Simulation exercises are most successful when they become part of the standard curriculum and not an extra-ordinary, additional component (Issenberg et al. 2005; McGaghie et al. 2010a). Determining which components of a curriculum are enhanced using simulation-based education, and incorporating the exercises into the existing model, result in a more goal-directed and sustained use of the tool.

This approach has the added benefit of helping determine what personnel, equipment, space and economic resources will be needed to carry out the training. Also, for an existing curriculum, it allows for a critical review of how the curriculum is being administered and how learning objectives are best met using the different teaching modalities available to the healthcare educator. Developing a comprehensive plan before implementation will save time and valuable resources.

Implementation

In this section, three examples are presented to further illustrate the process of curriculum integration. These and other examples from the literature all share a common framework: planning, implementation, and evaluation phases (see Table 1). Ideally, a team composed of the educator/course director, content expert, and simulation technician (may all be the same person depending on simulation program size) evaluates the curriculum and determines where and how simulation will be integrated using available resources.

This model works, with minor adaptations, at any level and is applicable whether simulation is being integrated over a module, a course or a four-year curriculum. If you are

Table 1. Curriculum integration framework.

Phase	Component	Examples/Comments
Plan	Develop a curriculum with expected outcomes	Cardiovascular system in medical school, the undergraduate nursing curriculum, or continuing education requirements for a given specialty
	Determine outcomes that are best addressed using simulation	Clinical skills, procedures, problem-solving, teamwork, etc.
	Determine the simulation to be used based on availability of resources and goals of teaching intervention	Full mannequin, task trainer, virtual reality, standardized patient, mixed-modality, etc.
	Determine mode of delivery for each intervention	Facilitator-led small group, peer-led, self-instruction
	Develop content for the simulation-based exercises	Cases, scenarios, skills lab
	Determine logistics and how faculty will be supported & trained	Faculty training session
	Establish how feedback will be incorporated and develop tools to aid in effective feedback	Verbal/written, formalized debriefing, incorporating videos, etc.
Implement	Implement the simulation-based educational exercises and new curriculum	Pilot test with sample group
	Troubleshoot any components as they arise during this phase, and address	Scenarios take longer than planned and more prompts are needed for learners to remain engaged
Evaluate	Evaluate effectiveness/assess learning outcomes	Assess skill performance, knowledge, attitudes, clinical impact, etc.
	Evaluate learner satisfaction	Evaluate simulation exercise, instructor/facilitator, feedback
	Evaluate instructor satisfaction	With process, teaching modality
Revise	Based on results of evaluation and new evidence, make revisions to simulation exercises or curriculum	As needed, continuous process

developing a curriculum, the process is similar, except that learning objectives and outcomes addressed by simulation-based exercises should be identified from the outset.

In Boxes 1 and 2, we provide two examples from the literature of the process of integrating simulation into an established curriculum of an emergency medicine residency and a medical school cardiovascular curriculum.

Box 1. Example: Emergency medicine residency curriculum.

Binstadt et al. integrated simulation into a redesigned four-year emergency medicine residency curriculum (Binstadt et al. 2007). Their approach combined adult learning principles, medical simulation education theory, and standardized national curriculum requirements. They designed a complete set of simulation-based teaching modules covering emergency medicine, and integrated them into the Harvard-Affiliated Emergency Medicine Residency (HAEMR) curriculum.

They began by creating a comprehensive list of learning objectives mapping to the core content within each of the educational modules that needed to be covered. Next, a panel of experts from the residency program and the simulation center determined the best teaching methodology for each learning objective. Their teaching methodologies included large-group lecture, small-group seminar, self-directed learning or reading, partial-task simulation training, human patient simulation, and clinical teaching in the emergency department. Once they identified the modules with a strong simulation component, they developed ''courses'' focusing on a specific set of learning objectives. The courses were three hours long and the residents were divided into two groups based on residency year. Faculty members received objectives relevant to the topic area, a list of available resources and capabilities of the simulation center, and a template for designing the overall session and individual components.

Box 2. Example: Six-year medical school cardiovascular curriculum.

The University of Dundee integrated cardiovascular simulation throughout its six-year medical education curriculum (Issenberg et al. 2003). The curriculum is vertically integrated, where students build and elaborate on what they have already learned during three phases or six years of training. The faculty incorporated a cardiopulmonary patient simulator (CPS) during three phases using multiple modalities, including large-group lecture, small-group facilitator-led sessions, and independent study. In the **first phase**, they used the CPS to demonstrate normal and abnormal physiological principles in a large-group lecture format. This served to acquaint students with normal structure and function and help them understand the relevance of the basic science educational components to the physical examination. It also served to build enthusiasm in the students for future clinical problems they would encounter. During the **second phase** (second and third years of training), they used the CPS for consolidating clinical skills training. The skills included heart sounds recognition, and precordial, arterial and jugular venous pulse examination. Faculty used the CPS in lectures, small-group sessions, and independent learning throughout a four-week cardiovascular block. During the **third phase** (experience of clinical practice), faculty used the CPS in the virtual hospital ward experience for the advanced clinical skills elective. They also used the CPS for assessment in the objective structured clinical examinations (OSCEs), where one of the stations required students to auscultate a simulated murmur.

Challenges encountered

Some of the barriers to planning and implementing a comprehensive curriculum integration approach are similar to those encountered in developing a simulation program. Initial investment of faculty time is needed to evaluate the curriculum and determine the best way to incorporate simulation. Even before this step, there needs to be acceptance and support from senior administration and the faculty that will be involved to support the endeavor (simulation) and commit the needed resources. This is true whether the simulation program is on a small or large scale so that the scope of the project should align with the available resources. In addition, there must be accounting for the initial increased faculty time to develop or adapt content, and for the likely increased time in conducting the simulation interventions.

Competition for time in the curriculum, and scheduling, are additional challenges that must be addressed and negotiated. An example is competition with patient care duties during the clinical years of undergraduate medical education, or residency. Enlisting the faculty, clerkship directors and learners in recognizing the importance of the simulation components will aid in surmounting scheduling or time allotment obstacles (Petrusa et al. 1999). Faculty support in the form of developing scenario templates, providing technical assistance, and programming cases is important to the success of implementation and effectiveness of the program. Also, ensuring that there has been faculty development in the principles of simulation education is important to the satisfaction of both the instructors and the learners, as well as to the outcomes of educational intervention (Binstadt et al. 2007; Thompson & Bonnel 2008; Adler et al. 2009; Nagle et al. 2009).

Determining how best to integrate simulation is facilitated when an existing curriculum has a clearly defined map or objectives. A useful place to start is to look at the defined learning outcomes or core content defined by the overall curriculum, accrediting bodies, or a needs assessment.

Conclusions

Curriculum integration is critical to the success and effectiveness of simulation-based healthcare education (SBHE). The most powerful outcomes are achieved by having an organized and systematic approach to the incorporation of simulation in an existing or new curriculum (Issenberg et al. 2005). Simulation is one of several educational methodologies available to the healthcare educator to achieve learning outcomes. A comprehensive approach, beginning with defining or identifying learning outcomes, and then matching the learning objectives to the educational method(s) best suited to teach those objectives, will lead to improved outcomes. Meeting with, and enlisting the cooperation of, curriculum planners, such as the curriculum planning committee or course director, is vital to incorporating simulation into a program. Faculty support in the form of training, protected time, scenario development tools, and technical support is also incredibly important for the faculty to embrace and utilize the modality. As with all educational interventions, it is important to assess learning outcomes and participant satisfaction and make any needed modifications based on the findings. A continuous process of evaluation of the curriculum, and revising as necessary, is crucial in achieving the best results.

Feedback in simulation

Definition and background

Feedback to learners is a critical component to ensure effective learning in simulation-based education. The BEME review found feedback to be the most cited feature that led to effective learning (Issenberg et al. 2005). In a survey of simulation educators, Rall et al. found that debriefing, a specific form of feedback, was the most important part of training using simulation, and a respondent called it the "heart and soul" of simulator-based training (Rall et al. 2000).

Van de Ridder and colleagues operationalize the definition of feedback in clinical education as "*specific information about the comparison between a trainee's observed performance and a standard, given with the intent to improve the trainee's performance*" (Van de Ridder et al. 2008). This definition is helpful because it explains the *goal* of feedback as improving the trainee's performance, as well as the *process* of feedback, which involves identifying the cause of the performance gap between the trainee's observed and desired actions.

