MEDICAL TEACHER
2018, VOL. 40, NO. 7, 743–751
https://doi.org/10.1080/0142159X.2017.1391375

TWELVE TIPS

Twelve tips for efficient procedural simulation

Etienne Rivière[a,b,c], Danielle Saucier[d,e], Alexandre Lafleur[e,f], Miriam Lacasse[e,f] and Gilles Chiniara[b,g]

[a]Department of Internal Medicine, Haut-Leveque Hospital, University Hospital Centre of Bordeaux, Pessac, France; [b]Apprentiss Centre (Simulation Centre), Laval University, Quebec City, Canada; [c]Centre of Applied Research to Educative Methods (CAREM), University of Bordeaux, Bordeaux, France; [d]Department of Family and Emergency Medicine, Laval University, Quebec City, Canada; [e]Office of Education and Continuing Professional Development (Vice-décanat à la pédagogie et au développement professional continu), Laval University, Quebec City, Canada; [f]Department of Medicine, Laval University, Quebec City, Canada; [g]Department of Anaesthesiology and Intensive Care, Laval University, Quebec City, Canada

ABSTRACT
Procedural simulation (PS) is increasingly being used worldwide in healthcare for training caregivers in psychomotor competencies. It has been demonstrated to improve learners' confidence and competence in technical procedures, with consequent positive impacts on patient outcomes and safety. Several frameworks can guide healthcare educators in using PS as an educational tool. However, no theory-informed practical framework exists to guide them in including PS in their training programs. We present 12 practical tips for efficient PS training that translates educational concepts from theory to practice, based on the existing literature. In doing this, we aim to help healthcare educators to adequately incorporate and use PS both for optimal learning and for transfer into professional practice.

Introduction

Simulation is increasingly used worldwide as an educational tool in healthcare training programs. It has been proven effective in initial and continuing medical education (Cook et al. 2011) for both teaching and training (Nestel et al. 2011). It has also been demonstrated to improve patient care processes and outcomes, particularly patient safety (Brydges, Hatala, et al. 2015; Griswold-Theodorson et al. 2015).

Procedural simulation (PS) is one of the many forms of simulation, which also includes immersive simulation (IS), virtual simulation and simulated patients. It can be defined as any simulation activity that uses various teaching tools aimed at the acquisition of competencies required for a particular technique or procedure (Chiniara et al. 2013). Competency for a given procedure represents the ability to decide upon a course of action and adequately accomplish a somewhat complex procedure, in a variety of situations or cases. It therefore requires for its accomplishment not only the psychomotor skills, but also cognitive skills (heuristics, etc.) and communication skills (such as interactions with patients and other staff), and a sound knowledge base related to the procedure at hand. Airway management and neuraxial block are examples of techniques well suited to PS training.

Interest in this type of simulation has been rekindled by the recent concerns over patient safety (Ziv et al. 2003). Indeed, the modern evolution of medical clinical practice, with patient safety concerns, mandated reduced work hours, and shorter hospital stays, among other factors, has modified the training landscape for the acquisition of psychomotor competencies (Pugh et al. 2015). More and more institutions across the world are developing simulation centers, and PS is being increasingly used in healthcare teaching programs. Simulation has many benefits, among which the provision of a safe environment for learners, who are offered feedback and allowed to make mistakes without adverse effects on a patient, and without interfering with clinical practice.

However, integrating PS into healthcare curricula is not necessarily a simple process. It should be evidence-based, and grounded in learning theories. The many learning theories that underlie PS stem from different domains. To our knowledge, only few articles, if any, provide a synthesis that is helpful to clinical educators wishing to include PS into their curricula. Table 1 describes four frameworks that could be potentially useful for educators planning to include PS in their programs, and summarizes their pros and cons in terms of usefulness. However, none is fully adapted to educators in search of a practical but theory-informed framework, neither do they focus specifically on PS. In the present paper, we aim to provide 12 theory-informed practical tips for healthcare educators planning to include PS training sessions in their program. Our tips are based on the educational principles or theories listed below, as sound guiding principles for the use of PS in healthcare. Based on the literature review and our own experience with PS, we describe 12 practical tips that follow a "Design, Apply, Evaluate and Follow up" sequence summarized in Figure 1.

Tip 1

Simulation is but one tool: Choose it wisely!

Simulation is not an end in itself and must complement other activities. In fact, simulation might not always be the best instructional method (Ilgen et al. 2013), nor is it often the most cost-effective given the resources it requires.

CONTACT Gilles Chiniara gilles.chiniara@fmed.ulaval.ca Centre Apprentiss, Office 3770-F, Pavillon Ferdinand-Vandry, 1050 rue de la Médecine, Université Laval, G1V 0A6 Québec City, Québec, Canada

Table 1. A comparative summary of existing frameworks potentially useful for educators planning to include procedural simulation (PS) in their programs.

Framework Citation	Conceptual framework Kneebone (2005)	CNSH instructional design framework Chiniara et al. (2013)	BEME guide Motola et al. (2013)	Learn, See, Practice, Prove, Do, Maintain Sawyer et al. (2015)
Description	A conceptual framework for judging the usefulness of a given PS by selecting four key areas: - gaining and retaining technical proficiency, - the place of expert assistance in task-based learning, - learning within a professional context, - the affective component of learning	Dedicated framework and supporting taxonomy for instructional design (ID) to assist educators in creating appropriate simulation learning experiences. It presents four progressive levels describing the educational intervention: - medium of delivery of instruction - simulation modality selection - instructional method selection - presentation of the detailed characteristics of the intervention	BEME guide that provides practical guidance to aid educators in effectively using simulation for training, with best practices and illustrative case studies. Eight concepts are explained and detailed, applying to simulation in general: - curriculum integration - feedback - deliberate practice - mastery learning - range of difficulty - capturing clinical variation - individualized learning and approach to team training	A six-step pedagogical framework for procedural skill training: - Learn: requisite cognitive knowledge - See: observation of the procedure - Practice: deliberate practice on a simulator - Prove: mastery achievement required before … - Do: … performing procedure on patient independently - and Maintain: sustain clinical and simulated practice
Pros	- Good introductory article on conceptual frameworks for learning through PS - Explains landmarks for adequate PS: competency decay prevention, expert feedback, authenticity, and affective component of learning	- Structured and practical framework providing efficient tools to guide educators in selecting appropriate simulation media (zone of simulation matrix, media and simulation modality selection chart based on learning outcomes) - Framework evidence-based as much as possible	- Evidence-based as much as possible - Detailed guide with a lot of concrete examples - Highlighted practice points - Include a curriculum integration framework with concrete examples	- Structured framework that is grounded on a review of the literature using a critical synthesis approach - Evaluation of mastery based on mastery learning - Adopts a process-based approach to PS rather than an outcome-based approach (*see tip 8*) - Describes a checklist/global hybrid assessment tool
Cons	- One expert opinion - The theoretical concepts underlying PS sessions are introduced with no concrete tools to build a PS session	- Tackles simulation in general rather than PS itself - Terminology is somewhat idiosyncratic for non-experts in the field - Media selection chart is not updated	- Not a framework in itself, rather a guide introducing and detailing numerous concepts underlying simulation use - Tackles simulation in general rather than PS itself	- Focuses mainly on how learner should acquire procedural competencies, not on how educators should plan their PS sessions

