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Simulation Technologies in Higher Education: Uses, Trends, and Implications

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Overview

The January 15, 2009, emergency landing of an Airbus A320 in New York's Hudson River and the rescue of all 150 passengers was both fortunate and impressive, but the ability of Captain Chesley Sullenberger and the crew of US Airways Flight 1549 to ditch a plane with a double-engine failure and successfully evacuate all the passengers was the result of practice rather than divine intervention. Not receiving as much press, but no less impressive, are reports of the young emergency room team that saved a life by effectively handling its first cardiac arrest, or the dental school student who successfully restored a tooth for her first patient. Even though none of these individuals or teams had yet experienced the particular type of emergency or patient before they were called upon to act in "real time," they had all practiced their skills and drilled responses to similar scenarios using simulation or simulation technology.

Simulation is "an act of imitating the behavior of a physical or abstract system, such as an event, situation or process that does or could exist."[1] Simulation is not a new learning or training methodology. The cadaver in the anatomy or surgical skills lab, the standardized (actor) patients used in Objective Structured Clinical Exams (OSCE), and the virtual reality environment of the multimillion dollar flight simulator all represent important types of simulations.

Two major factors are contributing to the proliferation of simulation technologies on our campuses. First is the increasing availability of quality simulation resources, available via the Internet or through new devices and systems. Inexpensive, commodity-based products such as computers, sensors, haptic devices, immersive virtual reality displays, and so forth, together with increasing network bandwidth, are helping to make sophisticated simulation technologies affordable and far more accessible. Second is the growing focus on outcomes in education and the push not simply to transfer knowledge or have students pass courses but to teach and assess broader competencies more rigorously. Simulation technologies are proving to be valuable tools for effective competency-based education.

A competency is typically defined as the knowledge, attributes, skills, behaviors, and attitudes that enable an individual to perform a specific set of tasks or objectives to a given standard. The use of simulation for successfully improving the competencies of individuals and teams has been traditionally applied to situations where significant risk is associated with the skills or activities being practiced. The effective use of simulation in the training and assessment of astronauts, pilots, maritime captains, nuclear plant operators, and health professionals are just a few examples. The focus on developing and assessing competencies is now moving into all aspects of education, however, and the use of simulation technologies for education and assessment will not be far behind. Looking at new approaches to teaching and learning in the 21st century, Anne Moore postulates that "deciding what students need to know and should be able to do—in the context of a changing panoply of computing, information, and communications technologies—is a critical first step. Next to come will be rigorous assessments that demonstrate the manner and degree to which learning takes place."[2]

This ECAR research bulletin focuses on the rapid growth in the use of simulation technologies in higher education and the implications this will have for IT planning and policy decisions.

Highlights of Simulation Technology Uses, Trends, and IT Implications

Educators always hope that the knowledge, behaviors, and skills learned in the classroom will be effectively transferred to relevant situations in the real world. No two situations are identical, but it is commonly accepted that regularly practicing skills, with supervision, in a simulated environment promotes the successful transfer of these skills to real-world environments. This was obviously the case for the crew of US Airways Flight 1549, and our medical and dental schools know that it is also true for students as they begin treating patients.

Expert proficiency in any discipline or endeavor typically requires more than a thousand hours of deliberate practice.[3] Deliberate practice is performing a skill or a sub-skill, usually under supervision, while monitoring your performance, evaluating your success, and figuring out how to do it better. Access to this level of real-world experience is often not practical or appropriate, and this is leading to expanding use of simulation technologies as important tools in the educator’s toolbox.

Simulation Technologies in Higher Education

Advances in computer, visualization, and haptic technologies are fostering the rapid growth in the use of computer-based simulation for training and education. Driven by the needs of the health-related disciplines for “safe” learning environments, computer-based simulators are now being integrated into the curricula of medical, nursing, dental, and other health professional education.[4] Screen-based case simulations were one of the earliest forms of computer simulation technology. They have a proven track record in both education and assessment and are now an integral part of the national medical licensing exam.[5] Gaining in popularity are newer types of simulation technology that can be generally categorized into two general types: virtual reality (VR) simulators and computer-enhanced mannequins.

