Simulation and Adult Learning

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> Simulation is a technique—not a technology—to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner.[1]
>
> (David Gaba)

Simulation has been embraced by the medical community as an important method for improving clinical training and patient safety. Practitioners of simulation, or "simulationists," use a recipe consisting of clinically important medical cases, lessons learned from other high-reliability organizations and industries, computer-driven full-body manikin simulators, realistic procedural task trainers, and a dash of theatre to create memorable learning experiences that can be transferred directly to patient care. As Kyle and Murray have succinctly observed, "Clinical simulation is pretend for the purpose of improving behaviors for someone else's benefit."[2]

Medical simulation had existed primarily in task trainer and full-body low-fidelity forms until about 10-15 years ago. The first human patient simulator, Sim One, was developed in the late 1960s at the University of Southern California by J.S. Denson and Stephen Abrahamson and featured in *National Geographic* and *Life* magazines.[3-5] However, medical simulation as a discipline really gained momentum during the 1990s to 2000s because of the convergence of several key factors:

1. Dr. David Gaba's vision of immersive simulation—in 1988, Gaba and DeAnda described the first production of the first immersive simulation environment in their seminal work, "A Comprehensive Anesthesia Simulation Environment: Re-creating the Operating Room for Research and Training."[3] Dr. Gaba fabricated the anesthesiologist's "physical, as well as mental, task environment"[3] using an intubation/thorax mannequin and a variety of electronic inputs to replicate electrocardiograms and invasive pressures, pulse oximetry, temperature, and blood pressure. The authors described the use of scripts to present anesthesia scenarios that could be controlled by the simulation

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operator to react dynamically to the actions of the students. Additionally, key actors, such as the circulating nurse and the surgeon, were played by the simulation director. The paradigm of creating a realistic environment where the students were required to interpret the monitored data and physically perform tasks simultaneously forced subjects to "reallocate time and attention" and perform as if it were a real situation. They combined the scenario experience with video debriefing to create a reflective learning process. The described benefits of simulation included "(1) there is no risk to a patient; (2) scenarios involving uncommon but serious problems can be presented; (3) the same scenario can be presented sequentially to multiple subjects; (4) errors can be allowed which in a clinical setting would require immediate intervention by a supervisor; (5) if desired, the simulation can be halted for teaching and can be restarted to demonstrate different techniques; and (6) recording, replay, and critique of performance are facilitated using the simulator."[3]

2. The founding of the Society for Simulation in Healthcare in 2004 "to represent the rapidly growing group of educators and researchers who utilize a variety of simulation techniques for education, testing, and research in health care."[6] This society has facilitated interaction between multiple specialties and disciplines within the medical-related professions, including physician, nursing, allied health paramedical personnel, and industry. Additionally, the organization has had international influence and has successfully brought simulationists from around the world together to promote advancement of simulation-based training and education.
3. The pioneering work on expert-performance conducted by Dr. K. Anders Ericsson over the last two decades transformed the way medical educators think about how clinicians acquire clinical competence and, indeed, how medical expertise is defined. His concept of "deliberate practice" (DP), where training is focused on improving particular tasks, was central to the development of a unique simulation-based experiential learning pedagogy that has been adopted by physicians across many disciplines.[7,8] Dr. Ericsson was able to successfully translate his findings across multiple nonmedical domains to the medical community and encourage the use of simulation for training and assessment. "Research on medical expertise and simulation training in technical procedures and diagnosis provide exciting opportunities for establishing translational research on the acquisition of superior (expert) performance in the clinic by capturing it with representative tasks in the laboratory, reproducing it for experimental

analysis, and developing training activities, such as deliberate practice, that can induce measurable improvements in performance in the clinic."[9]