Feedback can come from different sources (e.g. simulator, facilitator, colleagues), and can be given at different times during the simulation encounter (e.g. immediate, real-time, or post-event). Depending on the learning objectives or type of simulation activity, feedback may be brief and simple or detailed and complex. The most common feedback modality is a formalized debriefing session that occurs after the simulation exercise. This post-event facilitated reflection and analysis helps the participants learn from the experience (Lederman 1992).

Importance of feedback in SBHE

Feedback ensures that learning objectives are met and that learning objectives arising from the experience are discussed. Although the simulation exercise itself *may* lead to learning, much more is gleaned by the participants if feedback is provided (Kolb 1984). Without a post-event reflective process, what the participants have learned is largely left to chance, leading to a missed opportunity for further learning, and making the simulation encounter less effective. Savoldelli found that simulation encounters alone, without feedback, did not lead to improvement of nontechnical skills of anesthesia trainees (Savoldelli et al. 2006). This is reinforced by Lederman, who describes the experience (simulation encounter) as the "raw data," which, through analysis (the debriefing), leads to real learning (Lederman 1992).

Debriefing allows for the opportunity to investigate a participant's knowledge, skills and attitudes that led to the actions observed during the encounter. This form of feedback helps to determine the cause of any variance between the observed actions and expected actions. Educators may assume the reason for a learner's behavior, but this hypothesis needs further testing to determine the true source of the observed performance gap. Rudolph and colleagues explain the process as analogous to detective work, in this case a "cognitive detective," who tries to uncover what "assumptions, goals, and knowledge base," together called "frames," led the participant to take specific actions leading to a performance gap (Rudolph et al. 2008). It is important to note that positive reinforcement of correct performance, with examples of what went well, is as important as noting the undesired actions or results. Debriefing allows an opportunity to find out the *why* of the actions observed during the simulation exercise, leading the participants to better informed self-assessment and self-correction. Although debriefing sessions are very useful, not all learning objectives require a formalized debriefing session. Feedback can be given at the simulator during or after a session, especially when teaching technical or psychomotor skills.

Implementation

For feedback to be most effective, educators should focus on the three components of planning, pre-briefing, and providing the feedback. We refer to these as the three Ps of feedback (Figure 1).

1. Plan

To incorporate feedback effectively into simulation education, facilitators should determine how and when the feedback will be provided in a manner consistent with the learning objectives for the simulation session. This should be done at the time of planning the session or developing the scenario. Clinical protocols or guidelines should be available, if pertinent, and instructional components for faculty should be prepared.

Ensure that you also have the flexibility to examine learner-generated, or what Fanning and Gaba call "emergent," objectives (Fanning & Gaba 2007). These are objectives that are not predetermined, but arise during the simulation, such as a knowledge gap or systems issue that should be addressed. It is important to note that not all objectives will be able to be discussed, so the facilitator must decide which are most important for the given session.

2. Pre-brief/prepare the participants

Most educators agree that there should be a "pre" event preparation of the learners where rules and expectations are explained to the participants. At this time, the environment should be described as non-threatening, confidential, and "psychologically safe" (Fanning & Gaba 2007; Rudolph et al. 2008). This allows participants to know what is expected and to participate fully as respected trainees. Since there is usually some introduction to the simulation environment and simulator, this is a good time to incorporate the feedback preparation.

3. Provide feedback/debrief

Feedback from the simulator/during the scenario: Feedback from the simulator (e.g. physiologic response to drug administration, verbal response, haptic feedback) is useful during a simulation exercise to help guide the participants and meet learning objectives. In this regard, the feedback "script" should be planned and expressed, so the reactions of the simulators

The 3 Ps of Feedback

1. Plan
2. Pre-brief
3. Provide Feedback/Debrief

Figure 1. The three Ps of feedback.

or actors in the scenario serve to inform the participants if their actions are correct, incorrect or neither. Many competencies can be acquired using simulation, including technical, communication, assessment, decision-making, and team dynamics. Feedback can be a clinical or physiologic response (or non-response) from the simulator, or a verbal response from the simulator or actors.

In the example in Box 3, the actions or inactions of the participant led the simulator to provide feedback that allowed trainee 1 to know, "I did something right. The patient is improving." and trainee 2 to know, "I must be missing something because the patient's condition is worsening." In this setting, facilitators can choose to give feedback during the scenario or at the end.

Another example of simulator-driven feedback includes - haptics (Box 4). Using sensors and visual and audio cues, the simulator is able to indicate to the learners whether they are in the correct anatomic location, using appropriate force, and performing a psychomotor skill properly. These features are an integral component of endoscopic, endovascular, and pelvic simulators.

Scenarios are often allowed to unfold in their entirety, with feedback provided afterward. However, another option is to stop a scenario after a critical event has occurred and provide immediate feedback and instruction about the diagnosis or treatment of a disease process, healthcare provider communication, or other pre-determined learning objective.

Box 3. Example of physiological and verbal feedback from the simulator.

Simulation Scenario: Patient with asthma. O_2 saturation: 89%, diffuse wheezes on pulmonary examination.

Trainee 1 appropriately assesses the patient and applies a nebulizer treatment → Simulator O_2 saturation changes to 95% over 1 min, and wheezes diminish. Simulator states, "Thank you, I feel much better."

Trainee 2 does not recognize bronchospasm and/or does not provide appropriate treatment → O_2 saturation decreases to 80%, and simulator states, "I can't breathe. I feel like I am getting worse."

Box 4. Example of verbal and force feedback from endoscopic simulators.

Feedback is provided in these task trainers by the reaction of tissue (e.g. resistance felt by operator), and the response of a patient experiencing discomfort (e.g. audible groans) if undue force or insufflation is applied.

Post-event debriefing: Multiple debriefing models have been described in the literature (Thatcher & Robinson 1985; Petranek 2000; Gaba 2001; Owen & Follows 2006; Rudolph et al. 2006; Edelson 2009). A detailed description of these models is beyond the scope of this work, and we refer the reader to the references for further information. The general structure for debriefing sessions begins with participant reactions, followed by in-depth analysis, and ends with a discussion of lessons learned and take home points. It is the responsibility of the facilitator to guide the learners through this process and ensure that they progress beyond the reactions phase.

We provide an example using the plus/delta debriefing concept. Plus/delta debriefing is a strategy that enables participants to consider the "pluses" (what went well) and the "deltas" (what they would like to change about their performance). It is very straightforward to implement. Begin by making two columns. Label one column with a plus (+) sign and the other with the Greek letter delta (Δ). Have participants brainstorm under the "+" sign what they believe the strengths of the individual or team were, and under the "Δ" sign, what the weaknesses were or what could be improved. Lists can be completed as a group, or individually and then combined. Lists may also be subdivided into individual, team, system, and other pertinent categories. The facilitator can also add to the list if she/he has other findings that the participants did not list. The plus/delta method is very useful when time for debriefing is limited (e.g. a course with many students and a total time of 20 min for the scenario and debriefing session). It is useful for individuals and groups, and allows for self-reflection and initial processing of events. The method identifies those actions the participants thought were most important, and allows the facilitator to focus on a few specific learning points (see Table 2 for an example). A key point is to begin the session by reviewing what went well, creating a more open environment for the discussion of what needs improvement. Facilitators should not allow the debriefing session to focus only on superficial analysis of observed actions, or include only technical aspects of the scenario, rather than offering an opportunity for participants to further develop their meta-cognition skills (ability to reflect and think about one's own thinking).

Table 2. Plus/delta debriefing model example.

Plus (+)	Delta (Δ)
Individual: – Introduced self to family – Used appropriate personal protective equipment – Adequately assessed patient – Made correct diagnosis Team: – Team leader identified early	Individual: – Learn algorithms well to know next steps/correct treatment Team: – Clarify communication/cross check – Ensure roles are clearly defined to increase efficiency and decrease confusion System: – Maintain and label equipment (decrease delay to treatment)

Scenario: A multidisciplinary team is asked to respond to a patient's room. The team finds a male patient in cardiac arrest with an initial rhythm of ventricular fibrillation. The patient's family is present in the room.

Other considerations: Recordings of sessions

Audio-video recorded review can be a useful self-evaluation tool when it is incorporated into debriefings. Often learners are not aware of their actions or do not recall exactly what was said or done, and a recording can be used to recall events and illustrate a critical event during the scenario. Although results of studies are mixed as to whether event recordings with later debriefings are superior to direct verbal feedback during a session, they can be a powerful learning tool (Byrne et al. 2002; Scherer et al. 2003; Savoldelli et al. 2006). The challenge with using recordings during debriefings is that they can be time-consuming, and can turn the focus away from a good discussion. To make a specific point, facilitators can note the scenario time of a critical event during the session on their checklist or notes sheet, replaying the event during the debriefing. This may be more useful and time-efficient than replaying the video in its entirety.