BEME: Best Evidence Medical Education; CNSH: Canadian Network of Simulation in Healthcare.

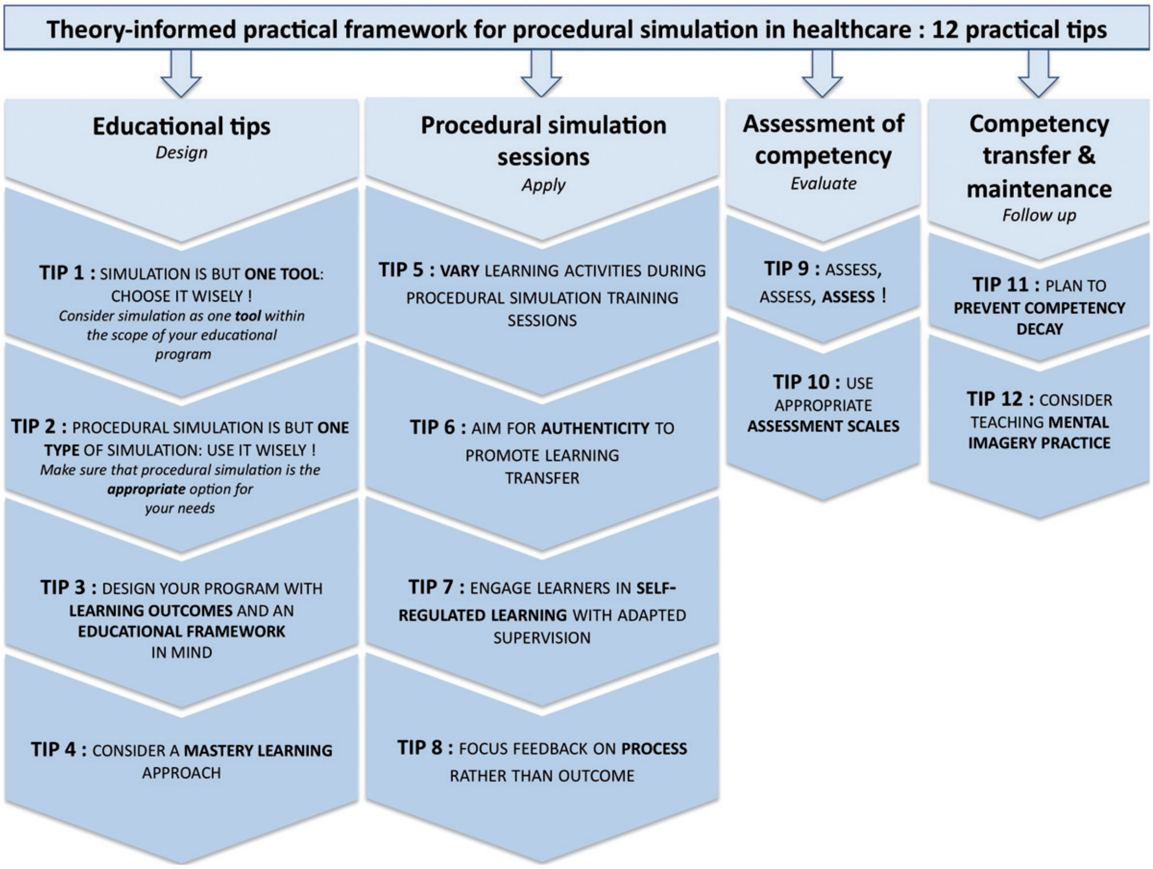

Figure 1. Twelve theory-informed practical tips introduced for educators planning to include procedural simulation in their healthcare programs.

The selection of simulation can be based on the acuity (severity of the potential consequences of the event) and opportunity (frequency) of the target event, as described in the zone of simulation matrix model (Chiniara et al. 2013). According to this model (Figure 2), events that lend themselves most to simulation in a given population of learners are those whose consequences can be dire on the patient (high acuity/low opportunity, i.e. drug-induced anaphylactic shock); or high acuity/high opportunity, i.e. trauma management in the emergency department), and those that occur less frequently (low acuity/low opportunity, i.e. ultrasound-guided peripheral catheter insertion) (Chiniara et al. 2013). Invasive technical procedures in humans can be mostly considered of high acuity (risk of iatrogenic complications), although this will vary depending on the clinical and training context.

Tip 2

Procedural simulation is but one type of simulation: Use it wisely!

Simulation includes a wide range of educational experiences. It is thus important to select the right simulation option for the targeted competency domains or learning outcomes (Harden 2007). One conceptual framework, developed by the Canadian Network for Simulation in Healthcare, provides tables for the selection of media and simulation modalities (Chiniara et al. 2013). According to this framework, PS is best suited for training in techniques and procedures, along with their associated beliefs and attitudes, either through self-learning with motor practice, or through directed learning.

Figure 2. The zone of simulation matrix, reproduced with permission (Chiniara et al. 2013). *Acuity* is defined as the potential severity of an event or a series of events and their subsequent impact on the patient. *Opportunity* is defined as the frequency in which a particular department or individual is actively involved in the management of the event. The "zone of simulation" is that area in which simulation may be advantageous over other instructional media. Within this zone, simulation can serve as an acceptable substitute or complement to other, less expensive, media and methods. This matrix is a useful tool to educators for determining whether PS could be a suitable instructional method.

