

HIGH-FIDELITY PATIENT SIMULATION: A DESCRIPTIVE WHITE PAPER REPORT

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Summary

The introduction of high-fidelity manikin-based simulation into the healthcare provider education curriculum represents a significant shift in healthcare provider education. While the use of simulation in more primitive forms has been found in healthcare education for many years, recent improvements in technology have created highly realistic simulators capable of very high levels of fidelity – to the point that it is often possible to “suspend disbelief” in the learning environment, making the situation appear to be quite real.

There are many drivers currently in place that are pushing the use of simulation in the learning environment. These include:

- The growth of medical knowledge – The ever increasing body of medical knowledge presents new challenges to curriculum planners. Educators must find new ways of accommodating this volume of knowledge in the curriculum.
- Changes in medical education – Calls for increased accountability and outcomes measurement are being voiced in medical, nursing, and allied health education. Education practices and curricula that have been in place for decades must change to meet new demands for improving learner outcomes.
- Patient safety – It is no longer acceptable to use patients as primary learning models for healthcare provider students. Simulation offers a suitable alternative to allow student learning and initial demonstrations of competence to take place in a patient-free environment.
- Realism – Technology has advanced to the point where simulation at relatively high levels of fidelity has become affordable for many healthcare education organizations.
- Patient availability – Improvements in care in the clinical environment have reduced the numbers of many types of patient cases making what were once

commonly seen diseases or events much more rare. This has led to a reduced opportunity for students to be exposed to these patient conditions during clinical training. Simulation can serve as a replacement for many of these conditions and augment the clinical experience.

- Student availability – Increasing learning demands combined with schedule restrictions have limited the availability for many student populations. Simulation offers an opportunity to program a student's learning activity with greater efficiency.
- Standardization and replication – With the pressures for improved learner outcome measurements, simulation offers the capability to create standardization in evaluation by providing consistent replication of patient cases.

While the body of peer-reviewed literature evidence on the efficacy of high-fidelity manikin-based simulation is still relatively young, what has been reported has demonstrated that simulation is a viable learning strategy in healthcare provider education. However, much of this data is limited to knowledge and skill acquisition in the learning environment. There is still relatively very little data available on how well manikin-based simulation learning transfers to the clinical environment. Still, based on research showing the ability of students to meet learning objectives with higher degrees of success with manikin-based patient simulation, simulation has considerable face validity.

Other research has shown high-fidelity manikin-based patient simulation has been received well by learners. Research has demonstrated simulation has high degrees of acceptance among learners and that learners have felt highly satisfied with their simulation learning experience, even more so than learners who did not have simulation available for use. Learners' confidence in their ability is also higher when the learning environment includes high-fidelity patient simulation.

While no one theory can explain or predict outcomes in patient simulation, as a learning strategy, high-fidelity manikin-based simulation is bolstered by several learning theories.

Education theories that have a role in explaining how simulation works include:

- Constructivism – Originating with the works of John Dewey and moving forward to other theorists such as Piaget and Vygotsky, the basic premise of constructivism is that learners each have a unique knowledge base and rebuild that knowledge based on new information. Three tenets of constructivism that have relevance to simulation are:
 - Each person brings his or her own unique experience and knowledge set to the situation. Simulation allows learners to pull from their own frame of reference and apply themselves to the situation. Each learner has the potential to approach the situation in their own manner.
 - Learning occurs through active exploration when an individual's knowledge does not fit the current experience. Simulation offers the opportunity to push learners past their current knowledge level and see new areas where knowledge may be lacking.
 - Learning requires interaction within a social context. A fundamental function of manikin-based simulation is the team approach to patient care. Whether it is a single- or multi-disciplinary team in the simulation, effective interaction with team members is often a requirement for success in simulation.
- Experiential Learning – Based on concepts presented by Kurt Lewin and David Kolb, experiential learning theory (ELT) is frequently mentioned in the simulation literature as a leading learning theory that supports simulation learning. There are two primary components for ELT to be effective. First is an active experience in which the learner interacts with the learning environment. Simulation provides this immersive

experience very well. However, the experience itself is not where the learning occurs. Learning happens in the second component, a reflective process that reviews the actions of the experience and identifies areas for improvement. The process then continues in a cycle that builds on each experience and reflective action.

- Adult Learning Theory – Developed from concepts presented by Eduard Lindemann and Malcolm Knowles, adult learning theory centers on six assumptions that make andragogy (the teaching of adults) different from pedagogy (the teaching of children). All six assumptions can be observed in patient simulation. These assumptions are:
 - Adults have an intrinsic need to know
 - Adults have self-responsibility
 - Adults have a lifetime of experiences
 - Adults have an innate readiness to learn
 - Adults have a life-centered orientation to learning
 - Adults have internal motivators
- Brain-based Learning – One relatively new learning theory that has received very little attention in the simulation literature is brain-based learning (BBL). This learning theory examines how the brain learns. Several theorists are still actively contributing to building this learning theory. One BBL concept that is very applicable to patient simulation is Renate and Geoffrey Caine's three essential elements for learning. They stated three elements were necessary for learning:
 - Relaxed alertness – Learners must be alert to new challenges, but not so much so that fear (including fear of failure) interferes with the learning process. Simulation represents a safe environment for learners to face new challenges without the fear of patient harm.