Conclusions

Feedback is critical to effective learning in simulation, and it should be planned and intentional, regardless of when (during or after the session), how (technique) or by whom (faculty, peers) it is given. Training in feedback and debriefing techniques for simulation faculty is critical for effective use of simulation and professional development. This training can come from reviewing the literature, debriefing training modules, and formalized instructor courses where the faculty member can participate in deliberate practice in debriefing.

Deliberate practice

Definition and background

Deliberate practice involves repetitive performance of intended cognitive or psychomotor skills in a focused domain, coupled with rigorous skills assessment. Learners receive specific, informative feedback resulting in increasingly better skills performance in a controlled setting (Issenberg et al. 2005). The term "deliberate practice" was initially used by Ericsson in instructional science research, and has since been adopted in medical education (Ericsson 2004). It incorporates at least nine features (McGaghie et al. 2010a):

(1) highly motivated learners, with good concentration, who address
(2) well-defined learning objectives or tasks at an
(3) appropriate level of difficulty, with
(4) focused, repetitive practice that yields
(5) rigorous, reliable measurements, that provide
(6) informative feedback from educational sources (e.g. simulators, teachers), that promotes
(7) monitoring, error correction, and more deliberate practice, that enables
(8) evaluation and performance that may reach a mastery standard, where learning time may vary but expected minimal outcomes are identical, and allows
(9) advancement to the next task or unit.

Deliberate practice is not only for novices, nor does it require that the person providing the assessment necessarily be more skilled than the learners. Elite sports or music coaches have never been thought of as having more technical skill than the individuals they mentor, but they are keen observers and skilled at providing feedback. Such an example can prove useful when introducing simulation to adult learners who might fear humiliation or the exposure of knowledge or skills deficits during training.

Importance of deliberate practice in SBHE

Deliberate practice provides an important conceptual framework to guide the use of simulation as a science of training. It is grounded in information processing and behavioral theories of skill acquisition and maintenance. The goal of deliberate practice is constant skill improvement. Ericsson's research has found that deliberate practice is a more powerful predictor of superior expert performance than experience or academic aptitude (Ericsson 2006). There are also practical reasons that deliberate practice is essential, as in the case of procedures performed so rarely (e.g. emergency cricothyrotomy) that few could master such skills without practice and feedback in a non-clinical setting. These infrequent procedures are often associated with high-risk situations that lead to medical errors. Deliberate practice has a key role in preparing practitioners for these critical events.

Implementation of deliberate practice in SBHE

Remember that deliberate practice need not be technical and need not involve sophisticated gadgets. In Boxes 5, 6 and 7 are examples illustrating the range of competencies and sophistication of the simulations that can be achieved with deliberate practice.

Challenges encountered

The challenge for many simulation programs is that, while learners are enthusiastic about a simulation experience, it occurs only once or infrequently. The need for repetition and the need for increasing the challenge of the task are resource-intensive. For deliberate practice to be effective, there have to be multiple simulation experiences that cannot be the same,

Box 5. Example: Knot tying.

First-year medical students in a surgery interest group want to learn how to tie knots. One student has read an instruction manual and has repetitively practiced tying a one-handed knot incorrectly, because he had no feedback during his self-administered tutorial.

An alternative approach is to have students use blocks of wood, each with 2 parallel rubber tubes, and view a video of an instructor correctly tying knots. After the students view the video several times, the instructor observes their hand motions, pointing out what they are doing correctly and incorrectly. Each student then ties approximately 200 knots, and over the session, becomes competent in this skill. The instructor repeats the tutorial weekly for one month, focusing on increasing the students' speed, while maintaining competence. This is an example of deliberate practice using a low-technology task training simulation with specific real-time feedback.

Box 6. Example: Performing colonoscopy.

As a gastroenterology fellowship director, you are responsible for your fellows becoming skilled in performing a colonoscopy. You use a virtual colonoscopy task trainer and schedule Saturday mornings to teach the fellows the fundamentals of this skill. Prior to the practice session, fellows read about the procedure and watch videos of a skilled surgeon performing it.

During the session, you observe the fellows' technique in reaching the cecum, visualizing the entire colon, and performing biopsies. At different times during the practice session, the virtual trainer provides feedback on how close the probe is to touching the colon wall. You provide real-time feedback on each aspect of the procedure, and allow for and encourage adjustments in the trainees' techniques. This is an example of deliberate practice using a mid-level technology task training simulation that provides its own feedback along with that of the facilitator.

Box 7. Example: Radiograph interpretation.

In certain circumstances, it is possible to incorporate deliberate practice without having an onsite expert providing feedback. Pusic et al. describe the use of learning curves to assess the deliberate practice of radiograph interpretations (Pusic et al. 2011). In this computer-based learning model, pediatric residents reviewed cases of ankle radiographs and had to characterize the films as either normal or abnormal. They were then given immediate feedback, comprised of a visual overlay indicating the region of abnormality (if any), and the final official radiology report. This teaching and testing digital case bank recorded learners' answers, and generated longitudinal learning curves characterizing things such as a learner's accuracy. This is a novel form of deliberate practice that uses computer-generated feedback to enhance learning. Unlike the first two examples, in this case, there is no expert directly accompanying the learners, rather pre-programmed feedback.

but must revolve around a focused domain. An example might be undifferentiated hypotension. One could device multiple cases of simulated patients, each experiencing hypotension, but each representing a different etiology and requiring different work-up and treatment.

Another challenge of deliberate practice is identifying finite psychomotor and cognitive skills that can be analyzed and critiqued during an observed simulation activity. Each of these steps must be observed, critiqued and then reproduced to allow for repetition and subsequent observations. The challenge for the instructor is to delineate finite steps in a process. Even a relatively simple task such as an intravenous line insertion involves hand washing, universal precautions, localizing an appropriate vessel, selection of an appropriately sized catheter, preparation of equipment, attentiveness to a patient's pain, safety, and movement issues, and correct equipment disposal methods.

Conclusions

Repetition of psychomotor or cognitive skills, in a controlled setting, coupled with rigorous skills assessment and feedback, are the key elements comprising deliberate practice. There is a range of competencies that can be addressed with this training framework, and evidence clearly demonstrates new skills can be acquired and sustained.

Mastery learning

Definition and background

There has been a steady movement toward outcomes-based medical education that focuses on learner performance and achievement of specific competencies. Mastery learning is a rigorous approach to competency-based education. The goal of mastery learning is to ensure that all learners achieve the objective level of mastery performance, a higher level than competence alone, with little or no variation. The time needed to achieve the mastery standard will vary between learners so that each will have his/her own "learning curve." Learners may have mastered some educational outcomes before beginning training, may move quickly through others, and may require significant time and training to master still others (McGaghie et al. 2010a). Simulation-based mastery learning, or SBML, has been shown to not only significantly improve skills for all participants, but to also lead to skill retention up to one year post-intervention (Barsuk et al. 2010). Mastery learning has seven complementary features (McGaghie et al. 2010a):

(1) establishment of a minimum passing *mastery* standard for each educational unit, usually through pilot testing of representative populations of learners
(2) baseline assessment to determine appropriate level of difficulty of initial educational activity
(3) clear learning objectives, sequenced as units ordered by increasing difficulty
(4) engagement in educational activities (e.g., skills practice, data interpretation) that are focused on reaching the objectives
(5) formative testing to gauge unit completion at the minimum passing *mastery* standard
(6) advancement to the next educational unit when measured achievement meets or exceeds the mastery standard, or
(7) continued practice or study on an educational unit until the mastery standard is reached.

The elements of deliberate practice are often used in the educational activities carried out as part of mastery learning interventions. Two essential components of a comprehensive mastery learning program are:

(1) defining appropriate outcomes or mastery standards that the learner must achieve at each level; and
(2) developing educational units of increasing levels of difficulty through which learners must progress.