PS must complement other instructional methods to enhance the efficiency of an educational program. Knowledge of a procedure itself and its place in patient management should ideally be learnt by students through other means, such as reading material and/or video demonstration, prior to simulation (Seropian 2003). In addition, other simulation modalities, such as IS, which reproduces real-life situations in authentic workplace environment, might complement PS to contextualize the knowledge required for learning.

Care should be taken when using PS within the scope of a wider, "hybrid" simulation. Hybrid simulation activities, combining PS with either IS or simulated patients, are helpful to develop attitudes, beliefs or clinical ethics related to a technical procedure (Edinger et al. 1999). Hybrid simulations must be designed appropriately by allotting specific time for technical skills training, as well as communication with the patient or team (Kneebone et al. 2002). As for IS, it is mainly used for the practice of team training and crisis resource management (Rosen et al. 2008; Jaffrelot et al. 2013; Boet et al. 2014) and is not the most appropriate method for teaching procedures, except for some life-threatening bedside procedures like difficult airway intubation (Sudikoff et al. 2009; Nishisaki et al. 2011).

Tip 3

Design your program with learning outcomes and an instructional framework in mind

Any sound learning program should be designed with a solid instructional framework. Several such frameworks have been suggested and adapted to simulation (Kneebone 2005; Chiniara et al. 2013; Motola et al. 2013; Sawyer et al. 2015). A brief summary of those frameworks is provided in Table 1, and interested readers are referred to the articles cited for further details. Cognitive load theory (Fraser et al. 2015; Naismith et al. 2015) provides an additional framework for designing simulations that optimize learning by minimizing extraneous load (related to the instructional method) and managing intrinsic load (related to the task and learner's current level of expertise). In other words, PS activities should be designed in order to maximize the learner's cognitive resources that are dedicated to the task (Leppink and Duvivier 2016).

Since it is tempting to unduly increase the number of PS tasks or activities, learning outcomes must be clearly defined during the instructional design process, both for the training session and for the individual simulation tasks. These outcomes usually are knowledge and skills related to task planning and performance, as well as underlying beliefs and attitudes. They can be based on existing competency frameworks or generated through task analysis of the relevant domain (Weinger et al. 1994).

Tip 4

Consider a mastery learning approach

Mastery learning is a solid basis for effective simulation (Cook et al. 2013; Eppich et al. 2015), including PS (Barsuk et al. 2009, 2012, 2015, 2016). It is recognized as a necessary component of competency-based education (McGaghie 2015). Mastery learning (Kulik et al. 1990) is a systematic approach in which learners proceed to a new, more complex learning outcome only after having achieved significant mastery in the prior outcome. Task difficulty and complexity is hence progressively increased each time mastery in an underlying task is achieved. To that end, learners' knowledge, skills and attitudes are rigorously assessed after each task or learning outcome. They are improved by repetitive deliberate practice, guided by iterative and robust feedback, without any time limitation for achieving competency. Indeed, mastery learning's main limitation is the variable time needed for each learner to achieve a given learning outcome.

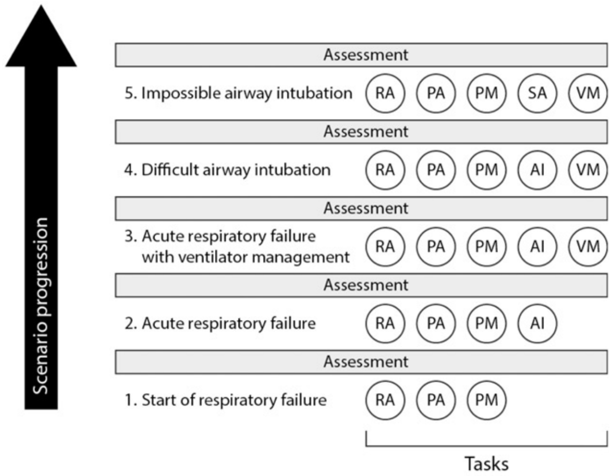

Figure 3. Example of a complete procedural simulation program for airway management based on a mastery learning approach. Nested tasks: RA: resources assessment; PA: patient assessment; PM: pre-medication; AI: airway intubation; SA: surgical airway; VM: ventilator management. Based on Eppich et al. (2015).

Figure 3 exemplifies a mastery learning approach used in a program for anesthesiology residents aimed at acquiring competency in airway management. In the first learning task or scenario, the learner starts by assessing available resources (team, material) and patient information (records, examination), and learning medication used for airway management. In scenario 2, the learner proceeds to normal (easy) airway intubation, with assistance. In scenario 3, the learner performs intubation without assistance, checks for complications and manages the ventilator. In scenario 4, the learner proceeds to a difficult airway intubation. Finally, in the last scenario, the learner manages a "cannot intubate" situation and must perform a surgical airway. Moving on to each step is preceded by a rigorous assessment that demonstrates proficiency in the previous scenario.

Tip 5

Vary learning activities during procedural simulation sessions

According to the schema theory of motor skill learning (Schmidt 1975), learning activities should vary during PS sessions. This theory suggests that an abstract cognitive structure, called a general motor scheme, directs the execution of a family of movements and actions. A progressive variation of the training task parameters and a tight control of four sources of information (or learning variables) allow for the creation of the general motor scheme. These sources are: the initial conditions of the environment and training task; the variables of each parameter of the task; the sensory feedback; and the task's objective results (Taktek 2009). To be effective, training on a given task should be done with progressive variations in each of the four sources. For example, better task achievement will be reached if learners perform bronchoscopy on a model with different anatomical variations. Specific surgical training tasks, called OSATS (Objective Structured Assessment of Technical Skills), have been developed in conformity with this theory. They are also used to standardize skills assessment (Martin et al. 1997; Reznick and MacRae 2006).

Tip 6

Aim for authenticity to promote transfer

The ultimate goal of PS is transfer of competency to real life. However, competencies cannot be separated from the context in which they have been acquired: learning is contextualized or "situated" (Brown et al. 1989). Authenticity of the learning context is thus the cornerstone of transfer. A learning activity is authentic inasmuch as it involves the same cognitive or physical processes as the target task, irrespective of simulation "fidelity" or realism. In fact, low physical fidelity has yielded comparable learning outcomes as higher-fidelity simulation in teaching endo-urological skills (Matsumoto et al. 2002).

