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A M E R I C A N C O L L E G E O F



P H Y S I C I A N S<sup>®</sup>



## Lessons for Continuing Medical Education From Simulation Research in Undergraduate and Graduate Medical Education\*

### Effectiveness of Continuing Medical Education: American College of Chest Physicians Evidence-Based Educational Guidelines

William C. McGaghie, PhD; Viva J. Siddall, MA; Paul E. Mazmanian, PhD; and Janet Myers, MD, FCCP

**Background:** Simulation technology is widely used in undergraduate and graduate medical education as well as for personnel training and evaluation in other healthcare professions. Simulation provides safe and effective opportunities for learners at all levels to practice and acquire clinical skills needed for patient care. A growing body of research evidence documents the utility of simulation technology for educating healthcare professionals. However, simulation has not been widely endorsed or used for continuing medical education (CME).

**Methods:** This article reviews and evaluates evidence from studies on simulation technology in undergraduate and graduate medical education and addresses its implications for CME.

**Results:** The Agency for Healthcare Research and Quality Evidence Report suggests that simulation training is effective, especially for psychomotor and communication skills, but that the strength of the evidence is low. In another review, the Best Evidence Medical Education collaboration supported the use of simulation technology, focusing on high-fidelity medical simulations under specific conditions. Other studies enumerate best practices that include mastery learning, deliberate practice, and recognition and attention to cultural barriers within the medical profession that present obstacles to wider use of this technology.

**Conclusions:** Simulation technology is a powerful tool for the education of physicians and other healthcare professionals at all levels. Its educational effectiveness depends on informed use for trainees, including providing feedback, engaging learners in deliberate practice, integrating simulation into an overall curriculum, as well as on the instruction and competence of faculty in its use. Medical simulation complements, but does not replace, educational activities based on real patient-care experiences. (CHEST 2009; 135:62S–68S)

**Key words:** deliberate practice; mastery learning; simulation; systematic review

**Abbreviations:** AHRQ = Agency for Healthcare Research and Quality; BEME = best evidence medical education; CME = continuing medical education; GME = graduate medical education; UME = undergraduate medical education

This article has four sections. The first defines medical simulation and summarizes presumptive findings about simulation-based continuing medical education (CME) from the Agency for Healthcare Research and Quality (AHRQ) Evidence Report.<sup>1</sup> The report aims to synthesize the results of nine literature reviews about “the effectiveness of simu-

lation methods in medical education *outside of* CME.”<sup>1</sup> It also serves as a foundation for other sections of this article. The second section amplifies the findings from best evidence medical education (BEME) in one of the nine reviews.<sup>2</sup> The BEME review warrants special attention because it receives superficial coverage in the AHRQ Evidence Report,<sup>1</sup>

addresses a different question about simulation in medical education beyond its effectiveness, is not confined to a single medical specialty or medical simulator, and offers practical advice about simulation-based medical education program planning and operation. The third section distills and presents lessons learned about best educational practices drawn from both the AHRQ report and the BEME review as well as from two graduate medical education (GME) and research programs and other published sources. The fourth section presents implications for CME grounded in the preceding narrative, the changing focus and professional character of CME, and observations about education for other learned professions.

Medical education using some form of simulation generally has been aimed at the junior trainee both for undergraduate medical education (UME) and for GME. The benefits of simulation derive from its standardization and reproducibility in contrast with the traditional apprenticeship approach to teaching where medical students and residents learn through practice with real patients in the clinic or hospital setting. With the increasing number of patients who are hospitalized and the shorter lengths of hospital stays, requirements for limited trainee work hours, and an emphasis on patient safety, simulation has received greater attention at the UME and GME levels. However, simulation seldom is discussed in the context of CME.