4. The Institute of Medicine publication, "To Err is Human: Building a Safer Health System," released November 1, 1999, highlighting the prevalence of medical errors in the health care system, brought patient safety to the forefront of the medical and lay consciousness and generated action to define and implement new methods to systematically design safety into all processes of care.[10] Simulation-based training was proposed as a core method for creating learning environments to measure and improve the understanding of the nature and frequency of errors. "Use Simulations Whenever Possible" was recommended to health care organizations and teaching institutions for "training novice practitioners, problem solving, and crisis management, especially when new and potentially hazardous procedures and equipment are introduced." The report also recommended that the use of Crisis Resource Management techniques, modified from the aviation industry's Crew Resource Management systems, in dynamic settings, such as the emergency department and operating rooms, to improve communication and reduce error "should be more widely applied."[10]
5. The timely development of commercially available full-body high-fidelity manikin simulators at the turn of the millennium allowed for the actualization of the visions of Dr. Gaba and the Institute of Medicine and has since fueled widespread implementation of immersive simulation-based training on multispecialty and multidisciplinary levels. Laerdal Medical (Wappinger Falls, NY) launched SimMan, its adult-sized portable high-fidelity manikin in 2002. It has since developed its infant simulator, SimBaby, in 2005 and SimNewB, its neonatal simulator, in 2008. Medical Education Technologies, Inc (METI) (Sarasota, FL) debuted their Emergency Care Simulator in 2003, and BabySIM, their infant simulator in 2005. Gaumard Scientific (Miami, FL) produced the first high-fidelity birthing simulator, dubbed "NOELLE," with its own neonate, "Newborn HAL."

The result of the confluence of these developments has been the progressive, almost viral spread of medical simulations across disciplines. As technology continually improves and simulationists become more sophisticated with their scenario orchestration, there has been an increase in the realism of simulation and the opportunity to practice in simulated environments. The positive impact is now being described in terms of real patient outcomes.[11-13]

There is one critical point to remember when discussing the efficacy of simulation training: in order for our students to really learn, *we have to ensure that a proper learning environment is created for them*. This principle is the real basis for effective simulation-based training and resides in *adult learner-centered* educational principles. The remainder of this article describes the types of simulation currently available, the framework for simulation-based training, and the educational pedagogy that serves as the foundation for medical simulation with adult learners.

Types of Simulation

Simulation has traditionally been divided into low and high fidelity. Low-fidelity simulation classically refers to task-trainers designed for procedural training, such as airway heads, IV arms, static cardiopulmonary resuscitation manikins, and the like. High-fidelity simulation refers to full-body software-controlled manikins with dynamic mechanical features, such as airway obstruction (laryngeal occlusion, tongue swelling, or trismus), heart sounds, lung sounds (wheezing, rales, crackles, absence of breath sounds), bowel sounds, central and peripheral pulses, and seizure simulation. Most can accommodate a wide variety of procedures, such as bag-mask ventilation, endotracheal intubation, cricothyrotomy, tube thoracostomy, and placement of a Foley catheter. The most fully featured simulators can detect anesthesia gases, sweat, and tear; produce mydriasis/miosis; and have the ability to register medication administration and dosage. Specialty high-fidelity manikins include neonatal simulators and a pregnancy simulator that has all the features of high-fidelity manikins, but also can deliver an infant.

Experienced simulationists know this categorization is often arbitrarily simplistic, and with technological advance, these categories are becoming more blurred. Low-fidelity trainers are becoming more realistic with each generation. Central line torsos now can provide anatomically realistic ultrasound images so that ultrasound-guided central line placement can be practiced. Trainers have been developed for lumbar puncture training with interchangeable modules to simulate an obese or elderly patient, thus increasing the difficulty level. By combining low-fidelity task trainers in an immersive environment while a standardized patient interacts with the participants, we can turn a low-fidelity simulator into a high-fidelity experience. Likewise, a "high-fidelity" full-body manikin simulator can be reduced to a simple airway task trainer or cardiopulmonary resuscitation manikin if the simulation does not provide all the accessory stimuli (patient voice, nursing confederate communication, storytelling) or if the software capabilities are not used properly. As virtual reality and

computer simulation becomes increasingly immersive and mainstream, it may be that these modalities will provide the most realistic simulation experience in the future.