Indeed, task realism (or fidelity) is not the only prerequisite for effective transfer. Other important factors are: the learner's intrinsic motivation (Deci and Ryan 1985; Fox and Miner 1999); adapting the learning task to a novice's mastered skills in order to avoid negative transfer (Hatala et al. 1999); and the context of learning (situated cognition, see Brown et al. 1989). It should be noted that the concept of fidelity is often used inappropriately; for example, PS is often defined as "low-fidelity", because it does not reproduce the environment, even though it reproduces the task authentically.

Therefore, focusing mainly on functional task alignment or authenticity, i.e. matching simulation characteristics to task requisites, rather than physical resemblance, is recommended (Hamstra et al. 2014). For example, an airway intubation simulator that does not look fully human but provides adequate tissue elasticity and airway anatomy to allow for a correct task reproduction is preferable to a realistic-looking full-body human simulator with a stiff airway.

Tip 7

Engage learners in self-regulated learning (SRL) with adapted supervision

Ensuring that students "learn how to learn" is paramount nowadays, as new medical knowledge and techniques constantly emerge. SRL is important in acquiring psychomotor competencies and ensuring proficiency at a high level of expertise. Bridges et al. demonstrated that SRL prevented competency decay at three months, compared to instructor-regulated learning, in the context of lumbar puncture simulation training (Brydges et al. 2012).

The social-cognitive model of SRL suggests four steps in the learning process during PS: the learner watches, then imitates the instructor (or instructional media) during the *observational* and *emulative* stages, he self-selects sources of learning in the *self-control* stage, and finally he successfully and spontaneously adapts to new situations in the *adaptive* stage (Schunk and Zimmerman 1997; Schunk 1999). In order to engage learners in SRL, they should control the affective, cognitive and behavioral processes during learning (Sitzmann and Ely 2011). This control occurs not only during the emulative and observational stages of the four-step model, but also by involving the learners in defining the learning outcomes and choosing the learning strategies.

Supervision is a cornerstone of PS training sessions, as immediate rectification, based on objective criteria, is of major importance for future SRL (Brydges, Manzone, et al. 2015). It sustains learner's intrinsic motivation, which is crucial for learning (Deci and Ryan 1985; Fox and Miner 1999; Kaufman 2003). It also fosters positive emotions in learners to anchor new learning (Ferro 1993; Cassar 2004; Kneebone 2005). It enhances transfer by alternating between contextualization (i.e. discussing knowledge and competencies as applied in the learning context), de-contextualization (i.e. abstracting overarching principles), and re-contextualization (i.e. applying acquired knowledge in new contexts) during feedback (Frenay and Bédard 2004; Kriz 2010). Moreover, better outcomes are achieved with adequate supervision that shares responsibility in achieving goals between learner and supervisor (Brydges, Manzone, et al. 2015).

Learners should be encouraged to create communities of practice and learning, as achieving mastery resides not in the educators' efforts, but in the organization of communities of practice of which educators are but one part (Lave and Wenger 1991; Wenger 2008). Interactions between learners themselves (peer-to-peer feedback) and/or with instructor(s) in a constructivist framework are important, and promote ongoing SRL (Montgomery et al. 2012; Murdoch et al. 2013; Pucher et al. 2013).

Tip 8

Focus feedback on process rather than outcome

Feedback is key in simulation (Decker et al. 2013). It can be defined as "specific information about the comparison between a trainee's observed performance and a standard, given with the intent to improve trainee's performance" (van de Ridder et al. 2008).

It is usually tempting to assess learner's competency based on his outcome in the task rather than on the processes that led to the specific outcome. In fact, most procedural simulators do provide immediate outcome feedback through the success or failure of the task (natural feedback). However, it has been shown that students who focus on outcomes and not on procedures tend to fail significantly more in performing venipuncture in a clinical context (Cleary and Sandars 2011). Hence, *process-based* feedback should be a priority in PS and is essential for deliberate practice (Ericsson 2004). Emphasis on the quality of task performance (process or descriptive feedback) fosters learning, especially for complex tasks (Johnson et al. 1993). While process feedback is usually provided by an expert supervisor, some simulators can enhance feedback through computer-generated information (augmented feedback) (Botden et al. 2008; Alaraj et al. 2013).

Tip 9

Assess, assess, assess!

Assessment is key to learning. It is essential in SRL (Cleary and Sandars 2011; Brydges and Butler 2012) (see tip # 7) and is the cornerstone of mastery learning and deliberate practice (see tip # 4). How summative assessment should be done in PS, however, is still a matter of debate (Bould et al. 2009), as few if any technical skill assessment measures have demonstrated sufficient validity. Yet, assessment drives learning (Swanson et al. 1995; Lafleur and Côté 2016). What's more, summative assessment is mandatory in mastery learning as it provides feedback to students and determines whether they can proceed or not to the next step in learning.

As for formative assessment, it is beneficial to students since it actively involves them in the learning process, thus yielding improved knowledge retention (Rolfe and McPherson 1995; Parry et al. 2013; Evans et al. 2014; Cook et al. 2015; Mitra and Barua 2015). As discussed in the previous tip, feedback is an integral part of formative assessment for PS and should be provided frequently and abundantly.

Tip 10

Use appropriate assessment scales

Choosing an appropriate instrument for assessment of competency is an important issue when integrating simulation in learning programs. Recent studies suggest that checklists have shortcomings when assessing technical skills as they can omit essential competencies (McKinley, Strand, Ward, et al. 2008) and may lack specificity: high checklist scores do not always rule out incompetence (Ma et al. 2012; Walzak et al. 2015). As such, global rating scales (GRS) are preferred for competency assessment. As an example of an appropriate assessment tool, a team recently introduced a GRS to assess technical competency in simulated bedside procedures (Walzak et al. 2015). They used a scale ranging from "not competent to perform independently" to "above average competence to perform independently", applied to items such as "appropriate preparation of instrument pre-procedure", "appropriate analgesia", "specific components of technical ability", "aseptic technique" and "seeks help where appropriate". Such scales with more generic criteria assess not only technical competency, but also competency in the overall procedure, and are particularly well adapted to PS (McKinley, Strand, Gray, et al. 2008).

Other indicators can also be used for assessment in PS, such as the numerous objective metrics provided by computerized simulators (so-called virtual-reality simulators), e.g. time required and number of movements for specific surgical interventions (Aggarwal et al. 2009; Van Bruwaene et al. 2014). Such assessment tools can be useful to compare novice and expert performance and to engage in deliberate practice. However, rather than trusting predetermined goals set by simulator manufacturers, the metrics that correspond to local performance standards of expertise should be measured in any given institution or based on established guidelines.