This article reviews the use of simulation education in baseline assessment of knowledge and skills, education grounded in learning objectives, intended outcomes expressed in metrics, deliberate practice with feedback, rigorous outcome evaluation, and professional accountability. These constructs are addressed thoroughly in a call for CME reform in the United States.<sup>3</sup> This article urges the physician-learner to participate in CME activities that include deliberate practice and where he or she can work toward a mastery learning of CME objectives. Physician-teachers should design CME activities that make use of

teaching techniques that assist the physician-learner in mastery learning and deliberate practice, embrace outcome measurement, and address cultural barriers to incorporate these educational approaches. Simulation as a teaching technique can be used by the physician-teacher to achieve these goals.

#### DEFINITION AND AHRQ EVIDENCE REPORT

Medical simulation is defined as “a person, device, or set of conditions which attempts to present [education and] evaluation problems authentically. The student or trainee is required to respond to the problems as he or she would under natural circumstances. Frequently the trainee receives performance feedback as if he or she were in the real situation.”<sup>4</sup> “Simulation procedures for evaluation and teaching have the following common characteristics:

- Trainees see cues and consequences very much like those in the real environment.
- Trainees can be placed in complex situations.
- Trainees act as they would in the real environment.
- The fidelity (exactness of duplication) of a simulation is never completely isomorphic with the real thing. The reasons are obvious: cost, [limits of] engineering technology, avoidance of danger, ethics, psychometric requirements, time constraints.
- Simulations can take many forms. For example, they can be static, as in an anatomical model [for task training]. Simulations can be automated, using advanced computer technology. Some are individual, prompting solitary performance while others are interactive, involving groups of people. Simulations can be playful or deadly serious. In personnel evaluation settings they can be used for high-stakes, low-stakes, or no-stakes decisions.”<sup>4</sup>

Medical simulations are located on a continuum of fidelity, ranging from detached, multiple-choice examination questions;<sup>5</sup> to more engaging task trainers (arms for phlebotomy practice); to full-body, computer-driven mannequins with sophisticated physiologic features that respond to pharmacologic and mechanical interventions.<sup>6</sup> Simulations also include standardized patients who are live persons trained and calibrated to portray patients with a variety of presenting complaints and pathologies. Decades of experience and research demonstrate that standardized patients are highly effective for medical education and evaluation.<sup>7</sup> Standardized examinees (students) also have been used as a way to calibrate and improve clinical skills examinations.<sup>8,9</sup> Medical educators have recently combined these modalities where standardized patients, inanimate models, and medical equipment are integrated to evaluate train-

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ees' technical, communication, and other professional skills simultaneously.<sup>10</sup>

The AHRQ Evidence Report included a review of nine systematic reviews published between 1990 and 2006 that sought to evaluate the effectiveness of simulation methods in medical education outside of CME. The investigators abstracted data about study characteristics, educational objectives, learning outcomes, summary of results, conclusions, and quality of each review and graded the evidence of these articles according to each educational objective and outcome related to participant knowledge, attitudes, skills, practice behaviors, and clinical outcomes. The quality of each review was established using criteria derived from the Quality of Reporting of Meta-analyses statement,<sup>11</sup> which is intended for use only as a guide for preparing reports on quantitative metaanalyses that include randomized controlled trials.

The AHRQ report has several limitations, the most important is the review methodology, which failed to find two eligible reports.<sup>12,13</sup> This and other issues make the report's findings about simulation difficult to interpret unequivocally. Nevertheless, the AHRQ report<sup>1</sup> argues that the overall "direction of evidence points to the effectiveness of simulation training, especially for psychomotor skills (*eg*, procedures or physical examination techniques) and communication skills," despite the low strength of the evidence "due to the small number of appropriate studies and scarcity of [reliable] quantitative data." We add to these deficits the narrow focus of eight of the nine-included reviews (*ie*, single medical specialty, single simulation method) and the weakness of most primary studies covered in the reviews. These limitations are attributed, in part, to the lack of consensus about standardized methods to quantify clinical competence, a persistent problem in medical education research. The AHRQ authors also speculate that other limitations may include difficulty of establishing "clinical realism [high-fidelity] for participants," and "other features that may be responsible for inadequate quality of evidence in this field."<sup>1</sup>