Procedural Training

A multitude of task trainers are available to teach procedural skill acquisition in a variety of areas. A partial list includes noninvasive airway management, endotracheal intubation, surgical airways, difficult airway adjuncts, cardiac defibrillation and pacing, tube thoracostomy, central line placement, intravenous and intraosseous initiation, drug administration, lumbar puncture, birthing, and ultrasound, among others. Procedural simulation is covered in-depth in the article by Ahn and Menon in this issue.

Immersive Simulation

Immersive simulation is a planned educational activity where a learner or group of learners take part in the care of a simulated medical patient in an environment where the theatrical presentation is realistic enough for the participants to feel immersed in the surroundings, suspend disbelief, and manage the scenario as if the patient were real.

Doerr and Murray describe the "Simulation Learning Pyramid" that serves as the foundation for creating effective simulation-based experiences. The 4 elements of the pyramid are (1) the simulation plan; (2) the simulation; (3) the debriefing; and (4) transference.[14] Alinier has deconstructed the components of simulation even further and has devised a "Sequence to play the game known as Clinical Simulation" (Table 1).[15]

The simulation plan is a script designed by the instructors comprising the following elements: (1) predefined learning goals and objectives; (2) a description of how the case will play out, including plans for appropriate responses from the simulator to the participants' actions; (3) scripts for actors who play the voice of the simulator, the confederates (family member, nursing, prehospital provider, consultants, etc) as the learners are guided through the simulation. Included in the plan should be a method for setting the stage for the exercise and creating a safe learning environment as part of the introduction (Table 1).

There are numerous methods and environments for creating immersive *simulation*. Simulation centers are but one example. In situ simulation, where the scenario is executed in the clinical work area—such as the emergency department, intensive care unit, medical floor, ambulance, helicopter, or a moulaged field response—can provide an equal experience and has its own advantages. Participants manage the simulated

TABLE 1. The "Sequence to play the game known as Clinical Simulation"

(1) Welcome the participants and create a friendly, supportive atmosphere
(2) Introduce the faculty
(3) Presession evaluation to determine baseline knowledge, skills, and attitudes
(4) Explanation of session plan
(5) Ice-breaking activity recommended if participants do not know each other
(6) Explanation of the basic simulation rules, the philosophy
(7) Introduction to the patient simulator and simulation environment
(8) Basic "warm-up" scenario for the whole group
(9) Clarification discussion
(10) Separation of participants into groups—"hot seat" and observers
(11) Scenario execution
(12) End scenario
(13) Facilitate debriefing
(14) Summarize the important learning points
(15) Switch groups
(16) Repeat steps 11-14 for subsequent scenarios
(17) Conduct an overall session debriefing
(18) Postsession evaluation
(19) End session

Adapted from Alinier G. Chapter 76—Learning through play: simulation scenario = obstacle course + treasure hunt. In: Kyle RR, Murray WB, editors. Clinical Simulation: Operations, Engineering and Management. London: Elsevier/Academic Press, 2008. p. 745-9.

patient in their actual environments and perform tasks with their own equipment, allowing for increased realism, and possibly enhanced transfer of the experience into actual clinical care.

In addition to the physical space, providing stimuli—monitors, sounds, laboratory data, electrocardiogram, radiologic studies, nursing, family, and consultants—creates realism. Adding task trainers so that participants have to perform the actual procedure during an immersive simulation can provide additional performance measurement and imbue the learner with enhanced self-efficacy when a similar scenario presents during actual patient care. Adding standardized patients to interact with the learners allows for even more interaction and can train or assess communication skills.

Debriefing is a critical exercise in the simulation experience. The students use this as a time for critical reflection on the simulation. Facilitators guide the students through the management of the case by discussing the learning objectives and providing diagnostic feedback on the students' performances. Key insights from simulation-based training are derived during this important exercise. We want our learners to appreciate the positive aspects of their performance even when the outcome is not what they had hoped to have, but also to understand where they need to improve by providing constructive, directed feedback. Often,

the participants will volunteer what they feel they need to improve on without prompting.