Tip 11

Plan to prevent competency decay

Once achieved, competency will decay over time without regular practice, a phenomenon called "deskilling" (Arthur et al. 1998; Sawyer et al. 2015). Time before deskilling of simulation-acquired competency is variable and depends mainly on learners' experience. It will happen quicker in novice learners compared to experienced caregivers (Arthur et al. 1998; Howells et al. 2009). Other factors that affect time before deskilling include nature of the task (cognitive vs physical, with cognitive skills decaying first), similarity of context between retrieval and retention (Arthur et al. 1998), length of time before using the skills, degree of overlearning (Perez et al. 2013), and learning methods (with interactive activities such as simulation being superior to observation or didactic methods) (Waters et al. 2014). In one study, deskilling in hemodialysis catheter insertion occurred within 6 months to one year in nephrology fellows and thus required "booster training" at 6 months (Ahya et al. 2012).

Simulation holds a place of choice for "re-skilling" or "skill maintenance" (Kneebone et al. 2004; Ahya et al. 2012; Sawyer et al. 2015). To that end, several methods to provide simulation-based maintenance of competency can be used: "dressed rehearsals", "rolling refreshers," "just-in-time training", and "booster training" (Kovacs et al. 2000; Niles et al. 2009; Scholtz et al. 2013; Bender et al. 2014; Sawyer et al. 2015). However, there is still a paucity of research on "deskilling" time, as well as optimal timing of "re-skilling" sessions.

Tip 12

Consider teaching mental imagery practice

Mental imagery practice could be a useful tool to prevent competency decay (Cocks et al. 2014; Rao et al. 2015). Procedural memory is a form of long-term memory in which information is learnt by two means: self-repetition maintenance (information is mentally repeated) and self-repetition integration (information is semantically associated with what is already known) (Gupta and Cohen 2002). Experience is essential in creating this memory, as is repetition. Mental imagery practice, the process of mentally rehearsing a technique before executing it, can be useful to facilitate technical competency acquisition and maintenance, as it has been shown in elite sport athletes for a long time (Woolfolk et al. 1985), and more recently suggested for surgeons (Cocks et al. 2014; Rao et al. 2015). A cyclical six-stages technique for imagery practice has been described in surgery, but is applicable to other domains: task definition, prior learning, mental rehearsal, reflection, problem solving and reality check (Hall 2002). Learners should be taught how to apply this six-steps sequence prior or concomitantly to simulation sessions and task execution, as an effective SRL strategy, in order to enhance training and psychomotor competency acquisition.

Conclusions

As summarized in Figure 1, in order for PS to be effective, it must be included in an educational program (tip #1), created through a rigorous instructional design process (tip #2) with clearly identified learning outcomes (tip #3) upon which simulation training and assessment (tips #9 and 10) are based. Planning for task variation (tip #5) and adequate authenticity to promote transfer (tip #6) is crucial for PS sessions. Providing adequate process-based feedback (tip #8) is the basis of learner's self-regulated progression (tip #7) to mastery. To that end, mastery learning (tip #4) and mental imagery practice (tip #10) can be useful methods. Formative and summative assessments (tips #9 and 10) must be integrated into the curriculum, as required for mastery learning. Finally, competency decay must be taken into account (tip #11), and prevented through recurrent training sessions, sustained SRL, and imagery practice (tip #12).

It is now clear that competencies acquired through PS training can be transferred to actual clinical practice (Bagai et al. 2012; Dawe et al. 2014) with a large benefit on learners' confidence and efficiency (Brydges, Hatala, et al. 2015). It is of note that factors other than the simulator itself play a positive role in competency transfer. Some have been discussed in this paper, and it is our hope that the 12 tips we introduce will allow educators to design better activities for learning through PS.

The strength of our approach is to convert theory-informed concepts about PS into practical tips for healthcare educators. These tips constitute an overall conceptual framework as well as specific practical steps for instructional design of PS training activities.

Beyond the emphasis on the 12 tips, it is important to note that the role of healthcare educators is paramount in simulation-based activities such as PS. Indeed, a major issue in managing a simulation center is to retain competent instructors as long as possible (Kim et al. 2011). This issue should be given specific attention in order for any simulation program to remain active, attractive, and provide a high quality learning experience.

Finally, more research should be conducted on preventing deskilling in trainees, and, more widely, in professional caregivers. As with learning a new language, maintaining newly acquired procedural competencies seem to rest on repeated deliberate practice through simulation, using imagery practice, and, ultimately, applying the newly developed skills on patients. However, new strategies to fight against competency decay should be of particular interest for researchers in the field of simulation, as shown, for example, with hybrid immersive/PS (Boet et al. 2011).

Acknowledgements

We would like to thank students, patients, and colleagues that shared their PS experiences with us. ER would especially like to thank professors Jean-Luc Pellegrin, Jean-François Viallard, Didier Gruson, Chloé James, Pierre Dubus, and Patrick Dehail, from the University of Bordeaux, who made this work possible through their unconditional support.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

Funding

ER received funding from University of Bordeaux and University Hospital Centre of Bordeaux for his fellowship at Laval University in the Apprentiss Centre Gilles Chiniara was, until 2013, a paid educational consultant for CAE Healthcare (Montreal, Canada).

Notes on contributors

Etienne Riviere, MD, PhD, is an internal medicine physician and clinician educator who practices at the University Hospital Centre of Bordeaux in France. He was a student of the master program in health professions education at Laval University and a fellow at Apprentiss Simulation Centre while this manuscript was being written.

Danielle Saucier, MD, CCMF, FCMF, MHPE, is a family physician who practices in a Family Medicine Teaching Health Centre. She is a Professor in the Department of Family and Emergency Medicine at Laval University in Quebec City, Canada, where she is the Program director for graduate health professions education programs.

Alexandre Lafleur, MD, FRCPC, MHPE, is an internal medicine physician who practices at the Quebec City University Hospital Centre in Quebec, Canada. He is co-holder of the QMA-CMA-MD Chair of Educational Leadership in Health Sciences Education. He is assistant program director for internal medicine residency, in charge of simulation-based activities.

Miriam Lacasse, M.D., M.Sc., CCMF, is a family physician who practices at the CIUSSS de la Capitale-Nationale. She is an Assistant Professor in the Department of Family and Emergency Medicine at Laval University, co-holder of the QMA-CMA-MD Chair of Educational Leadership in Health Sciences Education.