## BEME REVIEW

One of the nine literature reviews cited in the AHRQ report but not explained in depth is a systematic review done under the auspices of the BEME collaboration.<sup>14</sup> The collaboration "involves an international group of individuals, universities, and organizations (*eg*, AMEE [Association for Medical Education in Europe], AAMC [Association of American Medical Colleges], ABIM [American Board of Internal Medicine]) committed to moving the medical profession from opinion-based education to evidence-based education. The goal is to

provide medical teachers and administrators with the latest findings from scientifically grounded educational research."<sup>2</sup>

The broad scope of the BEME systematic review<sup>2</sup> is distinct from the narrower focus on the effectiveness of simulation compared to other educational techniques. This article addressed best educational practices, reviewing 670 journal articles published between 1969 and 2003. Despite the original intent to conduct a quantitative metaanalysis, the studies were so heterogeneous and weak methodologically that the investigators resorted to a qualitative, narrative synthesis. The primary outcome of the BEME review is an inventory of 10 features and uses of high-fidelity simulations that lead to effective learning. These features are listed in order of reported frequency (percent) among the final BEME pool of 109 articles, and the report concluded that "the weight of the best available evidence suggests that high-fidelity medical simulations facilitate learning under the right conditions.<sup>2</sup> The 10 conditions<sup>2</sup> are as follows:

1. Feedback is provided during learning experiences (47%).
2. Learners engage in repetitive practice (39%).
3. Simulation is integrated into an overall curriculum (25%).
4. Learners practice tasks with increasing levels of difficulty (14%).
5. Simulation is adaptable to multiple learning strategies (10%).
6. Clinical variation is built into simulation experiences (10%).
7. Simulation events occur in a controlled environment (9%).
8. Individualized learning is an option (9%).
9. Outcomes or benchmarks are clearly defined or measured (6%).
10. The simulation is a valid representation of clinical practice (3%).

These findings, chiefly from UME and GME, are a guide for defining a research agenda on simulations as educational technologies. In contrast with the eight other literature reviews covered in the AHRQ Evidence Report, the BEME review spans a wide variety of medical specialties and simulation technologies across a long time frame. In addition, its emphasis on features and uses of medical simulation that lead to effective learning (*eg*, feedback, repetitive practice, curriculum integration), not just comparative effectiveness, sets a standard for understanding the benefits of simulation for medical education and personnel evaluation. The BEME review<sup>2</sup> on high-fidelity medical simulations also included a call for increased rigor in original simulation-based medical education research and improved

journal-reporting conventions. In particular, the authors suggested that journal editors insist that all reports of primary research include basic descriptive statistics (*eg*, means, SDs, effect sizes, number of cases per group) that will permit quantitative synthesis in subsequent metaanalyses.

A subset of 31 journal articles reporting 32 research studies within the 109 articles was found to contain enough empirical data to permit a quantitative metaanalysis. The studies were framed to address the question, “Is there an association between hours of simulation-based practice and standardized learning outcomes?”<sup>15</sup> Measured outcomes from these studies were cast on a standardized metric termed *average weighted effect size*. Hours of simulation-based practice in each study were grouped in the following five categories: none reported, 0 to 1.0, 1.1 to 3.0, 3.1 to 8.0, and 8.1 +. Data analysis revealed a highly significant “dose-response” relationship among practice and achievement, with more practice producing higher outcome gains. These results are presented in a subsequent report<sup>15</sup> that demonstrated a direct relationship between hours of simulator practice and standardized learning outcomes.