Importance of defined outcomes in a mastery learning model

Defining outcomes serves multiple key roles in a simulation exercise as well as longitudinally across a curriculum. Outcomes provide a clear direction for the faculty and can serve as the guiding principles for content, instruction and feedback. Furthermore, outcomes help specifically identify for the faculty what is to be learned or achieved. They also tell the learners what is to be accomplished. Ultimately, the emphasized outcomes, along with the learning environment, have an important influence on knowledge and skill acquisition. If a mastery learning model is used, benchmarks are critical to determine when the learner has attained the desired level of expertize.

An excerpt from *Alice's Adventures in Wonderland* (Carroll 1865) illustrates the importance of having a clear target (learning outcome) to determine the best path to take (intervention):

"Would you tell me, please, which way I ought to go from here?" said Alice.

"That depends a good deal on where you want to get to," said the Cat.

"I don't much care where," said Alice.

"Then it doesn't matter which way you go," said the Cat.

Setting outcomes for educational interventions is critical in simulation-based mastery learning, to determine when a learner has achieved the desired level of proficiency in a given skill.

Implementation

A mastery learning model can be implemented in SBHE to ensure that all of the learners attain a predetermined level of proficiency in a certain skill. A team at Northwestern Feinberg School of Medicine has developed a methodology using simulation-based mastery learning to train residents and fellows in multiple procedures, including central venous catheter insertion, advanced cardiac life support, thoracocentesis, and lumbar puncture (Wayne et al. 2006, 2008a,b; Barsuk et al. 2010, 2012). The process is summarized in Table 3, and two specific examples are given in Boxes 8 and 9 to further elucidate how it is practically implemented.

Table 3. Process for developing a mastery learning intervention.

Determine learning outcomes
What competencies should the learners master at the completion of the intervention?
⬇
Develop learning objectives based on the desired outcomes
⬇
Develop metrics (checklists/global rating scales)
These may be previously deviced, based on an expert model, based on existing national requirements/standards, or you may develop your own in consultation with experts (validity).
⬇
Determine minimum passing score using appropriate standard-setting methods (e.g., Angoff, Hofstee)
⬇
Ensure rater training and calibration
⬇
Use the rating instrument in a pilot to determine reliability
Make any necessary changes
⬇
Conduct simulation-based educational intervention with deliberate practice and feedback
⬇
Perform a clinical skills evaluation using developed checklist
Participants must meet pre-determined minimum passing standard (MPS)
⬇
Participants who do not meet MPS should engage in additional deliberate practice until they can achieve MPS

Box 8. Example: Lumbar puncture training for internal medicine residents.

Barsuk and colleagues used a simulation-based mastery learning intervention to train internal medicine residents in lumbar puncture (LP) (Barsuk et al. 2012). The intervention group was composed of 58 Post Graduate Year-1 (PGY-1) internal medicine residents. They developed and validated a 21-item checklist that was scored dichotomously – done correctly or done incorrectly. They also performed a pilot test to determine reliability. The minimum passing score (MPS) was determined as a mean of the Angoff and Hofstee standard setting methods.

Before the intervention, participants answered baseline questions and rated their procedural confidence. They underwent a clinical skills examination using the checklist. They then completed an educational session featuring a New England Journal of Medicine procedure video on lumbar puncture, an interactive LP demonstration, and deliberate practice with directed feedback. The residents then underwent a post-test using the same checklist and were expected to meet or surpass the MPS. Residents who did not achieve the MPS engaged in additional deliberate practice and were retested until the MPS was reached. The group of internal medicine residents was then compared to PGY 2–5 neurology residents who had been trained using standard clinical experience and training. The internal medicine residents who had undergone the simulation-based mastery learning intervention significantly outperformed the neurology residents who had not received the intervention.

Box 9. Example: Laparoscopic inguinal hernia repair training for surgical residents.

Zendejas et al. implemented a simulation-based mastery learning intervention to train PGY 1-5 surgical residents in laparoscopic, totally extraperitoneal (TEP) inguinal hernia repair (Zendejas et al. 2011). The residents were randomized to regular clinical practice and instruction, or the mastery learning intervention.

The mastery learning curriculum consisted of supervised practice sessions using a TEP task trainer and standard laparoscopy equipment. Participants practiced on the simulator until they demonstrated mastery, defined as reduction and successful repair of indirect and femoral hernias using mesh in less than two minutes in two consecutive attempts. The standard was determined by taking the average time that it took five experienced laparoscopic surgeons to repair both hernias. All residents were assessed on subsequent TEP laparoscopic repairs in the operating room. Residents randomized to the mastery learning group performed the procedure faster, with better operative performance scores and fewer complications.

Challenges encountered

Challenges in implementing simulation-based educational interventions using mastery learning principles are similar to those encountered when developing any rigorous, competency-based educational intervention (Frank et al. 2010). Development of appropriate assessment instruments for baseline and formative testing can require significant initial investment of faculty time. If mastery learning is to be implemented, the minimum passing standard must be determined in a systematic and valid manner. Appropriate expert raters must be consulted and their judgments used to set defensible standards, which will vary based on the standard-setting methods used (Downing et al. 2006). Setting of appropriate mastery standards can address the concern of competency-based medical education critics that learners may perceive an underlying message that achieving the MPS is more important than striving for excellence.

Conclusions

Just as a curriculum should have clearly defined outcomes, so should a simulation-based education intervention. In order to attain the desired results, clearly defined goals and benchmarks must be set. Mastery learning is a form of outcomes-based learning where there is a fixed achievement standard set at a level of excellence rather than competence. It allows learners to progress at their own speed but reach a uniform rigorous performance standard. Simulation-based mastery learning has been shown to be more effective than clinical training alone (McGaghie et al. 2011a; Barsuk et al. 2012) and to improve patient outcomes (Wayne et al. 2008a; Barsuk et al. 2009; Zendejas et al. 2011).

Range of difficulty

Definition and background

As trainees in healthcare professions progress through their training and endeavor to become proficient, or even expert, in their area of practice, they build upon previously attained competencies by engaging in activities of increasing difficulty. Learning effectiveness is optimized when trainees begin their activities at an appropriate level, demonstrate performance mastery relative to objectively set standards at that level, then proceed to training at progressively increasing levels of difficulty (Issenberg et al. 2005).

Importance of range of difficulty in SBHE

The value of simulation in providing planned and gradual increases in the difficulty of clinical problems presented to learners, with the opportunity for necessary repetition, has been recognized for more than 40 years (Abrahamson et al. 1969). In achieving competence, trainees should have ample opportunity to acquire and improve their knowledge and skills in a way that minimizes risk to patients. By providing experiences with a progressive increase in difficulty, SBHE provides the opportunity for learners to advance from inexperienced novices to competent practitioners, to experts and masters in specific domains.

Implementation

The level of the learner, their *a priori* knowledge and skills, and expected outcomes should be major factors in determining the difficulty and complexity of a simulation-based educational intervention. In some instances, especially for simple skills (e.g. inserting an intravenous line), learning the whole skill at once allows all steps to be coordinated and integrated in the appropriate context. However, learning a whole skill at once, rather than learning it in parts, can be detrimental to learning if the whole skill (e.g. inserting an endotracheal tube during a cardiac arrest) results in too high a cognitive load for the learner. Overall cognitive load will decrease with practice as some components of the skill begin to become automatic. It is important to ensure that interventions are not unnecessarily sophisticated or complex. For example, when teaching a novice the psychomotor skills involved in central venous catheter (CVC) insertion, having a room full of distraught family members and a patient in cardiac arrest in the next bed would certainly obscure the objectives of the exercise.

Examples of range of difficulty

There are several examples of effective educational interventions that use simulations of increasing levels of difficulty to achieve learning. The range of difficulty can be varied longitudinally across a curriculum, or within a single intervention, to achieve a defined outcome. Many of the current virtual reality (VR) simulators in laparoscopic surgery allow for practice at varying levels of difficulty across a broad range of clinical scenarios. In Boxes 10 and 11 are two examples with laparoscopic skills and cardiac bedside skills.

Box 10. Example: Laparoscopic skills.

Imperial College of London has developed a graduated laparoscopic training curriculum that has learners progress through three levels of several tasks as proficiency is achieved (Aggarwal et al. 2006). At the **easy level**, learners perform 12 tasks twice on the same day in two sessions that are more than one hour apart. At the **medium level**, learners repeat the 12 tasks (at a more difficult pace) twice on the same day in two sessions that are more than one hour apart. At the **hard level**, learners practice two tasks (manipulate diathermy and stretch diathermy). They perform these for a maximum of two sessions per day, the sessions being greater than one hour apart. Learners complete training when the following levels of proficiency (in two of the most difficult tasks) are achieved on two consecutive sessions:

- Right hand economy of movement <2.0
- Left hand economy of movement <2.0
- Total error score <150
- Time taken <25 s

Box 11. Example: Cardiac bedside skills.