Gilles Chiniara, MD, MHPE, is an anesthesiologist practicing at Quebec City University Hospital Centre. He is an Associate Professor of Anaesthesiology and holds a master of Health Professions Education from the University of Illinois at Chicago. He is currently the Scientific Director of the Apprentiss Simulation Centre at Laval University.

AL, ML, DS, and GC all teach within Laval University's graduate health professions education programs and are members of the Education and Continuing Professional Development Office.

References

Aggarwal R, Crochet P, Dias A, Misra A, Ziprin P, Darzi A. 2009. Development of a virtual reality training curriculum for laparoscopic cholecystectomy. Br J Surg. 96:1086–1093.

Ahya SN, Barsuk JH, Cohen ER, Tuazon J, McGaghie WC, Wayne DB. 2012. Clinical performance and skill retention after simulation-based education for nephrology fellows. Semin Dial. 25:470–473.

Alaraj A, Charbel FT, Birk D, Tobin M, Tobin M, Luciano C, Banerjee PP, Rizzi S, Sorenson J, Foley K, et al. 2013. Role of cranial and spinal virtual and augmented reality simulation using immersive touch modules in neurosurgical training. Neurosurgery. 72(Suppl 1):115–123.

Arthur W, Jr., Bennett W, Jr., Stanush PL, McNelly TL. 1998. Factors that influence skill decay and retention: a quantitative review and analysis. Hum Perform. 11:57–101.

Bagai A, O'Brien S, Al Lawati H, Goyal P, Ball W, Grantcharov T, Fam N. 2012. Mentored simulation training improves procedural skills in cardiac catheterization: a randomized, controlled pilot study. Circ Cardiovasc Interv. 5:672–679.

Barsuk JH, Ahya SN, Cohen ER, McGaghie WC, Wayne DB. 2009. Mastery learning of temporary hemodialysis catheter insertion by nephrology fellows using simulation technology and deliberate practice. Am J Kidney Dis. 54:70–76.

Barsuk JH, Cohen ER, Caprio T, McGaghie WC, Simuni T, Wayne DB. 2012. Simulation-based education with mastery learning improves residents' lumbar puncture skills. Neurology. 79:132–137.

Barsuk JH, Cohen ER, Mikolajczak A, Seburn S, Slade M, Wayne DB. 2015. Simulation-based mastery learning improves central line maintenance skills of ICU nurses. J Nurs Adm. 45:511–517.

Barsuk JH, Cohen ER, Wayne DB, Siddall VJ, McGaghie WC. 2016. Developing a simulation-based mastery learning curriculum: lessons from 11 years of advanced cardiac life support. Simul Healthc. 11:52–59.

Bender J, Kennally K, Shields R, Overly F. 2014. Does simulation booster impact retention of resuscitation procedural skills and teamwork? J Perinatol. 34:664–668.

Boet S, Borges BCR, Naik VN, Siu LW, Riem N, Chandra D, Bould MD, Joo HS. 2011. Complex procedural skills are retained for a minimum of 1 yr after a single high-fidelity simulation training session. Br J Anaesth. 107:533–539.

Boet S, Bould MD, Layat Burn C, Reeves S. 2014. Twelve tips for a successful interprofessional team-based high-fidelity simulation education session. Med Teach. 36:853–857.

Botden SMBI, Buzink SN, Schijven MP, Jakimowicz JJ. 2008. ProMIS augmented reality training of laparoscopic procedures face validity. Simul Healthc. 3:97–102.

Bould MD, Crabtree NA, Naik VN. 2009. Assessment of procedural skills in anaesthesia. Br J Anaesth. 103:472–483.

Brown JS, Collins A, Duguid P. 1989. Situated cognition and the culture of learning. Educ Res. 18:32–42.

Brydges R, Butler D. 2012. A reflective analysis of medical education research on self-regulation in learning and practice. Med Educ. 46:71–79.

Brydges R, Hatala R, Zendejas B, Erwin PJ, Cook DA. 2015. Linking simulation-based educational assessments and patient-related outcomes: a systematic review and meta-analysis. Acad Med. 90:246–256.

Brydges R, Manzone J, Shanks D, Hatala R, Hamstra SJ, Zendejas B, Cook DA. 2015. Self-regulated learning in simulation-based training: a systematic review and meta-analysis. Med Educ. 49:368–378.

Brydges R, Nair P, Ma I, Shanks D, Hatala R. 2012. Directed self-regulated learning versus instructor-regulated learning in simulation training. Med Educ. 46:648–656.

Cassar K. 2004. Development of an instrument to measure the surgical operating theatre learning environment as perceived by basic surgical trainees. Med Teach. 26:260–264.

Chiniara G, Cole G, Brisbin K, Huffman D, Cragg B, Lamacchia M, Norman D, Canadian Network For Simulation in Healthcare, Guidelines Working Group. 2013. Simulation in healthcare: a taxonomy and a conceptual framework for instructional design and media selection. Med Teach. 35:e1380–e1395.

Cleary TJ, Sandars J. 2011. Assessing self-regulatory processes during clinical skill performance: a pilot study. Med Teach. 33:e368–e374.

Cocks M, Moulton C-A, Luu S, Cil T. 2014. What surgeons can learn from athletes: mental practice in sports and surgery. J Surg Educ. 71:262–269.

Cook DA, Brydges R, Zendejas B, Hamstra SJ, Hatala R. 2013. Mastery learning for health professionals using technology-enhanced simulation: a systematic review and meta-analysis. Acad Med J Assoc Am Med Coll. 88:1178–1186.

Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, Erwin PJ, Hamstra SJ. 2011. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA. 306:978–988.

Cook MR, Watters JM, Barton JS, Kamin C, Brown SN, Deveney KE, Kiraly LN. 2015. A flexible postoperative debriefing process can effectively provide formative resident feedback. J Am Coll Surg. 220:959–967.

Dawe SR, Pena GN, Windsor JA, Broeders JAJL, Cregan PC, Hewett PJ, Maddern GJ. 2014. Systematic review of skills transfer after surgical simulation-based training. Br J Surg. 101:1063–1076.

Deci EL, Ryan RM. 1985. Intrinsic motivation and self-determination in human behavior. New York: Plenum.