#### LESSONS LEARNED ABOUT BEST EDUCATIONAL PRACTICES

The scholarship of the AHRQ report and BEME review is amplified by at least two other reviews<sup>12,13</sup> about simulation-based medical education that also can inform CME practices. One way to highlight advances in simulation-based UME and GME is to focus on exemplary education and research programs that identify their special features. Work completed by two medical simulation education and research programs<sup>16–27</sup> are illustrative, as they are thematic, sustained, and cumulative and are of special interest for chest physicians. Additional studies inform on academic standard setting<sup>28</sup> and mastery learning of clinical skills in advanced cardiac life support<sup>29</sup> and thoracentesis.<sup>30</sup>

A more recent report<sup>31</sup> discussed the “scope of simulation-based healthcare education,” pointing out that the best simulation-based medical education is a multiplicative product of simulation technology (*eg*, devices, standardized patients), teachers prepared to use the technology to maximum educational advantage, and curriculum integration. It argued that the major flaws in current simulation-based medical education stem from a lack of prepared teachers and curriculum isolation, not from technological problems or deficits.

The design of educational activities useful to practicing physicians assumes that CME program directors are knowledgeable about “what works” from scholarly

reviews<sup>2,12,13,15</sup> and from individual studies having strong research designs, such as randomized trials,<sup>24</sup> mastery learning research,<sup>29,30</sup> and cohort studies.<sup>32</sup> Program directors also should be informed about the latest scholarship on technology in medical education.<sup>33</sup> The key lesson is that medical simulation and other educational technologies are best used to complement, not replace, education grounded in patient care. CME in any form should be based on scientific best evidence rather than on opinion or habit.<sup>14</sup>

We endorse the position that CME best practices reside in educational programs that have the following three features: mastery learning, deliberate practice, and recognition and attention to cultural barriers within the medical profession that frustrate better CME programs. In particular, mastery learning and deliberate practice are ideally suited for simulation-based medical education. They also conform to accepted principles of adult education independent of teaching modalities.<sup>34</sup>

#### Mastery Learning

Essential elements of the mastery learning model have been described in earlier publications.<sup>35–37</sup> In brief, mastery learning has the following seven complementary features:

1. Baseline, or diagnostic testing;
2. Clear learning objectives, sequenced as units in increasing difficulty;
3. Engagement in educational activities (*eg*, skills practice, data interpretation, reading, focused on reaching the objectives);
4. A set minimum passing standard (*eg*, test score) for each educational unit;
5. Formative testing to gauge unit completion at a preset minimum passing standard for mastery;
6. Advancement to the next educational unit given measured achievement at or above the mastery standard; and
7. Continued practice or study on an educational unit until the mastery standard is reached.

The goal in mastery learning is to ensure that all learners accomplish all educational objectives with little or no variation in outcome. The amount of time needed to reach mastery standards for a unit’s educational objectives varies among the learners. To illustrate, in mastery learning studies on acquiring advanced cardiac life support<sup>29</sup> and thoracentesis<sup>30</sup> skills, approximately 20% of the internal medicine resident trainees needed more time beyond the minimum allocation to reach mastery standards. The extra time needed was usually < 1 h.

The mastery learning model also includes other options in simulation-based education. For example,

mastery learning can address learning objectives beyond skill acquisition to include knowledge gains; affective qualities, such as self-efficacy; or features of medical professionalism. Mastery learning requires a standardized curriculum for all learners, with uniform outcomes assessed by rigorous measurements and standards.<sup>28,38,39</sup>

### *Deliberate Practice*

Deliberate practice is an educational variable associated with delivery of strong and consistent educational treatments as part of the mastery learning model.<sup>40–43</sup> Although demanding of learners, deliberate practice is grounded in information processing and behavioral theories of skill acquisition and maintenance.<sup>40–42</sup> It has at least nine requirements that can inform CME, as follows:

1. Highly motivated learners with good concentration;
2. Engagement with a well-defined learning objective or task;
3. Appropriate level of difficulty;
4. Focused, repetitive practice;
5. Rigorous, precise measurements;
6. Informative feedback from educational sources (eg, simulators or teachers);
7. Monitoring, correction of errors, and more deliberate practice;
8. Evaluation to reach a mastery standard; and
9. Advancement to another task or unit.