- Orchestrated immersion in complex experiences – The instructor creates an immersive simulation experience with specific objectives.
- Active processing of experience – Similar to the reflective thought process found in experiential learning, learners must process the experience to identify areas for improvement.

High-fidelity manikin-based patient simulation is an essential learning tool in healthcare provider education at all levels. With a combination of multiple drivers and a growing body of evidence showing positive learner outcomes, patient simulation will be a key part of the healthcare provider education curriculum. However, as simulation technology advances, users must be cautious to use the technology as part of a coordinated curriculum that emphasizes learning outcomes and not just the use of technology.

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Background

Technology has become an important part of many classrooms. Health professions education is no different. One relatively recent technology in the health professions classroom is the use of high-fidelity manikin-based patient simulators. These devices replicate many human physiological functions and anatomical features. Learners interact with the simulator, discovering critical assessment information in the same manner they would with real patients. Once the simulator's medical condition is identified, learners then proceed with treatment options in an effort to correct the simulator's condition.

Manikin-based patient simulators of varying degrees of fidelity have been used in health professions teaching and been examined or reviewed in a variety of clinical areas including:

- emergency medicine (Bond et al., 2004; Bond et al., 2006; Bond & Spillane, 2002; Ellis & Hughes, 1999; Euliano & Mahla, 1999; Jones, Hunt, Carlson, & Seamon, 1997; Kobayashi et al., 2006; McLaughlin, Doezema, & Sklar, 2002; Reznek et al., 2003; Sanders, Haas, Geisler, & Lupien, 1998; Shapiro et al., 2004; Treloar, Hawayek, Montgomery, & Russell, 2001; Vozenilek, Wang, Kharasch, Anderson, & Kalaria, 2006; Wang & Vozenilek, 2005),
- trauma (Barsuk et al., 2005; Block, Lottenberg, Flint, Jakobsen, & Liebnitzky, 2002; Gilbert, Hutchison, Cusimano, & Regehr, 2000; Hammond, 2004; Hendrickse, Ellis, & Morris, 2001; Holcomb et al., 2002; Lee et al., 2003; Marshall et al., 2001),
- pre-hospital care (Bond, Kostenbader, & McCarthy, 2001; Hall et al., 2005; LeBlanc, MacDonald, McArthur, King, & Lepine, 2005),

- in-hospital care (DeVita, Schaefer, Lutz, Wang, & Dongilli, 2005; Lighthall et al., 2003; Mayo, Hackney, Mueck, Ribaud, & Schneider, 2004; St Clair, Oddone, Waugh, Corey, & Feussner, 1992; Wayne et al., 2005),
- pediatrics (Fiedor, 2004; Goodwin, van Meurs, Sa Couto, Beneken, & Graves, 2004; Halamek et al., 2000; Palmisano, Akingbola, Moler, & Custer, 1994; S. W. Roberts & McCowan, 2004; Tsai, Harasym, Nijssen-Jordan, Jennett, & Powell, 2003; Yaeger et al., 2004),
- obstetrics (Bonin & Posner, 2004; Deering, Brown, Hodor, & Satin, 2006; Deering, Hodor et al., 2006; Deering, Poggi, Macedonia, Gherman, & Satin, 2004; Dupuis et al., 2005; Euliano, Caton, van Meurs, & Good, 1997; Gurewitsch et al., 2005; Macedonia, Gherman, & Satin, 2003; Pittini et al., 2002; Robertson, 2006),
- and anesthesia (Abrahamson & Denson, 1969; Abrahamson, Denson, & Wolf, 1969; Berkenstadt et al., 2003; Blum, Raemer, Carroll, Dufresne, & Cooper, 2005; Blum et al., 2004; Cleave-Hogg & Morgan, 2002; Coopmans, 2005; Dalley, Robinson, Weller, & Caldwell, 2004; DeAnda & Gaba, 1991; Denson & Abrahamson, 1969; Detty Oswaks, 2002; Euliano & Good, 1997; Euliano, Lampotang, & Hardcastle, 1995; Euliano, Mahla, & Banner, 1998; Fallacaro, 2000; Farnsworth, Egan, Johnson, & Westenskow, 2000; Fletcher, 1995; Forrest, Taylor, Postlethwaite, & Aspinall, 2002; Gaba & DeAnda, 1988; Grant, 2002; Graydon et al., 2000; Henrichs, Rule, Grady, & Ellis, 2002; Hogan, 2004; Hotchkiss & Mendoza, 2001; Howard, Gaba, Fish, Yang, & Sarnquist, 1992; Loyd, 2004; Lupien, 2004; Monti, Wren, Haas, & Lupien, 1998; Morgan & Cleave-Hogg, 1999, 2000; Murray, Good, Gravenstein, van Oostrom, & Brasfield, 2002; Murray & Schneider, 1997; Norman & Wilkins, 1996; Register, Graham-Garcia, & Haas, 2003; Rosenblatt & Abrams, 2002; Schwid et al., 2002; Sinz, 2005; Sorenson, 2002; Via, Kyle, Trask,

Shields, & Mongan, 2004; Watterson, Flanagan, Donovan, & Robinson, 2000; J. Weller et al., 2003; A. K. Wong, 2004; Yee et al., 2005).