Measurement of transference should ideally be determined before implementing a simulation curriculum to determine its relative effectiveness and to see if the lessons learned are incorporated into actual clinical care and with what frequency. This type of information can be used as feedback to make adjustments to improve on the simulation plan, the simulation, and the debriefing.

Adult Learning Theory

Adult learning theory serves as the foundation for simulation-based training. It is well known that adults learn differently than children because of age, maturity, and life experiences. Their learning tends to be more self-directed and independent. During the 20th century, a growing body of educational theories and concepts has been developed to describe how adults learn best. Effective medical simulation-based training applies these theories in practice to promote effective acquisition and retention of clinical skills.

Malcolm Knowles, widely considered one of the world's leading scholar-practitioners in the development of adult learning theory, developed a conceptual framework for adult learning that he termed "andragogy."[16] Principal to this framework are several assumptions about the nature of adult learners that must be considered when developing educational programs for them. These assumptions about adult learners are as follows[16,17]:

1. Adults need to know *why* they need to learn something before undertaking the effort to learn it. This has been termed "the need to know." Adults who take the initiative to learn based on this have been observed to spend considerable energy exploring the benefits they will receive learning it and the negative consequences of not learning it.
2. Adults have a self-concept biased toward independent and self-directed learning. Adults feel responsible for their own lives and their own learning. They resist or resent activities labeled as "education" that they feel is imposed on them.
3. Adults have acquired a great deal of life experience. Life experiences are a rich source of learning and have helped shape adults' self-identity more deeply than in children.
4. Adults value learning that helps them cope with the demands of their everyday life. This has been termed "the readiness to learn" and argues that adults become most willing to learn those things that are immediately applicable.

5. Adults are more interested in life-centered (also referred to as problem-centered or task-centered) approaches than subject-centered approaches to learning. Adults are more willing to learn things that are relevant and applicable to real-life situations.
6. Adults are more motivated to learn by internal drives than external ones. The most potent motivators for adults are internal pressures, such as the desire for increased job satisfaction, self-esteem, quality of life, or self-efficacy.

Based on these assumptions, Dr. Knowles formulated the following seven strategies to facilitate adult learning[16,17]:

(1) Establish an effective learning climate where learners feel safe and comfortable expressing themselves;
(2) Involve learners in the mutual planning of curriculum and methods;
(3) Have learners diagnose their own needs to promote internal motivation;
(4) Encourage learners to devise their own learning objectives;
(5) Encourage learners to identify resources and devise strategies for using resources to meet their learning objectives;
(6) Support learners in carrying out their learning plans;
(7) Involve learners in self-evaluation to promote and develop skills for critical self-reflection.

John Dewey, considered the most influential educational theorist of the 20th century, brought the concept of experiential learning to higher education. He theorized that all learning has a *purpose* at its endpoint. The initiation of learning begins with an *impulse* or experience.[18] In order for learning to occur, the impulse must then involve *observation* of the surrounding condition. Observation, to Dewey, meant not acting immediately on the impulse, but reflecting on the experience and comparing it to prior experiences. "*Knowledge* of what has happened in the past in similar situations in the past, a knowledge obtained partly from recollection and partly from the information, advice, and warning of those who have had a wider experience"[18] is considered in conjunction with the observations. *Judgment* combines observation and knowledge into an interpretation of the significance of the experience. Judgment translates the meaning of the experiences into the *purpose*—a desire to change or to create a plan of action for future similar experiences.