The goal of deliberate practice in a CME mastery-learning context is to require constant improvement of skill and knowledge rather than maintenance of a minimal level. Ericsson<sup>40–42</sup> cites data that underscore a “4/10 rule” about development of expertise in any field, as follows: it takes 4 h of deliberate practice every day for 10 years to become a world-class performer like an Olympic athlete, cutting-edge scientist, chess master, patient-care provider, or writer. Even Michael Jordan took 500 free throws every day throughout his professional basketball career to maintain and improve his professional edge.<sup>44</sup>

Deliberate practice using medical simulation has been shown to improve medical performance in several medical and surgical specialties.<sup>45</sup> In a small study of pulmonary fellows trained with virtual bronchoscopy,<sup>46</sup> trainees demonstrated equal or better facility with an airway training model compared with skilled colleagues with several years of experience. This cascaded approach to education shapes “deliberate practice pedagogy.”<sup>47</sup> Joined with a mastery-learning program structure, the combination creates the potential for a more standard way to assess knowledge and competence.<sup>48</sup>

### *Cultural Barriers*

It is unlikely that educational innovations involving simulation-based mastery learning and deliberate practice will receive a warm reception in the medical community. Innovations will be used effectively only after barriers in medical culture are acknowledged, addressed, and breached. Adoption of innovation in medical education at all levels has been slowed by inertia, habit, absence of audit and accountability, and other cited barriers. Medical education culture needs to embrace innovation and its diffusion as energizing opportunities that will boost professional competence, morale, and patient care. Specifically, barriers in contemporary medical culture that inhibit advancement of simulation-based CME are as follows:

1. A group of scholars stated in 1978 that the most powerful force in medical education is inertia.<sup>37</sup> This statement probably is still true, and the CME community must change habits and embrace evidence-based, outcomes-focused educational models to replace approaches featuring passive lectures, seat time, and continuing educational units.
2. Clinical medical education has a traditional patient-centered focus, grounded in Osler’s writing<sup>49</sup> about medical education in the 19th century. The focus is completely shifted in the medical simulation environment to the learner’s education and skill acquisition, rather than the care of the patient.
3. Evaluation apprehension is a pervasive fear among physicians about being identified as lacking knowledge, judgment, or clinical skill, especially in a public setting, and it is endemic in medical culture.<sup>50</sup> CME practices that include rigorous diagnostic assessments of physicians’ baseline skill and knowledge probably will meet stiff resistance unless privacy of the learners is protected. Such assessments usually reveal professional deficits, even among advanced clinical learners.<sup>24,25,29,51</sup>
4. There is a widespread belief in medical education that seniority and clinical experience are proxies for clinical competence. This belief contrasts with research findings that clinical experience alone is not associated with better performance at basic skills, like cardiac auscultation,<sup>52</sup> responses to acute intraoperative events in anesthesia,<sup>19</sup> or the wider competency of delivering quality health care.<sup>53</sup>
5. Medical education rarely has had rigorous assessment of its short- or long-term impact on patient care or clinical outcomes, such as those obtained through audit, accountability, and performance improvement.<sup>54</sup>

6. The medical profession has been insular, rarely looking to other professions for educational models, ideas, or approaches to education and personnel assessment. For example, medicine has much to learn about team training from aviation<sup>55</sup> and from nuclear power plant operation.<sup>56,57</sup> Professional education for clergy roles also offers ideas to medicine about career formation and shaping a public-service identity.<sup>58</sup>
7. Faculty development, especially about the effective use of simulation technology to promote learner achievement, must become a priority training goal.<sup>33</sup> Simple or sophisticated simulation technology will be ineffective or misused unless faculty members, including physicians and other health professionals, are prepared as simulation educators.

#### IMPLICATIONS FOR CME

Simulation technology as an educational tool could lead to significant changes in medical education, including a new emphasis on skill and knowledge acquisition and maintenance, integration of the technique into a comprehensive clinical curriculum that includes certification and recertification, adoption of mastery learning and deliberate practice, and increased competence and outcome measurement. Research should focus on valid and reliable tools for more systematic outcome measurements, with the ultimate goal of improving the quality of patient care. Policies that inform physician performance and govern the privilege to practice not only need to endorse the effective educational use of simulation technology, but also tackle sources of cultural resistance to its adoption.