The University of Miami developed a multi-year cardiac bedside skill curriculum in which the difficulty of each task increases with each stage of training.

Cardiac Finding: A simulator presents a fourth heart sound at the apex.

Level	Population	Tasks	Example
1	1st year medical student	Identify finding	"I hear a fourth heart sound."
2	2nd year medical student	Correlate finding with underlying patho-physiology	"This fourth heart sound is caused by an increased after-load on the left ventricle."
3	3rd year medical student	Generate a differential diagnosis	"Possible causes are aortic stenosis, hypertension, etc."
4	2nd year internal medicine resident	Make a management decision	"Order an EKG, consult a specialist, and initiate medical therapy."

Challenges encountered

There are a number of practical challenges in implementing simulators with a range of difficulty. It is essential to align the difficulty level with trainee learning level and the desired outcomes. Simulations for novice trainees may not require simulators with high mechanical fidelity or simulations that are overly complex. Scheduling can be difficult in mastery learning interventions as each learner may achieve mastery performance at a different rate, and additional time may need to be set aside for remediation of learners.

Conclusions

SBHE can be utilized to help novice trainees become proficient in, or even masters of, specific tasks and domains by providing access to simulations with a range of difficulty. For simulations at each level of difficulty, other concepts discussed in this article, such as deliberate practice, feedback and individualized learning can be applied. When combined with appropriately defined and measured outcomes, simulations of increasing difficulty can be used as part of mastery learning.

Capturing clinical variation

Definition and background

Simulations that can capture or represent a variety of patient problems and conditions are more useful than those having a narrow patient range (Issenberg et al. 2005). Utilizing simulations that encompass a broad range of patient pathophysiology and treatment responses allows learners to experience a broader range of patients than might otherwise be encountered in the clinical setting alone. This also allows for standardization of curricula using simulation by ensuring that all learners have the clinical exposure required to attain all of the competencies expected in a given course or curriculum. This may be particularly important for rural areas where patient volume and pathology may be restricted and for rare, life-threatening conditions where proficiency is critical, but access in the real-life clinical setting is limited.

Importance of clinical variation in SBHE

Patient safety and patient-centered care are the focus of twenty-first century healthcare. In this new and developing context, healthcare education is going through a great transformation in order to produce the most competent healthcare providers. Academic institutions or groups, such as the Accreditation Council for Graduate Medical Education (www.acgme.org/acgmeweb), Royal College of Physicians and Surgeons of Canada (www.royalcollege.ca), and The Scottish Doctor (www.scottishdoctor.org), emphasize the importance of competencies in patient care. These organizations commonly state that physicians should possess a defined body of knowledge, clinical skills, procedural skills and professional attitudes, directed at providing effective patient-centered care within the boundaries of their discipline, personal expertise, the healthcare setting, and the patient's preferences and context.

The evolution of our healthcare systems, and education within them, has resulted in limited work hours of physicians and other allied healthcare professionals, and has led to fewer patient encounters and clinical procedural experience. This, combined with prevention of medical errors, patient safety, and the goal of finding improved and more efficient training approaches, has profoundly altered the ways we train healthcare providers. Increased specialization among medical disciplines has led healthcare professionals to experience a narrow patient range. Symptom presentations and injuries of patients are becoming more complex. Future clinicians need to be educated and trained to encounter the various clinical presentations of patients. Below are some specific examples that demonstrate educational and training issues in the current evolving healthcare system.

- General internists and trainees currently perform far fewer invasive procedures than they once did (Wigton & Alguire 2007), and at the same time, increased awareness of patient safety and quality requires proper qualifications to perform invasive procedures. Invasive bedside medical procedures are associated with greater risks for serious errors and complications, leading to an increase in length of stay and higher associated healthcare cost (Reynolds et al. 2006).
- Due to increased longevity, the complex nature of disease, and ever increasing therapies, patients are admitted to the hospital with multiple medical problems. This situation demands that healthcare providers have many clinical management competencies. In a healthcare era where patient care is optimized with clinical specialty, it is important to train physicians to develop competency for general care, as well as critical, and emergency or crisis situations.
- International medicine and rural medicine encounter various difficulties in patient care due to limited resources and experiences. Simulation training provides the opportunity to be "immersed" and "experienced" in areas where the range of real patients may be restricted.

Implementation

To fulfill these competencies, clinicians should be able to manage patients from the common to the rare, and from the healthy patient to the very critical patient. They must also be able to handle unexpected emergency events with least harm to the patient. In addition to providing exposure to a range of conditions, it is important to provide opportunities for learners to train with the range of tools and equipment they are likely to encounter in clinical practice. Advances in medical devices can drive the need to have a range of simulation scenarios so that learners are prepared not only to manage a variety of conditions, but to do so with a range of tools and equipment options.

In Boxes 12, 13 and 14 are some examples of education strategies showing effectiveness in capturing clinical variation in simulation-based learning.

Box 12. Example: Cardiac murmur interpretation.

At the University of Miami, educators use simulation to demonstrate the range and variations of common cardiac murmurs (Gordon et al. 2007). For example, the various presentations of mitral regurgitation are simulated, linked to the underlying anatomic defect of the mitral valve apparatus.

Mitral valve apparatus defect	Mitral regurgitation characteristic(s)
Calcified mitral valve annulus	Combined mitral regurgitation and stenosis
Ruptured chordae tendineae	Short, early systolic murmur heard at apex
Valve degeneration from rheumatic fever	Holosystolic murmur heard at apex
Dilated left ventricle from cardiomyopathy	Holosystolic murmur with third and fourth sounds
Papillary muscle dysfunction from ventricular aneurysm	Crescendo-decrescendo systolic murmur at apex radiating anteriorly
Systolic anterior movement from hypertrophic cardiomyopathy	High pitched, crescendo murmur

Box 13. Example: Orotracheal intubation.

At the University of Utah, educators have developed a curriculum to train novice learners to perform orotracheal intubation (Thomas et al. 2010). They incorporated the following difficult airway attributes and determined the eventual success rates of the learners. The difficult airway features to which learners were exposed included:

- Cervical immobilization
- Trismus (difficulty opening mouth)
- Pharyngeal obstruction
- Using a straight blade
- Laryngeal spasm
- Tongue edema

Box 14. Example: Patient sedation in a dental office.

At the University of Colorado, dentists developed a curriculum to teach crisis management during complications that may result during local anesthesia and sedation procedures (Tan 2010). They developed cases that reflect the possible range of serious problems that may occur in a dental office. These included:

- Anaphylaxis
- Laryngospasm during procedural sedation
- Sedative medication overdose
- Multiple drug interaction with resultant cardiac arrhythmia

The range of conditions does not have to be limited to the hospital environment. Indeed, the number of diagnostic and therapeutic procedures performed under sedation in patients outside the operating room setting has increased substantially over the past decade (Krauss & Green 2006). This has important consequences, as healthcare providers must be able to recognize and manage the various clinical situations that might arise during the sedation procedures.

Challenges encountered

Perhaps the greatest challenge in using the clinical variation afforded by simulation is choosing what to incorporate into the session(s). The clinical variation within a scenario or course should be driven by the learning outcomes. Additionally, choosing a simulator with the necessary clinical or physiologic characteristics can be challenging. One approach is to conduct a careful needs assessment and focus on the most important clinical cases to be encountered. Optimally, this should be a sample of the clinical cases likely to be encountered in the healthcare provider's clinical practice, and those required by certifying bodies. There is a need to balance the range needed to represent the clinical domain with the depth of learning and the availability of resources (faculty and staff time, simulators, etc.). One solution to limited resources is collaboration, and increasingly, there are online repositories (e.g. MedEdPortal, www.mededportal.org) where faculty may access resources (e.g. simulation scenarios, assessment tools) developed by colleagues at other institutions.

Conclusions

Simulation is a very useful tool in capturing the clinical variation found in patient populations. This is increasingly important as a confluence of factors has come together to limit clinical and procedural exposure for trainees. Additionally, the need to standardize curricula and ensure that trainees achieve mastery of critical competencies makes the clinical variation afforded by simulation particularly important. The expected learning outcomes should be the guiding principle for faculty to determine the range of content to be incorporated in a course or educational intervention.