Virtual Reality Simulators and Serious Gaming

Surgical or procedural simulators, using instruments such as laparoscopes, endoscopes, or dental instruments, allow realistic interactions with virtual reality environments to yield promising training and assessment venues. These VR-based devices are capable of simulating anatomical variations as well as various pathologies and complications. Most use standard high-resolution video displays, with growing numbers incorporating 3D video and immersive VR technologies. Because interactions with the environment take place within the computer’s memory and can be easily quantified, these systems often use evidence-based metrics to objectively track and assess performance. For many procedures, proficiency levels demonstrated in a simulator are found to correlate well with real-world procedural experience, and skills developed in simulation-based training transfer well to the real-world environment.[6]

Web-based VR technologies have also been making significant inroads into and greatly expanding the possibilities for the use of simulation in healthcare and higher education. The best known is Linden Lab's Second Life, which now has over 600,000 active users. Hospitals are using the 3D representations of their facilities in Second Life to train operating room teams and to engage staff in disaster preparedness drills, without the significant expense and disruption of operations associated with real-world drills.[7] A rapidly increasing number of colleges and universities now have a presence in Second Life and are using this virtual world to support education in a variety of disciplines, ranging from language education, English, and theater arts to engineering, chemistry, and biology. A related initiative, serious games, has capitalized on the rapid development and success of the computer gaming industry. Serious games are those that have been designed with a purpose other than pure entertainment. These games marry the entertainment and playability of computer games with defined educational, training, or other objectives. A number of studies have shown that serious gaming is an effective learning tool and that students enjoy this form of education. VR technologies and serious gaming are taking root in higher education. Despite the fact that these technologies are still rudimentary and at the early stage of development, their potential is vast. Groups such as the Immersive Education Initiative are "working together to define and develop open standards, best practices, platforms, and communities of support for virtual reality and game-based learning and training systems."[8] As new lower-cost devices are developed that provide learners with even more realistic interactions with virtual environments, the use of these technologies via dedicated computer systems and over the Internet will undoubtedly increase.

Life-Sized, Computer-Controlled Mannequins

A second principal type of high-fidelity simulator, primarily used in health education, is the life-sized, computer-controlled mannequin. These are available in adult, child, and infant models, and they effectively simulate various physiological functions (breathing, pulses, pupil dilation, and so forth). A simulated patient monitor is used to display physiologic parameters, with a computer controlling the mannequin's various systems. These simulators respond to several types of interventions, with the more advanced models displaying appropriate responses to changes in the composition of the breathing gas or the injection of coded drugs. Many models also simulate some forms of anatomical variation, such as airway structure. Such mannequins have been used successfully to teach basic physiological concepts as well as provide training in the management of various medical scenarios.[9] They have also proven invaluable for team-based training, where competencies such as communication skills and teamwork can also be developed.[10]

Using Simulation for Learning and Assessment

Current educational programs are generally focused on the numbers and types of courses or other requirements a student needs to complete. Traditionally, little effort has focused on integrating knowledge or skills and developing competencies across courses. More recently, there has been enhanced attention across all disciplines to develop cross-cutting competencies in areas such as writing and communication skills or critical thinking. Focusing on improving the quality of patient care, the American College of Graduate Medical Education was the first to put forward the use of competencies to assess interns and residents in their programs. The effectiveness of this approach for improving the quality of patient care is driving the articulation and adoption of core competencies for students by a growing number of health professional schools. These are being tracked throughout integrated curricula, resulting in the development of more interdepartmental courses.

This move toward interdepartmental courses and competency-based education is also knocking at the door of undergraduate institutions. A report sponsored by the Association of American Medical Colleges (AAMC) and the Howard Hughes Medical Institute (HHMI) titled "Scientific Foundations for Future Physicians: Report of the AAMC-HHMI Committee" was recently issued. Following a multiyear study, an expert committee recommended that premedical requirements (and learning) shift from required courses to competencies, matching the general trends in medical education.[11] The report defines for the first time scientific competencies for future medical school graduates and for undergraduate students who want to pursue a career in medicine.

Currently, simulation technologies are often used in two situations: 1) low-frequency events that require high acuity, such as emergency landing procedures, and 2) training for procedures that are irreversible, such as surgery and patient care. The use of simulations will grow as they begin to be used more frequently for assessing student performance—for communication skills, critical thinking, and application of knowledge.

Simulation technologies are powerful educational tools that are becoming more widely used due to their effectiveness in providing powerful learning experiences.[12] The typical use of simulation is for formative assessments, where individuals or teams are given constructive feedback on their performance for a given scenario in a simulated environment. An extensive and growing literature attests to the benefits of this form of training. In contrast, the validity of using simulated environments and simulation technologies for high-stakes (pass/fail or go/no-go) assessments has been questioned. Simulation is only a proxy for a real environment, and an individual's ability to suspend disbelief could influence his or her behaviors and performance.

Despite these reservations, the suitability of simulation technologies for assessing complex competencies, as well as favorable cost and safety factors for these tools, are driving increased interest in assessment-based simulation. Environments that rely on computers and computer interface devices have been the easiest to adapt to provide a meaningful assessment environment. Laparoscopic surgical procedures are now commonly practiced in simulated environments, and in some cases (e.g., placing a carotid stent) a level of proficiency needs to be demonstrated in simulated environments before the Food and Drug Administration will allow a surgeon to place the device in a patient.