Simulation will never replace the situational context and complex interactions learned through interaction with real patients. Expert mentors will always be needed not only to verify trainee performance in real situations, but also to judge the simulators' *in vivo* fidelity. Nevertheless, cultural barriers should not hinder the adoption and informed use of simulation technology as a powerful and effective educational tool to maximize physician and other health professional training and, ultimately, to improve patient care.

#### CONFLICT OF INTEREST DISCLOSURES

**Dr. McGaghie** has twice served as a paid speaker at Simulation Users Network (SUN) events sponsored by Laerdal Medical Corp.

**Ms. Siddall** has no conflicts of interest.

**Dr. Mazmanian** has no conflicts of interest.

**Dr. Myers** has no conflicts of interest.

#### REFERENCES

- 1 Marinopoulos SS, Dorman T, Ratanawongsa N, et al. Effectiveness of continuing medical education. Rockville, MD: Agency for Healthcare Research and Quality: 2007. Evidence Report/Technology Assessment No 149
- 2 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
- 3 Spivey BE. Continuing medical education in the United States: why it needs reform and how we propose to accomplish it. *J Contin Educ Health Prof* 2005; 25:134–143
- 4 McGaghie WC. Simulation in professional competence assessment: basic considerations. In: Tekian A, McGuire CH, McGaghie WC, eds. *Innovative simulations for assessing professional competence*. Chicago, IL: Department of Medical Education, University of Illinois at Chicago, 1999; 7–22
- 5 Boulet JR, Swanson DB. Psychometric challenges of using simulations for high-stakes assessment. In: Dunn WF, ed. *Simulators in critical care education and beyond*. Des Plaines, IL: Society of Crit Care Med, 2004; 119–130
- 6 Issenberg SB, McGaghie WC. Assessing knowledge and skills in the health professions: a continuum of simulation fidelity. In: Tekian A, McGuire CH, McGaghie WC, eds. *Innovative simulations for assessing professional competence*. Chicago, IL: Department of Medical Education, University of Illinois at Chicago, 1999; 125–146
- 7 Petrusa ER. Clinical performance assessments. In: Norman GR, van der Vleuten CPM, Newble DI, eds. *International handbook of research in medical education: part two*. Dordrecht, the Netherlands: Kluwer Academic Publishers 2002; 673–709
- 8 Pangaro LN, Worth-Dickstein H, MacMillan MK, et al. Performance of “standardized examinees” in a standardized-patient examination of clinical skills. *Acad Med* 1997; 72: 1008–1011
- 9 Worth-Dickstein H, Pangaro LN, MacMillan MK, et al. Use of “standardized examinees” to screen for standardized-patient scoring bias in a clinical skills examination. *Teach Learn Med* 2005; 17:9–13
- 10 Kneebone R, Nestel D, Yadollahi F, et al. Assessing procedural skills in context: exploring the feasibility of an Integrated Procedural Performance Instrument (IPPI). *Med Educ* 2006; 40:1105–1114
- 11 Moher D, Cook DJ, Eastwood S, et al. Improving the quality of reports of meta-analyses of randomized controlled trials: the QUOROM statement. *Lancet* 1999; 354:1896–1900
- 12 Issenberg SB, McGaghie WC, Hart IR, et al. Simulation technology for health care professional skills training and assessment. *JAMA* 1999; 282:861–866
- 13 Levine AI. Simulation for continuing health professional education. In: Loyd GE, Lake CL, Greenberg RB, eds. *Practical health care simulations*. Philadelphia, PA: Elsevier, 2004; 527–541
- 14 Harden RM, Grant J, Buckley EG, et al. BEME guide No. 1: best evidence medical education. *Med Teacher* 1999; 21:553–562
- 15 McGaghie WC, Issenberg SB, Petrusa ER, et al. Effect of practice on standardized learning outcomes in simulation-based medical education. *Med Educ* 2006; 40:792–797
- 16 Boulet JR, Murray D, Kras J, et al. Reliability and validity of a simulation-based acute care skills assessment for medical students and residents. *Anesthesiology* 2003; 99:1270–1280
- 17 Murray DJ, Boulet JR, Kras JF, et al. Acute care skills in anesthesia practice. *Anesthesiology* 2004; 101:1084–1095
- 18 Murray DJ, Boulet JR, Kras JF, et al. A simulation-based acute skills performance assessment for anesthesia training. *Anesth Analg* 2005; 101:1127–1134

