BEME review

Best evidence on high-fidelity simulation: what clinical teachers need to know

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Since the 1980s, medical education has witnessed a significant increase in the use of simulation technology for teaching and assessment. What had previously been thought of as just a hobby for technically savvy clinical educators has now been fully integrated into the culture of clinical training. This is true not only for undergraduate medical education, but also for postgraduate training and continuing professional development. Hundreds of medical schools worldwide have already developed, or are in the process of developing, clinical skills/

The most thorough search possible of peer-reviewed publications

Providing feedback is the most important feature of simulation

data synthesis using meta-analysis. The coding accuracy and inter-rater agreement for features of the journal articles was high. While the quality of the published research is generally weak, the weight of the best available evidence identified ten features and uses of high-fidelity medical simulations (in a range of specialties including anaesthesiology, cardiology and surgery) that lead to effective learning. We recommend that these features are considered as a minimum when using simulations in the clinical teaching and training of others.

simulation centres providing a wide range of simulations.[1] However, the significant allocation of funding and resources required for high-fidelity simulations demands evidence that this investment will yield positive outcomes. With this in mind, the Best Evidence Medical Education (BEME) Collaboration invited our group to review and synthesise existing evidence in educational science that addressed the question: 'What are the features and uses of high-fidelity medical simulations that lead to the most effective learning?' Our findings yielded a list of ten features that clinical teachers should be aware of and adopt when using high-fidelity simulations.

In 2005, we published a paper detailing the processes involved in a systematic literature review: the identification of articles, extraction of data, and analysis and synthesis of findings.[2] We searched five literature databases (ERIC, MEDLINE, PsycINFO, Web of Science, and TimeLIT) using 91 single search terms and concepts, and Boolean combinations of these. We also hand-searched specialist journals, posted internet queries using Google, and reviewed the 'grey literature' (for example, conference proceedings). The aim was to perform the most thorough search possible of peer-reviewed publications, as well as unpublished reports in the literature that had been judged for academic quality.

We then employed four screening criteria to reduce the initial pool of 670 journal articles (more than 2,100 abstracts) to a focused set of 109 studies. These criteria were: (a) the elimination of review articles in favour of empirical studies; (b) the use of a simulator as an educational assessment or intervention, with learner outcomes measured quantitatively; (c) comparative research, either experimental or quasi-experimental; and (d) research that involves simulation solely as an educational intervention.

Nine independent coders extracted data systematically from the 109 eligible journal articles, each coder using a standardised data extraction protocol. Qualitative data synthesis and tabular presentation of research methods were used, because heterogeneity of research designs, educational interventions, outcome measures and the time-frame available precluded

FEEDBACK

Not surprisingly, we found that providing feedback to learners regarding their performance is the single most important feature of simulation-based medical education towards the goal of effective learning. Focused constructive feedback can also slow the decay of acquired skills, as well as allowing learners to self-assess and monitor their progress towards skill acquisition and maintenance. Sources of feedback may be 'built-in' to a simulator in such a way that learners' actions result in a direct response from the simulator. For example, while defibrillating a 'patient' in cardiac arrest, the learner can view the response on the adjacent cardiac monitor. Alternatively, clinical teachers may also give feedback in 'real time' during educational sessions, or provide it *post hoc* by viewing a video recording of the simulation-based educational activity. Remember: the source of the feedback is less important than its presence.

Effective learning stems from learner engagement in deliberate practice

REPETITIVE PRACTICE

Opportunities for learners to engage in focused, repetitive practice – where the intent is skill improvement, not idle play – should be an essential learning feature of high fidelity medical simulations. Such practice involves intense and repeated learner engagement in a focused, controlled task, with the constant repetition giving learners the opportunity to detect and correct errors, polish their skills, and make their performance effortless and automatic. Recent research underscores the importance of repetition for clinical skill acquisition and maintenance,[3] and it has been shown that learners who are given opportunities for repetitive practice acquire necessary skills over shorter time periods than those with only routine exposure during clinical patient-care activities. This is an important factor when transferring the use of the learnt skills to real patients. Finally, the 'dose' of practice necessary should be determined by the learner's need rather than the instructor's demand. And simulators must be available (that is, to accommodate learner schedules) and in physically convenient locations (that is, close to hospital wards and clinics), to enable learners to practice skills repetitively.

CURRICULUM INTEGRATION

The integration of simulation-based exercises into the standard medical school or postgraduate educational curriculum is an essential feature of their effective use. Simulation-based education should not be an extraordinary activity; rather, educators should build simulations into the learners' normal training schedule and should base this instruction on the ways in which they will ultimately evaluate learner performance. Simulation should not be dependent on a single 'champion', who often has competing research and/or patient-care responsibilities, but be fully adopted within the wider educational programme of the medical school. Effective medical learning stems from learner engagement in deliberate practice, with clinical problems and devices in simulated settings in addition to patient-care experience. Medical education using simulations must be a required component of the standard curriculum, as optional exercises arouse much less learner interest.