Additionally, teaching with manikin-based patient simulation has involved many levels of health professions students and practitioners including:

- nurses (Alinier, Hunt, Gordon, & Harwood, 2006; Aronson, Rosa, Anfinson, & Light, 1997; Bearson & Wiker, 2005; Bremner, Aduddell, Bennett, & VanGeest, 2006; Diefenbeck, Plowfield, & Herrman, 2006; Feingold, Calaluce, & Kallen, 2004; Ferguson, Beerma, Eichorn, Jaramillo, & Wright, 2004; Fontaine & Norton, 2001; Griggs, 2003; Haskvitz & Koop, 2004; Hravnak, Tuite, & Baldisseri, 2005; Larew, Lessans, Spunt, Foster, & Covington, 2006; Lasater, 2005; Nehring, Ellis, & Lashley, 2001; Nehring & Lashley, 2004; Rauen, 2001, 2004; Ravert, 2004; Robertson, 2006; Scherer, Bruce, Graves, & Erdley, 2003; Schumacher, 2004a, 2004b; Spunt, Foster, & Adams, 2004; Yaeger et al., 2004),
- medical students (Bowyer et al., 2006; Cleave-Hogg & Morgan, 2002; Collins & Harden, 1998; Deering, Hodor et al., 2006; Devitt, Kurrek, Cohen, & Cleave-Hogg, 2001; Euliano, 2000, 2001; Ewy et al., 1987; Gilbert et al., 2000; Goodrow, Rosen, & Wood, 2005; J. A. Gordon, 2002; J. A. Gordon, Oriol, & Cooper, 2004; J. A. Gordon & Pawlowski, 2002; J. A. Gordon, Wilkerson, Shaffer, & Armstrong, 2001; Issenberg, Petrusa et al., 1999; Issenberg, Pringle, Harden, Khogali, & Gordon, 2003; Lane, Slavin, & Ziv, 2001; McKenzie, 2004; McMahon, Monaghan, Falchuk, Gordon, & Alexander, 2005; Morgan & Cleave-Hogg, 1999, 2000, 2002; Morgan, Cleave-Hogg, Desousa, & Lam-McCulloch, 2006; Morgan, Cleave-Hogg, McIlroy, & Devitt, 2002; Morgan, Cleave-Hogg, Guest, & Herold, 2001; D. Murray et al., 2002; Rogers, Jacob, Rashwan, & Pinsky, 2001; Steadman et al., 2006; Tan, Ti, Suresh, Ho, & Lee, 2002; Treadwell & Grobler, 2001; Via et al., 2004; J. Weller, 2004; J. Weller, Robinson, Larsen, & Caldwell, 2004; Woolliscroft, Calhoun, TenHaken, & Judge, 1987),

- resident physicians (Abrahamson & Denson, 1969; Abrahamson et al., 1969; Bond et al., 2004; Bond et al., 2006; Bond & Spillane, 2002; Byrick, Cleave-Hogg, & McKnight, 1998; Deering, Brown et al., 2006; Deering, Hodor et al., 2006; Deering et al., 2004; Denson & Abrahamson, 1969; Devitt et al., 2001; Euliano & Mahla, 1999; Gisondi, Smith-Coggins, Harter, Soltysik, & Yarnold, 2004; Hammond, Bermann, Chen, & Kushins, 2002; Howard et al., 1992; Issenberg, Gordon, & Greber, 2003; Issenberg et al., 2002; Lee et al., 2003; Lighthall et al., 2003; Loyd, 2004; Marshall et al., 2001; McLaughlin et al., 2002; Reznick et al., 2003; Savoldelli et al., 2006; Schwid et al., 2002; Tsai et al., 2003; Wackett, Anderson, & Thode, 2005; Wang & Vozenilek, 2005; Wayne et al., 2005; Yee et al., 2005),
- practicing physicians (Block et al., 2002; Blum et al., 2004; Devitt et al., 2001; M. S. Gordon et al., 1981; Rosenblatt & Abrams, 2002; J. Weller, Dowell, Kljakovic, & Robinson, 2005),
- and multidisciplinary healthcare teams (DeVita et al., 2005; Holcomb et al., 2002; Marsch et al., 2005; Palmisano et al., 1994; Raemer & Barron, 1997; Shapiro et al., 2004).

Development of Manikin-Based Patient Simulation Technology

The history of simulation in healthcare has been well documented by several authors including Bradley (2006), Cooper and Taqeutu (2004), Gaba (2004a), and Rosen (2004). While simulation has been used in many industries, simulation in healthcare often refers to aviation simulation as a model to emulate (Friedrich, 2002; Gaba & DeAnda, 1988; J. A. Gordon et al., 2001; Halamek et al., 2000; Hamman, 2004a, 2004b; Henriksen & Moss, 2004; Hotchkiss & Mendoza, 2001; Shaffer et al., 2001; A. K. Wong, 2004; S. H. Wong, Ng, & Chen, 2002). Shaffer et al. (2001) offered this explanation as to why the fields of aviation and medicine share similar ties to simulation:

“Expert domains” like aviation and medicine are characterized by unstructured problems, where a potentially unlimited number of features are related in unclear and complex ways. Theorists argue that skill development in such domains requires practical experience, rather than abstract “book learning.” Pilots and physicians must develop finely-tuned perceptual and motor skills, the ability to analyse complex situations quickly and accurately, based on limited information, and the ability to make sound decisions about how to proceed, based on their assessment of the tactical or clinical information. (p. 76-77)

The origins of aviation simulation are tied to Edwin Link who developed the first aircraft simulator, patenting the device in 1929. By the 1950’s, Link had connected his simulator to analog computer devices to provide feedback information to student pilots. Link’s rather simple invention in 1929 has since evolved into the highly complex flight simulators in use today in aviation and space. Interestingly, Link took his simulation experience into other fields, including the development of the first power plant simulator in the early 1970s.

Simulation in healthcare has a long history, although the use of manikins to serve as the simulation model is relatively new (Bradley, 2006). Simulation using animals as models dates back over 2000 years. Manikins were utilized as models in obstetrical care as early as the 16th century (Ziv, Wolpe, Small, & Glick, 2003). Manikins for the purpose of teaching medical procedures were introduced as a commercial product in 1911 with the Chase Hospital Doll – usually referred to as “Mrs. Chase.” These life-size manikins were primarily designed to teach basic nursing care and as early as 1915, models were introduced that allowed for the practice of injections and urinary catheterization (“Connecticut nursing history vignettes,” 2004).

However, the use of manikins as models for the purposes of practicing resuscitation medical procedures was not introduced as a widespread commercial product until 1960 when Asmund Laerdal, a Norwegian toy maker, was approached by a group of Norwegian anesthesiologists lead by Bjorn Lind to create a manikin for teaching mouth-to-mouth

ventilations. With additional input from Peter Safer, an Austrian-born US-based anesthesiologist, Laerdal Medical's manikin was modified to allow for the application of chest compressions. Introduced in 1960, the Laerdal Resusci Anne manikin was the first manikin specifically built to teach resuscitation skills.

The first computer controlled manikin-based patient simulator was introduced in 1967. SimOne was developed at the University of Southern California by a team lead by Stephen Abrahamson and Judson Denson. SimOne had many of the features found on the high-fidelity manikin-based patient simulators used today. As described by Abrahamson:

SimOne was quite lifelike in appearance, having a plastic skin which resembled that of a real (Caucasian) human being in color and texture. He (it was a male) had a configuration of a patient lying on an operating-room table with (1) his left arm extended and fitted with an intravenous port ready for intravenous injection; (2) his right arm fitted with a blood pressure cuff; and (3) his chest having a stethoscope taped over the approximate location of his heart. SimOne breathed, had a heartbeat, temporal and carotid pulses (all synchronized), and blood pressure. He was able to open and close his mouth, blink his eyes, and respond to four intravenously administered drugs and two gases (oxygen and nitrous oxide) administered through mask or tube (Abrahamson, 1997, p. 29).

The first appearance of SimOne in the medical literature was in 1969 with articles by Denson and Abrahamson (1969) and Abrahamson, Wolf, and Denson (1969). From its first appearance in the literature, SimOne set the stage for patient simulation as it is being conducted today. Denson and Abrahamson (1969) asked a series of questions as they opened their first published study;

Suppose a student could learn the necessary manual skills before his first examination of a patient. Suppose he could learn these skills in a planned, systematic orderly way. Suppose he could learn them rapidly in hours or days rather than months. How much

saving in instructor time and mental anxiety could be achieved? And, all of this with greatly reduced hazard or discomfort for how many patients? Could the use of simulation techniques answer these questions affirmatively? (p. 504).

Despite these questions being posed in 1969, these questions are still being asked today.

In their later article of that year, Abrahamson, Wolf, and Denson (1969) described an experimental study showing the device was useful in the teaching of anesthesia residents. The authors summarized their findings:

Despite the lack of statistical significance in several of the analyses, the investigators conclude that there is an advantage in time in the use of this computer-controlled patient simulator in the training of anesthesiology residents. Residents using the simulator tend to arrive at accepted professional levels of performance in fewer elapsed days and in a smaller number of trials in the operating room than do residents who did not have a training period on the simulator. (p. 57)

Hoffman and Abrahamson (1975) stated that SimOne demonstrated cost-effectiveness in several areas of medicine. These included induction of anesthesia, recovery room care, and pulse and respiration measurement. In evaluating the factors that contribute to cost savings in training, Hoffman and Abrahamson made the following comments:

When the cost-effectiveness of SimOne is assessed, the evaluator must consider not only decreases in faculty and student time and gains in student performance but also the number and frequency of personnel groups in need of training. Taking all these factors into account, data from these studies indicate a cost savings with the use of SimOne are such to justify its cost within a short period of time. (p. 1128)

Even with the potential offered by these early studies, SimOne was never an economically viable endeavor and no commercial outlet was ever established. After nearly 10 years of use, the one-of-a-kind device began to fall into a worsening state and eventually was evicted from its laboratory, making its demise complete.