Individualized learning

Definition and background

Individualized learning provides the opportunity for reproducible, standardized educational experiences where learners are active participants, not passive observers. Individualized learning is not simply learning on one's own, but is learning that provides unique experiences adapted to one's specific learning needs. Learning and motivation can be enhanced when learners take responsibility for their own progress (Boekaerts 1996). Individualized learning allows users to progress along their learning curve at a speed and acceleration that optimizes their learning as they progress towards competence or mastery in a given domain (Issenberg et al. 2005).

Importance of individualized learning in SBHE

Trainees are now being admitted to health professions schools with a diverse set of prior educational and professional experiences, and more often, residents are entering training programs from around the globe. Even within a given program, trainees are more frequently being trained in "community" or rural settings, or at hospitals or clinics that specialize in a very narrow area. This diversity in training provides excellent opportunities to gain clinical experience in certain areas, but can limit the depth and breadth of cases that trainees encounter. This diversity in prior educational, professional and clinical experiences contributes to a wide spectrum of learner knowledge, skills and attitudes. Tailoring learning to an individual's needs is therefore increasingly important and may lead to increased learning efficiency and effectiveness. Simulation is a valuable tool in providing individualized learning experiences. Simulators can be used for baseline testing and formative evaluation, and many allow complex clinical tasks to be broken down into component parts that learners can master at their own pace. As stated in the BEME review, "The goal of uniform educational outcomes despite different rates of learner educational progress can be achieved with individualized learning using high-fidelity medical simulations." (Issenberg et al. 2005).

Principles of individualized learning

The theory of directed self-guidance provides a useful model for individualized learning that can be applied to SBHE. Directed self-guidance is defined by Brydges and colleagues as "self-guided learning which is informed and structured by external influences. External direction helps shape the educational content and context, which impact the beneficial effects of self-guided learning" (Brydges et al. 2009). In this model, learners receive support and direction to enhance the self-directed learning approach. Self-guided learning is not an innate ability but is a skill a teacher and learner collaboratively develop. Simulation can be effectively used for individualized learning as part of directed, self-guided learning (Brydges et al. 2009). Determining the knowledge and skills a learner already possesses, and then allowing him or her to progress through training at a pace commensurate with his/her skill acquistion, is more efficient and perhaps more effective than a time-prescribed intervention.

Implementation

Figure 2 shows steps in developing an individualized learning program.

Challenges encountered

Self-directed individualized learning using SBHE faces a number of challenges related to the simulators, the learners, the instruction and the curriculum. Opportunities for

Example: Developing a Simulation-based Individualized Learning Program in Suturing Skills for First-year Surgical Residents

Step 1 - Diagnose Learning Needs: Learning needs will commonly be informed by objectives and outcomes defined by the requirements of training and anticipated areas of practice. The baseline knowledge and skills of the intern will depend upon the clinical experiences they have gathered during their medical school curriculum, electives, other training, and prior self-directed learning. A baseline knowledge and skills test using simulated suturing may be taken to determine the areas in which a trainee has learning deficits, and the educational activities adapted to address these needs.

Step 2 – Setting Learning Objectives: Objectives should be explicitly set at the outset, as should the means by which they are to be evaluated. The objectives include knowledge components, such as learning about the various types of suture material, instruments used in suturing, types of sutures and when they should be used, etc. The objectives may also include specific outcomes related to objectively set criteria such as time to place a prescribed number of sutures of a certain tensile strength on a particular simulated wound.

Step 3 - Identifying Resources for Learning: Interns may be familiar with certain resources that they can access, such as books, online videos, suturing models, etc. However, providing guidance regarding appropriate resources, including written materials or instructional videos prepared specifically by the instructor, or direct observation of an expert performing the suturing task in whole or in part, may ensure that learners are not reinforcing poor techniques.

Step 4 – Designing Learning Experiences and Strategies: Guidance regarding instructional design and engagement in effective learning activities is a key component of guided, self-directed learning. Learners who self-guided their access to instruction and set process goals (involving mechanisms of performing the task), compared to outcome goals (regarding the final product), performed better on retention than those whose access was externally controlled (Brydges et al., 2009). Faculty can provide the learner with defined process goals through an instructional video that is available during independent practice.

Step 5 – Providing Self-feedback: Self-assessment accuracy can be enhanced by feedback, including video feedback of one's performance, and by providing examples of various levels of performance for learners to use as benchmarks in self-assessment (Colthart et al. 2008). Simulators can provide assistance in self-assessment by providing feedback during the simulation (e.g., changes in physiologic variables in response to an intervention, flashing light when an error is made, etc.) or after a given simulation (time required to complete task, efficiency of hand movements made relative to an expert at the task, etc.).

Figure 2. Steps in developing an individualized learning program.

self-directed learning should be maximized by providing access to instructional materials and simulators on a schedule and at a location that meet the needs of trainees. This can be difficult in practice as simulation centers are often not optimally located within the clinical or education environments in which the learners spend most of their time. The significant cost of simulators and related equipment can understandably make programs reluctant to provide trainees with open access unless appropriate supervision and technical support can be provided. Scheduling issues are often complex as there are often many groups that may be using the simulation center for competing needs. Determining the conditions and simulators that maximize educational benefit can also be challenging, and may vary for each clinical skill and trainee.

Learners are obviously integral to directed, self-guided learning, and in order for any intervention to be successful, they must be motivated. Necessary support (e.g. technical support, peers, expert faculty) may need to be available, and systems for identifying when self-guided learning is not working should be developed. The curriculum must also be structured in such a way to allow self-directed learning to occur. If learners have too many competing interests for their time, they may not capitalize on learning opportunities. Dedicating time for self-directed learning is essential. As more programs have increasing outcome-based and self-directed components, the logistics of scheduling educational activities for all trainees will become increasingly complex.

Conclusions

Self-guided individualized learning should not be framed as a purely individual activity, as external resources are necessary for the trainee to experience the greatest educational benefit (Brydges et al. 2010). Through directed self-guided learning, educators create conditions for effectively learning through appropriate instructional design of unsupervised learning activities. Incorporating individualized learning based on previous trainee experience and rate of skill and knowledge acquisition may be logistically challenging, but would clearly be more efficient. If used appropriately, directed self-guided learning can maximize learning efficiency, minimize the overall use of educational resources, and may help improve the life-long learning skills of clinicians when they enter practice.

Approaches to team training

Definition and background

Salas and colleagues define teams as interrelated individuals, each with specific roles, working to accomplish a common goal. The interrelated individuals must interact and adapt to achieve specified, shared, and valued objectives (Salas et al. 1992). Teamwork is where coordination of effort, dynamic exchange of resources, and adaptation to changing situational factors occur. It is an interrelated set of team member thoughts, behaviors, and feelings needed for the team to function as a unit (Swezey et al. 1994). Salas and colleagues presented a model of teamwork that promotes effectiveness and coordinating mechanisms summarized in Table 4 (Salas et al. 2005a,b).

Team training includes a set of theoretically derived strategies and instructional methodologies designed to:

(1) increase the members' team competencies (underlying effective communication, cooperation, coordination, and leadership); and
(2) give team members opportunities to gain experience using these critical competencies (Lemieux-Charles & McGuire 2006).

The team training strategy is most effective when available tools, delivery methods, and content are combined. Team training in healthcare can be conceptualized across patient populations (e.g. pediatric teams, obstetric teams), disease type (e.g. stroke teams, trauma teams), or care delivery settings (e.g. pre-hospital care, operating room).

Importance of team training in SBHE

Teamwork is the key factor to patient safety. Healthcare is a multidisciplinary task where interaction of individuals from diverse backgrounds (expertise, training, experience, and culture) can affect patient care. These teams could be functioning in an environment characterized by high stress, high-stakes outcomes, and time pressures. Teamwork training is a hallmark of high-reliability organizations in fields such as aviation, nuclear power, and healthcare. Likewise, patient safety is directly impacted by teamwork. The Joint Commission reports indicate miscommunication as the root cause of nearly 70% of

Table 4. Teamwork competency model.