David Kolb, an organizational psychologist who was heavily influenced by Dewey, developed his now famous learning cycle (Fig 1) to

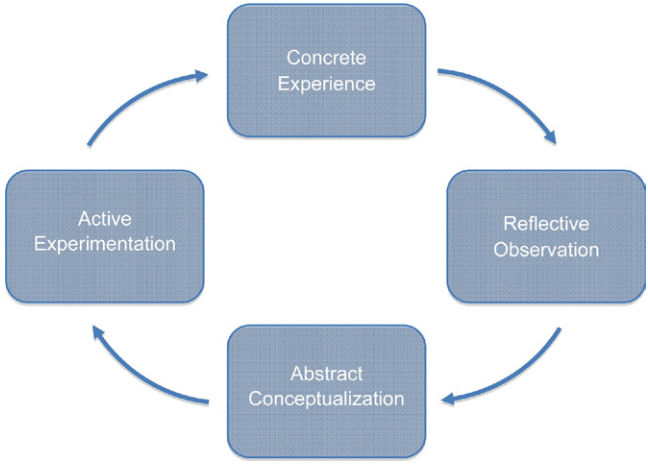

FIG 1. Kolb's learning cycle. (Adapted from Kolb DA. Experiential Learning: Experience as the Source of Learning and Development. Englewood Cliffs (NJ): Prentice-Hall, 1984.) (Color version of figure is available online.)

describe the learning process "whereby knowledge is created through the transformation of experience."[19] He considered learning *the* major process of human adaptation. The major tenets supporting his theory on learning include: (1) it is best conceived as a process, not in terms of an outcome; (2) it is a continuous process grounded in experience; (3) it requires the resolution of conflicts between dialectically opposed modes of adaptation to the world; (4) it is a holistic process; and (5) it involves transactions between person and the environment.[19]

Experiential learning as a process, according to Kolb, involves more than learning a set of facts or ideas (outcomes). Ideas are not immutable elements, but are continuously changed and reformed as a person experiments and reflects on the experiences they produce: "All learning is relearning."[19] Learning is a continuous adaption and resolution of the way a person conceptualizes the world and what a person actually experiences in the world.

Learners, if they are to be effective, need four different kinds of abilities—*concrete experience* abilities (CE), *reflective observation* abilities (RO), *abstract conceptualization* abilities (AC), and *active experimentation* (AE) abilities. That is, they must be able to involve themselves fully, openly, and without bias in new experiences (CE). They must be able to reflect on and observe their experiences from many perspectives (RO). They must be able to create concepts that integrate their observations into logically sound theories (AC), and

they must be able to use these theories to make decisions and solve problems (AE).[19]

In this way, Kolb's holistic approach unified learning as a "conceptual bridge across life situations such as school and work, portraying learning as a continuous, lifelong process." Kolb believed that the learning process must involve the person and the person's environment whereby the shared experience between the two is a transaction that leaves both person and environment changed.

Reflective practice describes the thought processes that professionals experience when they encounter a new or unexpected situation. Reflection in action, which occurs immediately, is the ability to learn and develop continually by creatively applying current and past experiences and reasoning to unexpected events while they are occurring. Reflection on action occurs later, after the event has occurred. It is the process of thinking back on what happened, what may have contributed to the unexpected event, whether the actions taken were correct or appropriate, what could have been done better, what should be done in the future to prevent a recurrence. The ability to understand how past experiences affect future practice is necessary for individuals to effectively improve their performance.[17]

Development of Expertise (Ericsson)

K. Anders Ericsson has revolutionized how we think about the way that individuals develop expertise. Before Ericsson's investigations, the definitions of medical expertise included possessing superior knowledge (ie, academic achievement), displaying the ability to teach (ie, lecturing), and accumulating many years of clinical experience. Age was felt to be correlated with wisdom.[8] Before Ericsson, physician and nursing expertise was often identified through peer-nomination processes among experienced professionals.[20]

He was one of the first to scientifically study the acquisition expert performance and determined that expertise required a period of 10 years to attain.[8] Moreover, he determined that mere practice was not enough. Expertise was only reliably attained with application of deliberate practice over these years. DP is defined as "a regimen of effortful activities designed to optimize improvement"[21] and involves "training (often designed and arranged by their teachers and coaches) focused on improving particular tasks."[8]