Support for Simulation Technologies

Proper management and provisioning of storage for the growing amounts of simulation-related digital information is a challenge. Collections of network attached storage (NAS) and storage area network (SAN) devices are commonly found in departments or centers that are using simulation technologies. For VR and computer-enhanced mannequin simulations, each session typically involves digital recordings from one or two video cameras, microphones, the simulated patient monitor, and the VR or mannequin administrative system. The sizes of the files associated with a simulation session primarily depend on the resolution of the video used and the complexity of the environments being simulated.

Video and other files associated with an active simulation program can represent multiple terabytes (TB) of new storage each year. Backups, indexing, searching, and reporting become ever more important functions as the amount of information increases and the importance of this information for academic programs and student credentialing continues to grow. Using database software to add structure and facilitate the location of particular pieces of information in a multi-TB data repository is quite common. Unfortunately, the vendors of the different types of simulation equipment have not standardized on a common environment, and a variety of simulation data management strategies are often found in a single organization. Trying to ensure that data stored in multiple databases and formats can be retrieved and integrated requires continual coordination.

During the recording process, the full simulation environment, as well as individuals' interactions with that environment, are recorded. The precise motion of a surgeon's hands and the timing and accuracy of a jet fighter pilot's responses are critical elements of the video capture. Faculty can use these videos to place time-marked flags that support their efforts to review the simulations with their students. Capturing and reviewing these recordings over wired and wireless networks requires fast, reliable networks. Storing and retaining these simulations for instructional and other purposes require flexible, searchable databases; large amounts of storage; and policies related to preservation, retention, and access. As long as simulations do not use real patient data, they are not subject to regulations such as the Health Insurance Portability and Accountability Act (HIPAA), and they might not require the security measures associated with patient information. However, recordings from simulation sessions are educational records, and if they contain personally identifiable information or grades, they might be subject to the protections under the Family Educational Rights and Privacy Act (FERPA).

What It Means to Higher Education

The exciting potential of simulation technologies cannot be overstated. Few of us go through life untouched by individuals who, for a time, hold our very existence in their hands. We want to trust that our surgeons and other medical personnel are experienced, highly skilled, and well trained. We want to trust that our loved ones are driving automobiles that have been designed, built, and tested to meet the highest standards of safety. We want to trust that our military and police personnel know how and when to use (and not use) the weapons in their arsenals. And when we're 30,000 feet in the air, we want to take comfort in knowing that our pilots can handle whatever mechanical and weather conditions they run into so that we can all arrive safely on the ground.

Electronic simulations are amazingly valuable technologies that can be applied to achieving these goals. They are already being used extensively, and their full potential has yet to be discovered. They can not only help people develop competencies but also help our institutions, faculty, and students measure and assess those competencies. Simulations can be used in the arts as well as the sciences—to experiment with stage sets, stage lighting, and museum displays without investing real-world dollars to build things that will eventually be discarded. Simulation technologies can be used by engineers, architects, and scientists to test everything from the identification of potential new drugs to discovering the impact of wind velocity on a yet-to-be-built skyscraper.

Simulation technologies share some characteristics that have been headaches for higher education for a long time. They are not yet built to standards that allow easy integration with each other or with enterprise student information systems or course management systems in use at most colleges and universities. Creative uses of the outputs from simulation technologies are limited by these integration factors. Similarly, institutions must carefully assess the impact of these technologies on campus networks, on data storage solutions, and on policies related to data preservation, access rights, and so forth. Imagine, for a moment, what might happen if the prosecutor in a medical malpractice suit against a surgeon were to subpoena all the surgeon's training records. Should schools be retaining the recordings of all simulation sessions used for training and assessment? There are many pedagogical reasons for institutions to retain these recordings, and there is an equal number of important reasons not to retain them.

The use of simulations on campus will continue to expand because they are effective pedagogical tools. It will also expand as the trend toward competency-based education and cross-discipline competency development expands. As stand-alone simulation units become more mission-critical, sophisticated, and integrated into assessment procedures, the current practice of department-based or stand-alone simulation units will have to be reassessed. Most likely, funding for and management of simulation technologies will become more centralized. This trend is likely to lead to the need for cross-discipline policies related to record retention and preservation, access rights, and data management.

Key Questions to Ask

- To what extent are simulation technologies currently used at my institution?
- What are the primary drivers for increased use of simulation technologies in our various schools and educational programs?
- How might simulation technologies be used in our programs for competency-based training and assessment?

- To what degree do we need to develop cohesive strategies for the IT support of simulation technology?
- What are our information stewardship responsibilities for recordings and records from simulation-based sessions?

Where to Learn More

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