At approximately the same time as SimOne was being developed in Los Angeles, another group of physicians and engineers was developing a different patient simulator in Miami, Florida. While not able to meet the strictest definition of a full-bodied high-fidelity manikin-based patient simulator, the “Harvey” cardiology simulator provided several innovations that were critical to the development of the high-fidelity manikin-based patient simulators in use today. Harvey was introduced in 1968 and featured:

... various physical findings, including blood pressure by auscultation, bilateral jugular venous pulse wave forms and arterial pulses, precordial impulses, and auscultatory events in the four classic areas; these are synchronised with the pulse and vary with respiration. Harvey is capable of simulating a spectrum of cardiac disease by varying blood pressure, breathing, pulses, normal heart sounds, and murmurs (J. Cooper & Taqueti, 2004, para 13).

Unlike SimOne, Harvey was able to be produced commercially and was integrated in healthcare professions education at institutions around the world. It is still being produced today. Importantly, Harvey was also able to make a significant contribution to the research literature and is featured in several peer-reviewed studies and articles that showed that simulation in cardiopulmonary assessment was beneficial (M. S. Gordon, Ewy, DeLeon et al., 1980; M. S. Gordon, Ewy, Felner et al., 1980; M. S. Gordon et al., 1981; M.S. Gordon, Issenberg, Mayer, & Felner, 1999; Issenberg, Gordon, Gordon, Safford, & Hart, 2001; Issenberg, Gordon et al., 2003; Issenberg, Pringle et al., 2003; Jones et al., 1997; Karnath, Thornton, & Frye, 2002; St Clair et al., 1992; Woolliscroft et al., 1987).

In 1986, David Gaba and Abe DeAnda developed the Comprehensive Anesthesia Simulation Environment (CASE) at Stanford University. Gaba worked with partner organization CAE-Link (a descendent of the original Link aviation simulation company) to license CASE technology and develop a commercially viable product in 1992. This product was later acquired by MedSim and marketed as the MedSim-Eagle. MedSim later terminated production and

support in part due to a failed business strategy of creating training centers (J. Cooper & Taqueti, 2004).

The MedSim-Eagle did offer several technological advances over the SimOne system. Physical characteristics included:

... airway anatomy that could be altered to mimic degrees of difficulty of intubation, palpable carotid and radial pulses, lungs that simulated behaviour during spontaneous and controlled ventilation, heart and breath sounds, eyes that opened and closed, and a thumb twitch, as used for monitoring neuromuscular blockade during anaesthesia. (J. Cooper & Taqueti, 2004, para 27)

Additionally, the MedSim-Eagle incorporated software developed by Howard Schwid at the University of California San Diego for a program there named the Anesthesia Simulator Consultant (ASC). The ASC software, coupled with the capabilities of the CASE system, provided a wide range of physiological models including, “cardiovascular and respiratory function, acid-base balance, and pharmacokinetics and pharmacodynamics representing numerous disease states (J. Cooper & Taqueti, 2004, para 27).”

Concurrent with the development of the CASE system, Michael Good and Joachim Gravenstein at the University of Florida developed the Gainesville Anesthesia Simulator (GAS). This simulator featured physical simulation of respiratory gas exchange. Additional enhancements to the GAS device included physiological and pharmacological mathematic models. GAS technology was licensed by Loral Data Systems, who later spun the division off into its own entity – Medical Education Technologies, Inc. (METI).

METI introduced the Human Patient Simulator (HPS) in 1996. It has subsequently followed with PediaSim in 1999, a simulator utilizing the HPS software but scaled down to mimic a child. In 2005, BabySim was introduced. The METI HPS represents the highest performance potential of any manikin-based patient simulator currently on the market (Lane et al., 2001). METI recently introduced the Emergency Care Simulator (ECS). The ECS is a more portable

unit than the HPS. It does not have all of the features found on the HPS, but provides sufficient high fidelity for the simulation of many medical emergency situations.

While being the first to enter the market with a full-bodied manikin for patient simulation purposes in resuscitation with the Resusci Anne in 1960, Laerdal Medical did not introduce a high-fidelity manikin-based patient simulator until 2000 with the introduction of SimMan. This device does not possess all the high-level functionality of the MedSim-Eagle or the METI HPS, but does provide adequate fidelity for many medical emergency situations and is similar to the METI ECS in its capabilities. The Laerdal Medical SimMan also differs from the others in that it does not operate on mathematical models for simulator responses. Instead, it operates on instructor controls coupled with script-based control logic. The Laerdal Medical SimMan patient simulator is the device to be used in this study. Details of the simulator's functions are found in Appendix B.

There have been other high-fidelity manikin-based simulators introduced. Among the most complex is the Leiden Anesthesia Simulator. This simulator was introduced in 1994 by the University of Leiden, Netherlands, and remains a one-of-a-kind device (Chopra, Engbers et al., 1994; Chopra, Gesink et al., 1994). Very recently, other commercially produced medium- to high-fidelity manikin-based simulators have been introduced. These include the HAL Mobile Team Trainer (Gaumard Scientific Company, Inc., Miami, FL) and the PDA STAT Manikin (Nasco, Inc., Fort Atkinson, WI).