Based on a review of research on skill acquisition, Ericsson and colleagues identified a set of conditions where practice has been uniformly associated with improved performance: (1) the individual must be

provided tasks with well-defined goals; (2) the individual must be internally motivated to improve; (3) the individual must be provided with contemporaneous (immediately after the experience) and diagnostic (describing specific items to work on to improve) feedback; and (4) the individual must be provided with ample opportunities of repetition and gradual refinements of their performance.[8] Individuals must be pushed beyond their current comfort level and the effort requires full concentration to achieve effect.

He correlated the skill acquisition learning curve with DP across multiple domains (ie, athletes, musicians, typists, chess masters) of elite international performance, noting that "expert performers have trained to be able to reproduce their superior performance under representative conditions in everyday life whenever it is required during competition and training," resulting from 10,000 hours of accumulated experience.[7,8]

He further observed that, "the age-related decreases in performance appear to result primarily from reductions of regular deliberate practice, rather than as a direct consequence of aging per se."[7] This finding is particularly relevant to clinical practitioners and implies that with regular deliberate practice, they can improve and maintain expertise even if they have been out in practice for years to decades.

Similar patterns for medical skill acquisition and decay based on practitioner level of training have been reported since the 1960s. One of the first medical investigations in clinical expertise, Butterworth and Reppert's investigation observed that cardiac auscultatory acumen was "highest by those physicians who had been certified in the subspecialty of cardiovascular disease while the lowest scores were made by physicians without specialized training who had been in practice for more than 20 years."[22] The next most accurate participants were those who were cardiology fellows. Medical students performed better than general practicing physicians who had 10 or more years of experience. The scores for the individual groups are summarized in Fig 2. The authors concluded that increased specialty training correlated with increased diagnostic ability and that there was a need for postgraduate training to maintain proficiency.

Dr. Ericsson's work defining the expert-performance approach is leading a cultural shift in medicine where the current practice of socially designated expertise is being replaced by recognizing expertise based on consistently demonstrable superior performance. We are now just learning how to best provide the necessary experiences to assist trainees using

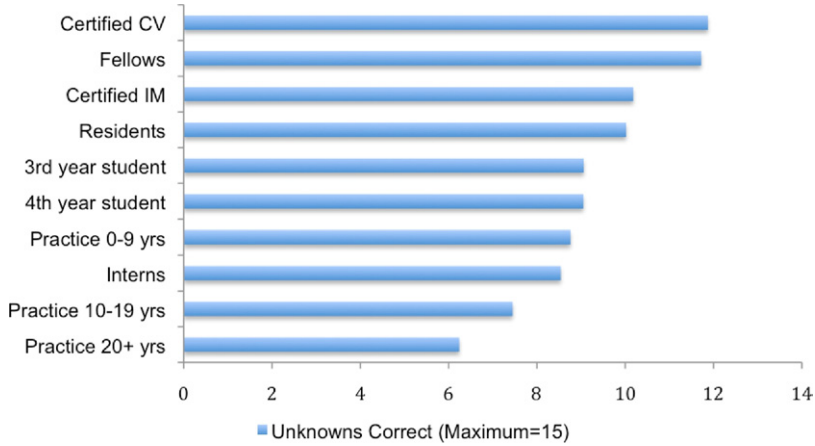

FIG 2. Cardiac auscultatory acumen by level of training. (Adapted from Butterworth JS, Reppert EH. Auscultatory acumen in the general medical population. JAMA 1960;174(1):32-4.) (Color version of figure is available online.)

simulation-based techniques to achieve superior performance in their medical specialties.