RANGE OF TRAINING LEVELS

Learning is enhanced when trainees have the opportunity to engage in deliberate practice of medical skills across a wide range of levels of difficulty. Learners begin at the basic-skills level, demonstrate performance mastery against objective criteria and standards, and proceed to training at progressively higher levels of complexity. Each learner will have a different 'learning curve' in terms of shape and acceleration, although long-term learning outcomes, measured objectively, should be identical. Encouraging learners to master increasingly complex skills will slow the overall decay of skills over time.

MULTIPLE LEARNING STRATEGIES

The adaptability of high-fidelity medical simulations to multiple learning strategies is both a feature and a use of these educational devices. Desired outcomes, available resources, and the educational climate or culture of the institution will determine which strategies are adopted. Multiple learning strategies include, but are not limited to: (1) instructor-centred education involving either (a) large groups (for example, lectures); or (b) small groups (for example, tutorials); (2) small-group learning without an instructor; and (3) individual, independent learning. Of course, the optimal use of high-fidelity simulations in such different learning situations depends on the educational objectives being addressed and the extent of prior learning among the trainees. The bottom line is that the educational tools employed should match the stated educational goals. High-fidelity medical simulations that are adaptable to several learning strategies are more likely to fulfil this aim.

CLINICAL VARIATION

High-fidelity medical simulations that can capture or represent a wide variety of patient problems or conditions may be more useful than simulations having a

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High-fidelity medical simulations should feature clearly defined outcomes

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narrower focus. An exception to this, of course, is simulators designed for a specific task, such as carotid stent placement. Simulations capable of sampling from a broad universe of patient demographics, pathologies and responses to treatment can increase the number and variety of patients that learners encounter. Boosting the variety of simulated patients seen by learners also helps to standardise the clinical curriculum across educational sites. This gives 'equity' to smaller programmes, often in remote locations, where the range of real patients may be restricted. Such simulations can also give learners exposure and practice experience with rare, life-threatening patient problems, where the presentation frequency is low but the stakes are high. This provides more 'contextual experiences', which are critical to developing problem-solving skills.

CONTROLLED ENVIRONMENT

In a controlled clinical environment, learners can make, detect and correct patient-care errors with no adverse consequences, and instructors can focus on the learners rather than the patients. In contrast to the uncontrolled character of most patient-care settings, high-fidelity simulations are ideal for providing a controlled, forgiving environment. Education in a controlled environment allows instructors and learners to focus on 'teachable moments' without distraction, and take full advantage of opportunities for deliberate practice. This also reflects a clinical and educational culture focused on ethical training involving both learners and patients.[4]

INDIVIDUALISED LEARNING

The opportunity for learners to have reproducible, standardised educational experiences where they are active participants, rather than merely passive bystanders, is an important aspect of the use of high-fidelity medical simulations, and learning experiences can be individualised and adapted to each student's unique learning needs. Simulations allow complex clinical tasks to be broken down into their component parts for educational mastery in sequence at variable rates, enabling learners to take responsibility for their own educational progress within the limits of curriculum governance. With individualised learning using high-fidelity medical simulations, the goal of uniform educational outcomes can be achieved despite different rates of trainee progress.

DEFINED OUTCOMES OR BENCHMARKS

In addition to individualised learning in a controlled educational environment, high-fidelity medical simulations should feature clearly defined outcomes or benchmarks for learner achievement. These are straightforward goals with tangible, objective measures of achievement. Learners are more likely to master key skills if the outcomes are defined and appropriate to their level of training.[5]

SIMULATOR VALIDITY

There are many types of educational validity, both in the presentation of learning materials and in measuring educational outcomes. A high degree of realism or fidelity provides an approximation to complex clinical situations, principles and tasks. Thus high simulator validity is important to help learners increase their visuo-spatial perceptual skills and to sharpen their responses to critical incidents. Clinical learners desire this realism (face validity) during their hands-on experiences. It is important to note, however, that the desired outcome should be matched with the appropriate degree of fidelity; a wide range of competencies can be learned and mastered with relatively low-fidelity simulators.

Many of these features are consonant with Ericsson's model of deliberate practice to achieve mastery in professional performance.[2] Most of the features are not unique to high-fidelity simulations, but rather reflect sound principles of good educational practice. We advise clinical teachers who use simulations to train and evaluate learners to incorporate as many of these features as possible into their training programmes. The outcome of such efforts is more likely to be an effective tool that meets students' educational needs.

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