Aside from high-fidelity manikin-based patient simulators, there are many others types of simulation used in healthcare provider education and training. Collins and Harden (1998), Issenberg, Gordon, Gordon, Safford, and Hart (2001), Lane, Slavin, and Ziv (2001), Maran and Glavin (2003), Miller (1987) and Ziv, Small, and Wolpe (2000) discussed several other forms of simulation. Their compiled list includes:

- Animal models – While having a long history of use in the education of healthcare professionals, animal models are used with much less frequency due to growing ethical concerns and costs.
- Human cadavers – Used for procedure simulation, cadavers provide very realistic simulations for certain skills. However, limited availability and costs often make this a prohibitive teaching tool.
- Standardized patients – Real people portray patients with scripted or outlined responses to the healthcare provider's questions or physical examination. While standardized patients supply very high realism for skills such as communication, it is not possible to perform invasive procedures.
- Written simulations – Paper and pencil gaming techniques that provide basic information to simulate return of cognitive knowledge.
- Computer-based clinical simulations – Computer-based representations of patients designed to determine or test clinical decision-making.
- Audio simulations – Designed to teach auscultation assessment procedures.
- Video-based simulations – Designed primarily as demonstration tools to present information on examinations techniques, dynamic processes, and communication skills.
- Three-dimensional or static models – These models, also called anatomic-pathologic simulators, can range from simple reproductions of anatomy to more complex models that allow for practice of procedures or assessment of anatomy or pathology.
- Task-specific simulators – Designed to teach specific skills or tasks such as cardiac catheterization surgical skills or laparoscopic surgical skills, these devices provide some level of virtual simulation through computer graphics.
- Virtual reality simulation – Provides an immersive computer-generated virtual world in which to conduct assessment and management of patients.

Another general classification of patient simulators that combines some of the elements of both three-dimensional models and task-specific simulators is partial- (or part-) task simulators (Sinz, 2004). Issenberg, Gordon, Gordon, Safford, and Hart (2001) used the term procedure skills simulator for this type of device. Maran and Glavin (2003) stated, "Part task trainers are designed to replicate only part of the environment (p. 24)." Partial-task simulators do not require the simulator to be a whole representation of the body with physiological responses that affect the whole body. Instead, partial-task simulators replicate anatomy and, in some cases, physiology of a single portion of the human body. As described by Beaubien and Baker (2004), the skills taught with part task simulators "segment a complex task into its main components (p. i53)." Rather than creating complex scenarios commonly done with high-fidelity manikin-based patient simulation, or as Beaubien and Baker described as full mission simulation, partial task trainers permit students to focus on individual skills instead of more comprehensive situations. Examples given by Miller (1987) included "the foot (to detect foot deformities), the knee (to isolate sports injuries), the rectum and colon (to practice physical examination skills and detect bowel disease), and the pelvis (to diagnose pregnancy or to practice obstetrical maneuvers during delivery (p. 37)". Other examples would be an arm with vascular structure to teach intravenous access procedures or a head with upper airway anatomy to practice advanced airway procedures.

Referring to comprehensive patient simulators, Gaba (2004b) explained a patient simulator was a "system that presents a fully interactive patient and an appropriate clinical work environment (p. i5)." He further elaborated that one of three presentations of this patient were possible: having the "patient" fully present as in manikin-based simulators, having the patient represented on a computer screen as in screen-based simulators, and presenting the patient in a more immersive computer-generated environment as in virtual reality simulators.

While these other forms of simulation do not offer the capabilities or utility of high-fidelity manikin-based patient simulators as used in this study, they have made significant contributions

to the literature. Much of this data can be extrapolated to show support for the use of high-fidelity manikin-based patient simulation.

The cost of simulation is related to the level of fidelity and the technology being employed. For high-fidelity manikin-based patient simulators, acquisition costs can range from \$30,000 for the Laerdal Medical SimMan or the METI ECS to over \$200,000 for the METI HPS. Optional equipment available for these simulators can make the purchase costs even higher. In addition to the simulator, it is critical to create a learning environment that replicates real-world settings, complete with appropriate medical equipment. Halamek et al. (2000) stated, "The key to effective simulation-based training is achieving suspension of disbelief on the part of the subjects undergoing training, ie, subjects must be made to think and feel as though they are functioning within a real environment (para 15)." Creating this environment adds additional costs to setting up a simulation-based medical education program.

Definitions

The literature on human patient simulation has attempted to define several of the terms used in this study. However, there is no general consensus on many of these terms - including a debate on whether the simulator is a *mannequin* or a *manikin* (Gaba2006). One key term that requires specific definition for this study is high-fidelity manikin-based patient simulator. The term fidelity has been problematic in its definition (Maran & Glavin, 2003). As defined by Miller (1987), "The term 'fidelity' is used to designate how true to life the teaching/evaluating experience must be to accomplish its objectives (p. 36)." Using this definition, fidelity becomes a sliding scale in which given the objectives, a single piece of medical simulation equipment may be able to provide a "high-fidelity" experience for one objective but be "low-fidelity" for another objective. An example would be the insertion of an intravenous (IV) catheter. If the objective were to merely teach the psychomotor skills required for inserting the catheter, a relatively simple and low-tech IV access arm partial-task simulator would suffice and provide a comparatively high-fidelity experience. But if the objective were expanded to include

communication with the patient, then the same device would suddenly become low-fidelity, as there is no feedback being delivered with IV catheter insertion and communication with the patient is not possible.