Decker S, Fey M, Sideras S, Caballero S, Rockstraw L (Rocky), Boese T, Franklin AE, Gloe D, Lioce L, Sando CR, et al. 2013. Standards of best practice: simulation standard VI: the debriefing process. Clin Simul Nurs. 9:S26–S29.

Edinger W, Robertson JD, Skeel J, Schoonmaker J. 1999. Using standardized patients to teach clinical ethics. Med Educ Online. 4:1–5.

Eppich WJ, Hunt EA, Duval-Arnould JM, Siddall VJ, Cheng A. 2015. Structuring feedback and debriefing to achieve mastery learning goals. Acad Med J Assoc Am Med Coll. 90:1501–1508.

Ericsson KA. 2004. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med J Assoc Am Med Coll. 79:S70–S81.

Evans DJR, Zeun P, Stanier RA. 2014. Motivating student learning using a formative assessment journey. J Anat. 224:296–303.

Ferro T. 1993. The influence of affective processing in education and training. In: Flannery DD, editor. Applying cognitive learning theory to adult learning: new directions for adult and continuing education. San Francisco: Jossey-Bass; p. 25–33.

Fox RD, Miner C. 1999. Motivation and the facilitation of change, learning, and participation in educational programs for health professionals. J Contin Educ Health Prof. 19:132–141.

Fraser KL, Ayres P, Sweller J. 2015. Cognitive load theory for the design of medical simulations. Simul Healthc. 10:295–307.

Frenay M, Bédard D. 2004. Des dispositifs de formation universitaire s'inscrivant dans la perspective d'un apprentissage et d'un enseignement contextualisés pour favoriser la construction des connaissances et leur transfert. In: Presseau A, Frenay M, editors. Le transfert des apprentissages: comprendre pour mieux intervenir. Saint-Nicolas. Canada: Les Presses de l'Université Laval; p. 241–268.

Griswold-Theodorson S, Ponnuru S, Dong C, Szyld D, Reed T, McGaghie WC. 2015. Beyond the simulation laboratory: a realist synthesis review of clinical outcomes of simulation-based mastery learning. Acad Med. 90:1553–1560.

Gupta P, Cohen NJ. 2002. Theoretical and computational analysis of skill learning, repetition priming, and procedural memory. Psychol Rev. 109:401–448.

Hall JC. 2002. Imagery practice and the development of surgical skills. Am J Surg. 184:465–470.

Hamstra SJ, Brydges R, Hatala R, Zendejas B, Cook DA. 2014. Reconsidering fidelity in simulation-based training. Acad Med. 89:387–392.

Harden RM. 2007. Outcome-based education-the ostrich, the peacock and the beaver. Med Teach. 29:666–671.

Hatala R, Norman GR, Brooks LR. 1999. Influence of a single example on subsequent electrocardiogram interpretation. Teach Learn Med. 11:110–117.

Howells NR, Auplish S, Hand GC, Gill HS, Carr AJ, Rees JL. 2009. Retention of arthroscopic shoulder skills learned with use of a simulator. Demonstration of a learning curve and loss of performance level after a time delay. J Bone Joint Surg Am. 91:1207–1213.

Ilgen JS, Sherbino J, Cook DA. 2013. Technology-enhanced simulation in emergency medicine: a systematic review and meta-analysis. Acad Emerg Med. 20:117–127.

Jaffrelot M, Boet S, Di Cioccio A, Michinov E, Chiniara G. 2013. Simulation et gestion de crise. Réanimation. 22:569–576.

Johnson D, Perlow R, Pieper K. 1993. Differences in task performance as a function of type of feedback: learning-oriented versus performance oriented feedback. J Appl Soc Pyschol. 23:303–320.

Kaufman DM. 2003. Applying educational theory in practice. BMJ. 326:213–216.

Kim S, Ross BK, Pellegrini C. 2011. Characteristics of a surgical trainer 2010-2020. Surg J R Coll Surg Edinb Irel. 9(Suppl 1):S45–S47.

Kneebone R, Kidd J, Nestel D, Asvall S, Paraskeva P, Darzi A. 2002. An innovative model for teaching and learning clinical procedures. Med Educ. 36:628–634.

Kneebone R. 2005. Evaluating clinical simulations for learning procedural skills: a theory-based approach. Acad Med. 80:549–553.

Kneebone RL, Scott W, Darzi A, Horrocks M. 2004. Simulation and clinical practice: strengthening the relationship. Med Educ. 38:1095–1102.

Kovacs G, Bullock G, Ackroyd-Stolarz S, Cain E, Petrie D. 2000. A randomized controlled trial on the effect of educational interventions in promoting airway management skill maintenance. Ann Emerg Med. 36:301–309.

Kriz WC. 2010. A systemic-constructivist approach to the facilitation and debriefing of simulations and games. Simul Gaming. 41:663–680.

Kulik C-LC, Kulik JA, Bangert-Drowns RL. 1990. Effectiveness of mastery learning programs: a meta-analysis. Rev Educ Res. 60:265–299.

Lafleur A, Côté L. 2016. Programmes' and students' roles in test-enhanced learning. Med Educ. 50:702–703.

Lave J, Wenger E. 1991. Situated learning: legitimate peripheral participation. Cambridge (UK); New York: Cambridge University Press.

Leppink J, Duvivier R. 2016. Twelve tips for medical curriculum design from a cognitive load theory perspective. Med Teach. 38:669–674.

Ma IWY, Zalunardo N, Pachev G, Beran T, Brown M, Hatala R, McLaughlin K. 2012. Comparing the use of global rating scale with checklists for the assessment of central venous catheterization skills using simulation. Adv Health Sci Educ. 17:457–470.

Martin JA, Regehr G, Reznick R, MacRae H, Murnaghan J, Hutchison C, Brown M. 1997. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg. 84:273–278.

Matsumoto ED, Hamstra SJ, Radomski SB, Cusimano MD. 2002. The effect of bench model fidelity on endourological skills: a randomized controlled study. J Urol. 167:1243–1247.

McGaghie WC. 2015. Mastery learning: it is time for medical education to join the 21st century. Acad Med Coll. 90:1438–1441.

McKinley RK, Strand J, Gray T, Schuwirth L, Alun-Jones T, Miller H. 2008. Development of a tool to support holistic generic assessment of clinical procedure skills. Med Educ. 42:619–627.

McKinley RK, Strand J, Ward L, Gray T, Alun-Jones T, Miller H. 2008. Checklists for assessment and certification of clinical procedural skills omit essential competencies: a systematic review. Med Educ. 42:338–349.