Creating an Effective Learning Environment for Adult Learning Utilizing Simulation

Dewey wrote, "Experience and education cannot be directly related to each other. . . A primary responsibility of educators is that they not only be aware of the general principle of the shaping of actual experience by environing conditions, but that they also recognize in the concrete, what surroundings are conducive to having experiences that lead to growth."[18] An educator has to be attentive to ensuring that the quality of the learner's experience is robust and facilitates the learning outcome desired. Moreover, Dewey believed that integrated educational experience is based on that educational experience *occurring* in a context of interaction between people and prior experiences to provide continuity of learning—"What he has learned in the way of knowledge and skill in one situation becomes an instrument of understanding and dealing with the situations which follow. The process goes on as long as life and learning continue."[18]

The most important goal for instructors is to create an atmosphere that is learner-centered.[23] There should be a strong sense of a "safe environment" where the participants do not feel threatened to make mistakes and where mistakes are used as opportunities for teachable moments rather than

embarrassing the learners. This must be established during the welcoming and introduction to the patient simulator and simulation environment.

The introduction to the simulator is important for clarification on how the participants should expect to interact with the simulator, family members, and confederate health care workers involved in the scenario.[23] The students are given an opportunity to listen to normal and abnormal heart and lung sounds, palpate the pulses, and locate the necessary medical equipment in the room to be able to manage the patient. This significantly decreases the ambiguity that arises from the limitations of the simulator and surroundings and goes a long way toward promoting participant suspension of disbelief.[24]

The most effective scenarios for participants allow trainees to experience complex situations and to see cues and consequences very much like those in the real environment. This allows trainees to act as they would in the real environment.[24] Attention to this concept helps them remain engaged in the scenario and invests them emotionally, especially when the patient is decompensating ("crashing"). After the case, care is taken to effectively debrief the experience with the participants. The debriefing session is just as important as running the scenario and is arguably more important for developing transference of the learning points to clinical behavior. During this period of self-appraisal and reflection, effective facilitators provide guided feedback and help trainees determine how to take responsibility for their own growth and learning after the session is completed. As Fanning and Gaba have concluded, "Adults learn best when they are actively engaged in the process, participate, play a role, and experience not only concrete events, in a cognitive fashion, but also transactional events in an emotional fashion."[25]

Several frameworks for evaluating the effectiveness of simulation training have been proposed. Kneebone has delineated four criteria for how simulationists should critically evaluate the quality of their simulations. These are: "(1) Simulations should allow for sustained, deliberate practice within a safe environment ensuring that recently acquired skills are consolidated within a defined curriculum which assures regular reinforcement; (2) simulations should provide access to expert tutors when appropriate, ensuring that such support fades when no longer needed; (3) simulations should map onto real-life clinical experience, ensuring that learning supports the experience gained within communities of actual practice; and (4) simulation-based learning environments should provide a supportive, motivational, and learner-centered milieu which is conducive to learning."[26] Another framework, used widely by industry, government, and academia, was created by Donald Kirkpatrick in 1959

and consists of four levels: Level 1—reaction; Level 2—learning; Level 3—behavior; Level 4—results.[27] Each level has an impact on the next level and each level is subsequently harder to measure. Level 1 (reaction) measures participant satisfaction. Level 2 (learning) measures the extent to which learners change attitudes, improve knowledge and skills because of the training. Level 3 (behavior) measures the extent to which the training led to a change in behavior. Level 4 (results) measures the bottom line impact of the training in the real world.[27]

Conclusions

Experiential learning is particularly suited for adult learners and practicing medical professionals because the integration of theory and simulated experience into clinical practice is pertinent and ongoing.[24-26] Immersive high-fidelity medical simulation provides a platform whereby participants learn by doing, thinking about, assimilating lessons learned, and incorporating them into everyday behaviors.[25,26] By incorporating principles of adult learning into curriculum development and debriefing, simulationists can improve the simulation experience for their trainees. Conducted well, these experiences can be practice-changing and significantly enhance clinical care.