Team competency	Definition
Team leadership	The ability to direct and coordinate the activities of other team members, assess team performance, develop team knowledge, skills and abilities, motivate team members, plan and organize, and establish a positive atmosphere.
Mutual performance monitoring	The ability to apply appropriate task strategies to develop common understandings of stress, skills and the environment external to the team itself.
Backup behavior	The ability to anticipate other team members' needs through knowledge about their responsibilities.
Adaptability	The ability to adjust team strategies and alter the course of action based on information gathered from the environment through the use of backup behavior and reallocation of intra-team resources.
Team orientation	An attitude characterized by a propensity to take others' behavior and input into account during group interaction, and the belief in the importance of team goals over individual members' goals.
Shared mental models	The shared understanding that team members hold.
Mental trust	The shared belief that team members will perform their roles and protect the interests of their teammates.
Closed-loop communication	The exchange of information between a sender and a receiver.

sentinel events (Joint Commission Sentinel Events 2011- www.jointcommission.org/sentinel_event). Furthermore, a review linking teamwork and patient outcomes found empirical support for the relationship between teamwork behaviors and clinical patient outcomes. Salas and colleagues point out that "training also provides opportunities to practice (when used with simulation) both task- and team-related skills in a 'consequence-free' environment, where errors truly are opportunities for learning and providers receive feedback that is constructive, focused on improvement, and non-judgmental" (Salas et al. 2008). Team training works in carefully designed curricula which allow opportunities for the deliberate practice of teamwork skills in a simulation-based medical environment (McGaghie et al. 2010a).

A growing body of literature indicates the impact of teamwork on clinical outcomes in several diverse clinical settings, such as ambulatory care (Campbell et al. 2001), nursing homes (Rantz et al. 2004), community-based care (Mukamel et al. 2006), emergency departments (Morey et al. 2002), intensive care units (Young et al. 1998; Wheelan et al. 2003; Dubose et al. 2008), operating rooms (Undre et al. 2006; Lingard et al. 2008), labor and delivery units (Thomas et al. 2006; Mooney & Neily 2007) and inpatient wards (Curley et al. 1998; Strasser et al. 2008). Despite the growing evidence and involvement from various healthcare disciplines, team training programs have struggled to achieve desired outcomes. Training success is highly dependent not only on curricula and instructional strategies, but on several more complex organizational variables such as leadership support, resource availability, training environment, and readiness for change (Salas et al. 2009).

Principles of team training

The rules and principles of team training using simulation are fundamentally similar to any other SBHE intervention. Salas and his team describe eight critical principles that are important to consider before, during, and after team training (Salas et al. 2008) (Table 5).

Implementation

There are many examples of simulation-based team training design, implementation, and evaluation in healthcare (Rosen et al. 2008a,b; Shapiro et al. 2008; Salas et al. 2009; Rosen et al. 2010; Weaver et al. 2010a,b,c,d). Fernandez and colleagues summarize the key components that are necessary for an effective team training program in the context of simulation (Fernandez et al. 2008):

(1) Clear linkages between organizational, personnel, and task analysis increase overall simulation program effectiveness.
(2) Conduct a multilevel needs analysis prior to implementing any team training program, especially when adapting and using outside programs.
(3) The goals of the program should be linked to the expectations of the organization.
(4) The culture of the organization, especially multi-ethnic culture, needs special attention. A number of problems can arise from socio-cultural differences.
(5) It is important to consider not only the training objectives and the instructional format, but also the strategy used to meet training goals. The interventions

Table 5. Principles of team training.

Principle	Content
1. Identify critical teamwork competencies and use these as a focus for training content.	– Teamwork is a complex process with many relevant types of knowledge, skills, and attitudes. – Teamwork focuses on leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation. – Examples are crew resource management, team-building, and cross-training programs.
2. Emphasize teamwork over task work, design for teamwork to improve team processes.	– Because of scarce time and availability for training, there is a tendency to include elements of both task work and teamwork into training sessions. – Most effective team training programs that improve team processes focus only on teamwork.
3. One size does not fit all. Let the team-based learning outcomes desired, and organizational resources, guide the process.	– Effective team training is guided by educational science. – Teamwork is more than knowledge; it also includes behavior and attitudes. – For effective team training, a mix of traditional methods of instruction (lecture), modeling/demonstration, and practice or simulation should be utilized.
4. Task exposure is not enough. Provide guided, hands-on practice.	– Effective team training also entails guided, hands-on practice. – High-fidelity simulation and role-playing are the most-utilized practice training methods.
5. The power of simulation. Ensure training reflects work environment.	– Effective training creates an environment in which trainees go through the same mental processes they will utilize on the job. – Simulation-based training offers opportunities for trainees to implement and practice skills in environments similar to what they will experience on the job. – Key to effective use of simulation-based training is to create realistic scenarios that trainees will or could potentially encounter on the job.
6. Feedback matters. It must be descriptive, timely, and relevant.	– Feedback can include both outcome-based and behavior-based information. – Feedback is usually in the form of a debriefing during which trainees discuss their own performance with the help of a facilitator.
7. Go beyond reaction data. Evaluate clinical outcomes, learning, and behaviors on the job.	– Training must be evaluated to measure learning outcomes and to determine program effectiveness. – Methodological approach to training evaluation (e.g., Kirkpatrick four-level typology) should be implemented (Kirkpatrick 1996).
8. Reinforce desired teamwork behaviors. Sustain through coaching and performance evaluation.	– The behaviors targeted during training must be reinforced on the job. – To promote the transfer of teamwork competencies targeted in training to the job environment, teamwork behaviors should be incorporated into coaching and mentoring sessions, as well as performance evaluation.

should vary depending on the training objectives, learner characteristics, and available resources.

(6) Teamwork development is a culture changing process. In order for a program to be effective, the concept of "team" must be embedded in the learners' work routine. It is therefore critical that a novice's initial exposure to teamwork occur within a familiar domain.

(7) In the early stages of learning, case studies and role playing are effective, efficient ways to engage learners and train them in teamwork. But in the later stages of learning, where experience and knowledge have been accumulated, high-fidelity medical simulation plays a very important role in delivering effective learning.

(8) Detailed training evaluations should occur to ensure that training is effective and goals are being met.

Examples of simulation-based team training programs

The examples of simulation-based team training implemented in various healthcare disciplines were developed with the same principles of simulation-based education summarized above. We will emphasize the key components that are important in implementing a successful simulation-based team training program (Table 6).

Challenges encountered

Although the importance of simulation-based teamwork training for healthcare providers is clear, there are several issues that challenge the development of effective provision of such training.

First is the multilevel nature of teamwork: Team members are heterogeneous in their roles and competencies, but must come together to achieve common goals. Therefore, it is imperative to perform a multilevel needs analysis before implementing any team training program. The second challenge involves performance measurement. It is important to design measurement tools that yield reliable data that enable others to make valid judgments to provide diagnostic and corrective feedback. Third, there are obvious time constraints on the target audiences for training. Clinical duties always take precedence, so it is often difficult to have staff attend training. Careful attention to overcoming time constraints and facilitating accessibility to training is very important. Some solutions are to develop a very short but focused program, or perform *in situ* simulation training. A fourth challenge common to many simulation-based training programs is the lack of faculty with expertise and experience in team training. Many organizations or institutions must make faculty development their priority in order to make simulation-based team training effective. Finally, organizational leadership must show full support and provide policies and reward systems for the trainers and the trainees. Without leadership support, it will be impossible to maintain and sustain simulation-based team training programs in an institution.

Conclusions

In recent years, it has become clear that training and practicing in "silos" poses a threat to patient safety. Healthcare is delivered in teams, and it is therefore logical that healthcare providers need to train as a team, not only during undergraduate education, but also in continuing education of practicing providers. Team training using simulation affords the opportunity for practitioners from different disciplines to come together to improve the skills used in the clinical setting. Miscommunication is the greatest source of error in healthcare delivery, and team training can be part of the solution.

Future directions of education using simulation

The changing paradigm of healthcare education

Over the past decade, it has become increasingly clear that exposure to patients in a clinical environment with *ad hoc* educational sessions is not sufficient to create competent healthcare practitioners (Joorabchi & Devries 1996; Mangione & Nieman 1997; Lypson et al. 2004; Friedman et al. 2008; Bell et al. 2009). Furthermore, it is evident that there is a need for curriculum standardization, deliberate skills practice, structured exercises, and outcomes-based evaluation with feedback. Training without these components leaves competency largely up to chance. Given the high-risk nature of medical practice, and that the outcomes directly impact patients' health and livelihoods, this is less than acceptable. The growing and sustained focus on medical error reduction and patient safety, and the need to provide safe, learner-centered and ethical training, lead us to a model that incorporates SBHE.