- 19 Murray DJ, Boulet JR, Avidan M, et al. Performance of residents and anesthesiologists in a simulation-based skill assessment. *Anesthesiology* 2007; 107:705–713
- 20 McGaghie WC, Pugh CM, Wayne DB. Fundamentals of educational research using clinical simulation. In: Kyle R, Murray WB, eds. *Clinical simulation: operations, engineering, and management*. Burlington, MA: Academic Press, 2008; 517–526
- 21 Stufflebeam DL. Guidelines for developing evaluation checklists: the checklists development checklist (CDC). Available at: <http://www.wmich.edu/evalctr/checklists>. Accessed January 12, 2009
- 22 Cummins RO, ed. *ACLS provider manual*. Dallas, TX: American Heart Association, 2001
- 23 American Heart Association. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2005; 112:IV1–IV203
- 24 Wayne DB, Butter J, Siddall VJ, et al. Simulation-based training of internal medicine residents in advanced cardiac life support protocols: a randomized trial. *Teach Learn Med* 2005; 17:210–216
- 25 Wayne DB, Butter J, Siddall VJ, et al. Graduating internal medicine residents' self-assessment and performance of advanced cardiac life support skills. *Med Teach* 2006; 28:365–369
- 26 Wayne DB, Siddall VJ, Butter J, et al. Longitudinal study of internal medicine residents' retention of advanced cardiac life support skills. *Acad Med* 2006; 81(suppl):S9–S12
- 27 Wayne DB, Didwania A, Feinglass J, et al. Simulation-based education improves quality of care during cardiac arrest team responses at an academic teaching hospital: a case-control study. *Chest* 2008; 133:56–61
- 28 Wayne DB, Fudala MJ, Butter J, et al. Comparison of two standard setting methods for advanced cardiac life support skills training. *Acad Med* 2005; 80(suppl):S63–S66
- 29 Wayne DB, Butter J, Siddall VJ, et al. Mastery learning of advanced cardiac life support skills by internal medicine residents using simulation technology and deliberate practice. *J Gen Intern Med* 2006; 21:251–256
- 30 Wayne DB, Barsuk JH, O'Leary K, et al. Mastery learning of thoracentesis skills by internal medicine residents using simulation technology and deliberate practice. *J Hosp Med* 2008; 3:48–54
- 31 Issenberg SB. The scope of simulation-based healthcare education. *Sim Healthcare* 2006; 1:203–208
- 32 Issenberg SB, McGaghie WC, Gordon DL, et al. Effectiveness of a cardiology review course for internal medicine residents using simulation technology and deliberate practice. *Teach Learn Med* 2002; 14:223–228
- 33 Association of American Medical Colleges. *AAMC Colloquium on Educational Technology: effective use of educational technology in medical education; summary report*. Washington, DC: Association of American Medical Colleges, 2007
- 34 Knox AB. *Helping adults learn*. San Francisco, CA: Jossey-Bass, 1986
- 35 Block JH, ed. *Mastery learning: theory and practice*. New York, NY: Holt, Rinehart and Winston 1971
- 36 Bloom BS. Time and learning. *Am Psychol* 1974; 29:682–688
- 37 McGaghie WC, Miller GE, Sajid A, Telder TV. *Competency-based curriculum development in medical education*. Geneva, Switzerland: World Health Organization, 1978; Public Health Paper No. 68
- 38 Adler M, Trainor JL, Siddall VJ, et al. Development and evaluation of high-fidelity case scenarios for pediatric resident education. *Ambul Pediatr* 2007; 7:182–186