Mitra NK, Barua A. 2015. Effect of online formative assessment on summative performance in integrated musculoskeletal system module. BMC Med Educ. 15:29.

Montgomery K, Griswold-Theodorson S, Morse K, Montgomery O, Farabaugh D. 2012. Transdisciplinary simulation: learning and practicing together. Nurs Clin N Am. 47:493–502.

Motola I, Devine LA, Chung HS, Sullivan JE, Issenberg SB. 2013. Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. Med Teach. 35:e1511–e1530.

Murdoch NL, Bottorff JL, McCullough D. 2013. Simulation education approaches to enhance collaborative healthcare: a best practices review. Int J Nurs Educ Scholar. 10:307–321.

Naismith LM, Cheung JJH, Ringsted C, Cavalcanti RB. 2015. Limitations of subjective cognitive load measures in simulation-based procedural training. Med Educ. 49:805–814.

Nestel D, Groom J, Eikeland-Husebø S, O'Donnell JM. 2011. Simulation for learning and teaching procedural skills: the state of the science. Simul Healthc. 6(Suppl):S10–S13.

Niles D, Sutton RM, Donoghue A, Kalsi MS, Roberts K, Boyle L, Nishisaki A, Arbogast KB, Helfaer M, Nadkarni V. 2009. "Rolling Refreshers": a novel approach to maintain CPR psychomotor skill competence. Resuscitation. 80:909–912.

Nishisaki A, Nguyen J, Colborn S, Watson C, Niles D, Hales R, Devale S, Bishnoi R, Nadkarni LD, Donoghue AJ, et al. 2011. Evaluation of multidisciplinary simulation training on clinical performance and team behavior during tracheal intubation procedures in a pediatric intensive care unit. Pediatr Crit Care Med. 12:406–414.

Parry GJ, Carson-Stevens A, Luff DF, McPherson ME, Goldmann DA. 2013. Recommendations for evaluation of health care improvement initiatives. Acad Pediatr. 13:S23–S30.

Perez RS, Skinner A, Weyhrauch P, Niehaus J, Lathan C, Schwaitzberg SD, Cao CGL. 2013. Prevention of surgical skill decay. Mil Med. 178:76–86.

Pucher PH, Darzi A, Aggarwal R. 2013. Simulation for ward processes of surgical care. Am J Surg. 206:96–102.

Pugh DM, Wood TJ, Boulet JR. 2015. Assessing procedural competence: validity considerations. Simul Healthc. 10:288–294.

Rao A, Tait I, Alijani A. 2015. Systematic review and meta-analysis of the role of mental training in the acquisition of technical skills in surgery. Am J Surg. 210:545–553.

Reznick RK, MacRae H. 2006. Teaching surgical skills-changes in the wind. N Engl J Med. 355:2664–2669.

Rolfe I, McPherson J. 1995. Formative assessment: how am I doing? Lancet Engl. 345:837–839.

Rosen MA, Salas E, Wilson KA, King HB, Salisbury M, Augenstein JS, Robinson DW, Birnbach DJ. 2008. Measuring team performance in simulation-based training: adopting best practices for healthcare. Simul Healthc. 3:33–41.

Sawyer T, White M, Zaveri P, Chang T, Ades A, French H, Anderson J, Auerbach M, Johnston L, Kessler D. 2015. Learn, see, practice, prove, do, maintain: an evidence-based pedagogical framework for procedural skill training in medicine. Acad Med J Assoc Am Med Coll. 90:1025–1033.

Schmidt RA. 1975. A schema theory of discrete motor skill learning. Psychol Rev. 82:225–260.

Scholtz AK, Monachino AM, Nishisaki A, Nadkarni VM, Lengetti E. 2013. Central venous catheter dress rehearsals: translating simulation training to patient care and outcomes. Simul Healthc. 8:341–349.

Schunk DH, Zimmerman BJ. 1997. Social origins of selfregulatory competence. Educ Psychol. 32:195–208.

Schunk DH. 1999. Social-self interaction and achievement behaviour. Educ Psychol. 34:219–227.

Seropian MA. 2003. General concepts in full scale simulation: getting started. Anesth Analg. 97:1695–1705.

Sitzmann T, Ely K. 2011. A meta-analysis of self-regulated learning in work-related training and educational attainment: what we know and where we need to go. Psychol Bull. 137:421–442.

Sudikoff SN, Overly FL, Shapiro MJ. 2009. High-fidelity medical simulation as a technique to improve pediatric residents' emergency airway management and teamwork: a pilot study. Pediatr Emerg Care. 25:651–656.

Swanson DB, Norman GR, Linn RL. 1995. Performance-based assessment: lessons from the health professions. Educ Res. 24:5–35.

Taktek K. 2009. Strategies of specific/variable physical practice and acquisition of motor skills: a literature analysis. Rev Sci Educ. 35:173.

Van Bruwaene S, Schijven MP, Miserez M. 2014. Assessment of procedural skills using virtual simulation remains a challenge. J Surg Educ. 71:654–661.

van de Ridder JMM, Stokking KM, McGaghie WC, ten Cate OTJ. 2008. What is feedback in clinical education? Med Educ. 42:189–197.

Walzak A, Bacchus M, Schaefer JP, Zarnke K, Glow J, Brass C, McLaughlin K, Ma IWY. 2015. Diagnosing technical competence in six bedside procedures: comparing checklists and a global rating scale in the assessment of resident performance. Acad Med. 90:1100–1108.

Waters PS, McVeigh T, Kelly BD, Flaherty GT, Devitt D, Barry K, Kerin MJ. 2014. The acquisition and retention of urinary catheterisation skills using surgical simulator devices: teaching method or student traits. BMC Med Educ. 14:264.

Weinger MB, Herndon OW, Zornow MH, Paulus MP, Gaba DM, Dallen LT. 1994. An objective methodology for task analysis and workload assessment in anesthesia providers. Anesthesiology. 80:77–92.

Wenger E. 2008. Communities of practice: learning, meaning, and identity. 16th ed. Cambridge: Cambridge Univ. Press.

Woolfolk RL, Parrish MW, Murphy SM. 1985. The effects of positive and negative imagery on motor skill performance. Cogn Ther Res. 9:335–341.

Ziv A, Wolpe PR, Small SD, Glick S. 2003. Simulation-based medical education: an ethical imperative. Acad Med Coll. 78:783–788.