> "Clinical experience alone does not guarantee the acquisition of clinical competence."
>
> – *Issenberg & McGaghie 2013*

Simulation-based education as a solution

The new model of healthcare education must incorporate simulation as a complement to clinical exposure, in a framework that incorporates mastery learning and ample opportunities for deliberate practice to achieve the expected competencies. Evidence increasingly shows that simulation-based healthcare education with deliberate practice leads to improved and lasting results compared with traditional clinical education (McGaghie et al. 2011b). Simulation may also substitute for clinical experience to ensure the needed exposure to a range of clinical cases. This is a necessity, due to increasing limitations for clinical training opportunities.

Simulation-based education is also part of the solution in the context of medical error reduction and patient safety. Simulations used to address miscommunication and other sources of error, especially in the context of team training and systems-based practice, are a crucial component in improving patient outcomes (Birnbach & Salas 2008; Salas et al. 2008; Kuehster & Hall 2010; Issenberg et al. 2011a,b). Simulations will increasingly be used to supplant animal and live-tissue

Table 6. Team strategies and tools to enhance performance and patient safety (Team STEPPS) for medical and nursing students.

Robertson and colleagues adapted the Team Strategies and Tools to Enhance Performance and Patient Safety (Team STEPPS) for use as an educational intervention for medical and nursing students (Robertson et al. 2010).

Component	Content
Needs analysis	– Despite the importance of teamwork and communication, these critical skills are not taught in health professions education. – Philosophy at both medical and nursing school is to teach and concurrently develop a culture around the importance of interprofessional teams and their role in the provision of patient-centered care.
Instructional methodologies	– Lecture followed by small-group problem-solving sessions, including interactive play, medical simulations, and review of video vignettes. – Standard debriefing process to lead the discussions focused on the use or absence of teamwork skills.
Simulation modules	– High-fidelity simulation and incorporation of crisis resource management training.
Implementation	– Half-day workshop for all first-year nursing students and third-year medical students. – Facilitators from the academic and clinical setting attended a two-hour training session.
Assessment and evaluation	– 12-item teamwork knowledge test on leadership, situation monitoring, mutual support, and communication (Hobgood et al. 2010). – 14-item Collaborative Healthcare Interdisciplinary Relationship Planning (CHIRP) scale for attitude assessment (Hobgood et al. 2010). – 17-item self-rating of the video vignettes using the Team Skills Checklist Video Rating (Hobgood et al. 2010). – 15-item training satisfaction survey from the Medical Team Training Program Evaluation Tool (Baker et al. 2006).

Example. Guise et al. developed a mobile obstetric emergency simulation and team training program. The mobile unit has the advantage of being practical, given the expense of simulation equipment, the time required for staff to develop educational materials and simulation scenarios, and the need to have a standardized program to promote consistent evaluation across sites (Guise et al. 2010). The system was successful in developing new skills, maintaining infrequently used clinical skills, and uncovering latent safety threats in the clinical setting.

Component	Content
Needs analysis	– Involved stakeholders in development, making the curriculum short, engaging, accessible, and clinically important, with a high perceived return on investment. – Obstetric emergencies, such as shoulder dystocia, postpartum hemorrhage, and eclampsia, were chosen because their time-critical nature makes communication and teamwork issues apparent.
Instructional methodologies	– Evidence-based clinical didactics, followed by teamwork skills training using SBAR (situation, background, assessment, and response), transparent thinking, and directed and closed-loop communication.
Simulation modules	– High-fidelity simulation using a mobile cart.
Implementation	– On-site schedule of 2.5 h for each visit. – Two emergency simulation scenarios were run, with facilitated team debriefing followed by a standardized clinical didactic session.
Assessment and evaluation	– Identification of latent quality and safety issues conducted by researchers through a thematic checklist (Baker et al. 2006).

Example. Rosen and colleagues developed an event-based approach to designing simulation scenarios and measurement tools for training and assessing teamwork skills in emergency medicine residents (Rosen et al. 2008b).

Component	Content
Needs analysis	– Training in teamwork skills in emergency medicine residency programs is very important due to the complex and time-pressured nature of patient care in emergency medicine. – A single encounter with a new and unknown patient in a chaotic and emotionally charged environment makes establishing rapport with the patient extremely difficult.
Instructional methodologies	– Event-based approach to training, to systematically link the content of training scenarios and measurement tools to the teamwork competencies being trained (Fowlkes et al. 1998).
Simulation modules	– High-fidelity simulation and incorporation of crisis resource management training.
Implementation	– Choose a clinical situation capable of meeting the learning goals. – Explicitly defined knowledge, skills, and attitudes necessary for effective performance in given clinical context. – Define expected behaviors associated with critical events, and create opportunities to perform, with triggers that elicit performance being trained.
Assessment and evaluation	– Create behavioral checklists using critical events and targeted responses. – Determine causes of effective and ineffective performance. – Use products of performance diagnosis to make decisions about what feedback to provide and what future training is needed.

models as pressures mount to curtail their use, and as the fidelity of the replicated tissue models increases. Simulation is also being increasingly considered as an enabling technology to facilitate implementation and translational sciences (McGaghie et al. 2011c).

In addition to traditional methods, simulation will increasingly be used as a tool for accreditation for licensure and maintenance of certification (Ziv et al. 2007; Buyske 2010; Holmboe et al. 2011; Steadman & Huang; 2012). Simulation-based training and assessment have already been incorporated in some specialties in a variety of countries for high-stakes examinations, and certification bodies are increasingly examining ways to incorporate simulation into requirements for initial certification, continuing education, and ongoing certification (Ben-Menachem et al. 2011; Levine et al. 2012).

In our endeavor to further understand the complex interactions between healthcare providers and their environment, simulation will be an important tool. Simulation will also be increasingly used to further study human factors in patient care, as it is well suited to better understand the interplay between human and environment.

Opportunities for research

In recent years, several summits, task forces and committees have been convened, and articles written, on future directions and needs in SBHE research. In 2011, the Society in Europe for Simulation Applied to Medicine (SESAM) and the Society for Simulation in Healthcare (SSH) organized an Utstein-style meeting with the goal of setting a research agenda for SBHE (Dieckmann et al. 2011). Research questions were categorized into three main themes: instructional design, outcomes measurement, and translational research (Issenberg et al. 2011a).

Instructional design. Questions still remain about how best to structure simulation interventions and the best frequency and timing for effective learning acquisition and skill retention. Deliberate practice has been shown to be an effective method for skill acquisition, but research is needed to determine the required intensity, duration and feedback characteristics (McGaghie 2008).

Feedback and debriefing are critical in optimizing learning using simulation. However, questions about what features lead to effective learning, when the best time is to provide feedback, how best to use digital recordings, and whether to use debriefings led by faculty, peers or the learners themselves, still remain to be answered. With regard to integration into the curriculum, the ideal balance between simulation-based education and other modalities must be defined.

Outcomes measurement. As we increasingly adopt outcomes-based education, we must develop and refine assessment tools that yield reliable data. Rigorous measures will allow for valid judgments about competence and are required for adequately evaluating progress and determining areas for improvement. Future studies are needed to set appropriate mastery standards for procedures and clinical skills, as are studies into the way in which simulations with a range of difficulty can best be used to achieve improved patient care practices that are retained over time.

Translational science. Similar to the biomedical translational science model that aims to transfer the results from laboratory research to the patient bedside, McGaghie states that SBHE translational science "demonstrates that results achieved in the educational laboratory (T1) transfer to improved downstream patient care practices (T2) and improved patient and public health (T3)." (McGaghie 2010b; McGaghie et al. 2011c). Much of simulation research, until recently, has focused on showing improved educational outcomes. Of late, some studies have shown that what healthcare trainees and practitioners learn using simulations transfers to behaviors in the clinical setting and can lead to improved patient outcomes and decreased errors and complications. Additional research is needed that substantiates that the skills learned using SBHE translate to improved patient outcomes and, ultimately, population health.

Conclusions

The goal of healthcare education is to develop competent and caring healthcare practitioners who are capable of providing the highest level of safe care to their patients. Determining the optimal path, and the elements needed to arrive at this goal, remains a challenge and work in progress. Over the past two decades, simulation has entered the scene in dramatic fashion and its use has grown exponentially. Borrowing from other high-risk fields that have been using simulation for quite some time, such as aviation and astronautics, we have increasingly begun to refine the most effective and efficient ways to use simulation in healthcare education. We are learning how best to provide feedback and debriefing with deliberate practice, in a mastery learning model, to create successful educational programs and lasting educational results. Research continues to inform best practices in SBHE to achieve educational outcomes, and improved clinical care and patient outcomes.

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