Beaubien and Baker (2004) noted that the term fidelity is frequently cited as a one-dimensional term that forces a static classification of simulation devices. Individuals with this perspective would have difficulty agreeing with the use of the terms as cited in the preceding paragraph.

Maran and Glavin (2003) offered this definition: "Fidelity is the extent to which the appearance and behaviour of the simulator/simulation match the appearance and behaviour of the simulated system (p. 23)." Expanding on this concept, Maran and Glavin further explained there is a difference between engineering fidelity and psychological fidelity:

Engineering, or physical fidelity is the degree to which the training device replicates the physical characteristics of the real task...Of much greater importance is the concept of psychological fidelity. This is the degree to which the skill or skills in the real task are captured in the simulated task. (p. 23)

Yaeger et al. (2004) broke fidelity down into three general classifications: low- medium- and high-fidelity. Their definitions of each stated:

- Low-fidelity simulators are focused on single skills and permit learners to practice in isolation.
- Medium-fidelity simulators provide a more realistic representation but lack sufficient cues for the learner to be fully immersed in the situation.
- High-fidelity simulators provide adequate cues to allow for full immersion and respond to treatment interventions.

Another component critical in high-fidelity manikin-based simulators is the ability to provide feedback (Bradley, 2006; Lane et al., 2001). Feedback comes in two forms. First is the simulator's response to treatment or intervention by the learner. As described by Joyce, Weil,

and Calhoun (2004), this is “self-generated feedback (p. 328).” High-fidelity simulators require the simulator to demonstrate appropriate responses to therapeutic interventions. This point of feedback is critical in determining the fidelity of a manikin-based simulation system. As Lane, Slavin, and Ziv (2001) noted, “an inherent feature of most advanced medical simulators is the ability to provide immediate feedback about clinical decision and quality of actions (p. 306).” For instance, if a medication is given to increase the heart rate, then the simulator should respond accordingly with a faster pulse. Conversely, if an intervention is provided that is not indicated and is potentially harmful, the simulator should respond with the physiological changes appropriate for this therapeutic misadventure.

A second form of feedback required in high-fidelity manikin-based patient simulators is the ability to provide objective feedback for participant review in the post-simulation setting. From the introduction of high-fidelity manikin-based patient simulators in the late 1960s, this feature has been key. Denson and Abrahamson (1969) highlighted this feature in their SimOne simulator:

At the instructor’s command, during or at the end of the training run, the computer will type out in detail a timed, chronological summary of all of the events of the exercise.

This printout includes all of the student’s manipulations of the simulator, the drugs given (their dosages and when they were given), and the occurrences of any other events. (p. 505)

The high-fidelity manikin-based patient simulators currently available all have proprietary software designed to log student actions and simulator responses for playback in the post-simulation debriefing. Instructors/Facilitators utilize this data to review the event with students as a means of encouraging student reflection on action and as a stimulus for students to consider how to change their actions to improve patient (simulator) response.

Cost Versus Benefit

Considering the high cost of high-fidelity manikin-based patient simulators compared to the more common manikins of lower fidelity, determining the impact of these devices on educational outcomes is critical in justifying their purchase and use. Today's healthcare market is under very tight financial constraints. Other authors have noted the need to justify the use of these expensive resources in the most appropriate manner possible. Tsai, Harasym, Nijssen-Jordan, Jennett, and Powell (2003) stated:

...a high-fidelity manikin-based simulation is expensive, as well as time and labour intensive. These factors may hinder many academic centers from adopting this technology into their educational activities. Justification about the value of use comparing high-fidelity simulation and traditional teaching strategies is necessary. (p. 72)

Kneebone (2005) concurred with this view, stating, "The relationship between simulator fidelity and educational outcomes is still open for discussion, however, and lower levels of fidelity may reduce technological limitations and cost without compromising outcomes (p. 551-552)." W. B. Murray and Schneider (1997) noted, "All levels of cognitive learning are not equally appropriate for full-environment simulation (para 5)." They continued, stating that lower levels of cognitive learning may be better presented in traditional classroom teaching. Higher function levels such as analysis may be better suited to simulation. Salas and Burke (2002) also reached the conclusion that full-environment high-fidelity simulation may not be needed for all cognitive learning objectives.

With reduced revenues from major payors, particularly governmental payors such as Medicare and Medicaid and the potential for more cuts in the future, many healthcare systems are forced to reduce expenses (Carey, 2006; Dickler & Shaw, 2000; Lederman, 2005; Phillips Jr. et al., 2004). Education departments are often among the first departments adversely effected (Hotvedt & Laskowski, 2002). Health professions education organizations, including higher education institutions and teaching hospitals, are also under financial constraints. One

study mentioned funding cuts that directly impacted its simulation program (Feingold et al., 2004). George Rupp, then president of Columbia University, noted the following in regards to the operation of Columbia-Presbyterian Medical Center:

The major sources of funds for academic medicine - government research grants, revenues generated from the care of patients by the medical faculty, and direct appropriations for the support of hospitals - are facing simultaneous threats. Congress is under pressure to reduce health care spending for the elderly and the poor. The funds that support the training of new doctors are specifically targeted for cuts (Rupp, 1996, para 4).