- 39 Issenberg SB, McGaghie WC, Brown DD, et al. Development of multimedia computer-based measures of clinical skills in bedside cardiology. In: Melnick DE, ed. *The Eighth International Ottawa Conference on Medical Education and Assessment Proceedings: evolving assessment; protecting the human dimension*. Philadelphia, PA: National Board of Medical Examiners, 2000; 821–829
- 40 Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Acad Med* 2004; 79(suppl):S70–S81
- 41 Ericsson KA, Charness N. Expert performance: its structure and acquisition. *Am Psychol* 1994; 49:725–747
- 42 Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev* 1993; 100:363–406
- 43 Cordray DS, Pion GM. Treatment strength and integrity: models and methods. In: Bootzin RR, McKnight PE, eds. *Strengthening research methodology: psychological measurement and evaluation*. Washington, DC: American Psychological Association, 2006; 103–124
- 44 Jordan M. *For the love of the game*. New York, NY: Crown Publishers, 1998
- 45 Ericsson KA. An expert-performance perspective of research on medical expertise: the study of clinical performance. *Med Educ* 2007; 41:1124–1130
- 46 Colt HG, Crawford SW, Galbraith O. Virtual reality bronchoscopy simulation: a revolution in procedural training. *Chest* 2001; 120:1333–1339
- 47 Farmer LC, Williams GR. The rigorous application of deliberate practice methods in skills courses. Paper presented at: the UCLA/IALS Sixth International Clinical Conference on Enriching Clinical Education; October 27–30, 2005; Los Angeles, CA
- 48 Ericsson KA, ed. *The road to excellence: the acquisition of expert performance in the arts and sciences, sports and games*. Mahwah, NJ: Lawrence Erlbaum Associates, 1996
- 49 Osler W. *The hospital as a college*. In: Osler W, ed. *Aequanimitas*. 2nd ed. Philadelphia, PA: P. Blakiston's Son & Co, 1906; 329–342
- 50 Good M-JD. *American medicine: the quest for competence*. Berkeley, CA: University of California Press, 1995
- 51 Eisen LA, Berger JS, Hegde A, et al. Competency in chest radiography: a comparison of medical students, residents, and fellows. *J Gen Intern Med* 2006; 21:460–465
- 52 Mangione S, Nieman LZ. Cardiac auscultatory skills of internal medicine and family practice trainees: a comparison of diagnostic proficiency. *JAMA* 1997; 278:717–722
- 53 Choudhry NK, Fletcher RH, Soumerai SB. Systematic review: the relationship between clinical experience and quality of health care. *Ann Intern Med* 2005; 142:260–273
- 54 Reed D, Price EG, Windish DM, et al. Challenges in systematic reviews of educational intervention studies. *Ann Intern Med* 2005; 142:1080–1089
- 55 Weiner EL, Kanki BG, Helmreich RL, eds. *Cockpit resource management*. San Diego, CA: Academic Press, 1993
- 56 Mathieu JE, Day DV. Assessing processes within and between organizational teams: a nuclear power plant example. In: Brannick BT, Salas E, Prince C, eds. *Team performance assessment and measurement*. Mahwah, NJ: Lawrence Erlbaum Associates, 1997; 173–195
- 57 Touquam JL, Macaulay JL, Westra CD, et al. Assessment of nuclear power plant crew performance variability. In: Brannick BT, Salas E, Prince C, eds. *Team performance assessment and measurement*. Mahwah, NJ: Lawrence Erlbaum Associates, 1997; 253–287
- 58 Foster CR, Dahill LE, Golemon LA, et al. *Educating clergy: teaching practices and pastoral imagination*. San Francisco, CA: Jossey-Bass, 2006



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