REFERENCES

1. Gaba DM. The future vision of simulation in health care. Qual Saf Health Care 2004;13(suppl 1):i2-i10.
2. Kyle RR, Murray WB. Introduction. In: Kyle RR, Murray WB, editors. Clinical Simulation: Operations, Engineering and Management. London: Elsevier/Academic Press, 2008. p. xxiv.
3. Gaba DM, DeAnda A. A comprehensive anesthesia simulation environment: re-creating the operating room for research and training. Anesthesiology 1988; 69(3):387-94.
4. White PT. Behold the computer revolution. National Geographic 1970;138(5): 596-7.
5. Eyerman JR. For student doctors, it's Sim the deathproof patient. Life 1967;63(23): 87, 90.
6. Society for Simulation in Healthcare. Our Society, undated. Accessed 2011. Retrieved from: http://www.ssih.org/SSIH/ssih/Home/AboutSSH/Default.aspx.
7. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med 2004;79(suppl 10): S70-81.
8. Ericsson KA. Deliberate practice and acquisition of expert performance: a general overview. Acad Emerg Med 2008;15(11):988-94.
9. Ericsson KA. An expert-performance perspective of research on medical expertise: the study of clinical performance. Med Educ 2007;41(12):1124-30.

10. Kohn LT, Corrigan JM, Donaldson MS, editors. To Err Is Human: Building a Safer Health System. Washington, DC: National Academies Press, 2000. p. 78-9.
11. Andreatta P, Saxton E, Thompson M, et al. Simulation-based mock codes significantly correlate with improved pediatric patient cardiopulmonary arrest survival rates. Pediatr Crit Care Med 2011;12(1):33-8.
12. Barsuk JH, McGaghie WC, Cohen ER, et al. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. Crit Care Med 2009;37(10):2697-701.
13. Cohen ER, Feinglass J, Barsuk JH, et al. Cost savings from reduced catheter-related bloodstream infection after simulation-based education for residents in a medical intensive care unit. Simul Healthc 2010;5(2):98-102.
14. Doerr H, Murray WB. Chapter 80. How to build a successful simulation strategy: the simulation learning pyramid. In: Kyle RR, Murray WB, editors. Clinical Simulation: Operations, Engineering and Management. London: Elsevier/Academic Press, 2008, p. 771-85.
15. Alinier G. Chapter 76. Learning through play: simulation scenario = obstacle course + treasure hunt. In: Kyle RR, Murray WB, editors. Clinical Simulation: Operations, Engineering and Management. London: Elsevier/Academic Press, 2008. p. 745-9.
16. Knowles M, Holton III, EF Swanson RA. The Adult Learner: the Definitive Classic in Adult Education and Human Resource Development, 6th edn. Boston, MA: Elsevier, 2005.
17. Kaufman DM. Applying educational theory in practice. BMJ 2003;326(7382): 213-6.
18. Dewey J. Experience and Education. New York, NY: Simon and Schuster, 1938.
19. Kolb DA. Experiental Learning: Experience as the Source of Learning and Development. Englewood Cliffs (NJ): Prentice-Hall, 1984.
20. Ericsson KA, Whyte 4th, J Ward P. Expert performance in nursing: reviewing research on expertise in nursing within the framework of the expert-performance approach. ANS Adv Nurs Sci 2007;30(1):E58-71.
21. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. Psychol Rev 1993;100(3):363-406.
22. Butterworth JS, Reppert EH. Auscultatory acumen in the general medical population. JAMA 1960;174(1):32-4.
23. Gordon J. ABC of learning and teaching in medicine: one to one teaching and feedback. BMJ 2003;326(7388):543-5.
24. Issenberg SB, McGaghie WC, Petrusa ER, et al. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach 2005;27:10-28.
25. Fanning RM, Gaba DM. The role of debriefing in simulation-based learning. Simul Healthc 2007;2(2):115-25.
26. Kneebone R. Evaluating clinical simulations for learning procedural skills: a theory-based approach. Acad Med 2005;80(6):549-53.
27. Kirkpatrick DL. Evaluating Training Programs: the Four Levels, 2nd edn. San Francisco (CA): Berrett-Koehler, 1998.