Phillips et al. (2004) summed it up by stating, "Teaching hospitals of all sorts are in dire straits (p. 75)." Phillips continued, asking, "How will teaching hospitals cope financially with patient safety mandates, increasing pressure to improve resident work environments and hours, rising malpractice premiums, and other rising health care costs (p. 77)?" Given the limited financial resources for these organizations, it is imperative that available money be budgeted appropriately and resources used to its best advantage.

An additional area of significance in this study is the ability to improve the training of healthcare providers. Shortcomings in the training of healthcare providers have been noted, especially in physician education. Issenberg, McGaghie Petrusa, Lee, Gordon, and Scalese (2005) noted:

Changes in the delivery of healthcare trigger major shifts in medical education methods. For instance, in the United States, the pressures of managed care are shaping the form of and frequency of hospitalizations, resulting in higher percentages of acutely ill patients and shorter inpatient stays. This results in less opportunity for medical learners to assess patients with a wide variety of diseases and physical findings. Despite increased cost-efficiency in outpatient care, reductions in physician reimbursement and shrinking financial resources constrain the educational time that physicians in training receive in

this environment. Consequently, physicians at all educational levels find it increasingly difficult to keep abreast of skills and topics that frequently appear in practice.

These problems have a direct effect on clinical training...The result is a decline in the quality of healthcare providers' bedside skills and a reduction in the ability to provide high quality and cost-effective medical care. (p. 12)

Salas and Burke (2002) noted that simulation is effective when the simulation fidelity is matched by training requirements. As they state, "When using simulations for training purposes, it is often assumed that more is better; that is not true...The level of simulation fidelity needed should be driven by the cognitive and behavioral requirements of the task and the level needed to support learning (p. 120)." With that in mind, effective training should be conducted with the most appropriate technology, not just the most advanced technology.

There is a continuing need for additional research to demonstrate efficacy. As one recent review noted:

...at the present time the quantity and quality of research in this area of medical education is limited. Such research is needed to enable educators to justify the cost and effort involved in simulation and to confirm the benefit of this mode of learning in terms of the outcomes achieved through this process. (Bradley, 2006, p. 254)

What is simulation?

There have been many definitions made as to what simulation is in education. Some of these definitions refer to the "simulator" while others refer to the "simulation."

- "A simulator is a training device that closely represents reality but in which the complexity of events can be controlled (Joyce et al., 2004, p. 327)."
- "Simulation is a training and feedback method in which learners practice tasks and processes in lifelike circumstances using models or virtual reality, with feedback from observers, peers, actor-patients, and video cameras to assist improvement in skills (Eder-Van Hook, 2004, p. 4)."

- “Simulation is a generic term that refers to the artificial representation of a real-world process to achieve educational goals via experiential learning (Flanagan, Nestel, & Joseph, 2004, p. 57).”
- “Simulation is a technique...to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner (Gaba, 2004b, p. i2).”
- “Simulation is the artificial representation of a phenomenon or activity (Larew et al., 2006, p. 17).”
- “Simulations are created experiences that mimic processes or conditions that cannot or should not be experienced firsthand by a student because of the student’s inexperience or the risk to the patient (Morton, 1997, p. 66).”
- Simulation “refers to an activity that is designed to help participants acquire insight into the complex relationships and interconnected structures within a particular context. It is a way of preparing for (or reviewing) action in the real world (Leigh & Spindler, 2004, p. 54).”

When examining the use of high-fidelity manikin-based patient simulators in health professions education, it is critical to not confuse the simulator with the simulation. As Gaba (2004b) described, “Simulation is a technique – not a technology (i2).” The devices are only part of the simulation. Dutta, Gaba, and Krummel (2006) observed a discrepancy in the research literature, stating, “A fundamental problem in determining the effectiveness of surgical simulation has been an inability to frame the correct research question. Are the authors assessing *simulation* or *simulators* (p. 301)?” Hammond (2004) recounted Gagne’s 1962 work examining military simulation:

He [Gagne] observed that it was not necessarily the device that was being simulated, but the operations or tasks associated with it. These included troubleshooting (ie,

diagnosis), procedures (ie, therapies), and communication of information (ie, team leadership). He concluded that the educational use of simulators should be at advanced stages and may include performance assessment. (p. 325)

Simulation has many applications. While at first glance, the teaching of psychomotor skills seems an obvious use for simulation; there are other areas where simulation can be effectively utilized. Rauen (2004) listed several areas in addition to psychomotor skill training where simulation has been utilized. Her list included teaching theory, patient assessment, use of technology, and pharmacology. She stated, "The emphasis in simulation is often on the application and integration of knowledge, skills, and critical thinking (para 3)."

As noted in Chapter 1, there is considerable debate about what constitutes a high-fidelity simulation. Too often, the definition is applied to the technology (Beaubien & Baker, 2004). There are several types of fidelity to be considered when evaluating the overall fidelity of the scenario. While developed for aviation simulation, the concepts suggested by Rehmann, Mitman, and Reynolds (1995) list several types of fidelity to consider that have implications in patient simulation. These include: "equipment fidelity, environmental fidelity, psychological fidelity, task fidelity, physical fidelity, and functional fidelity (p. vii)."

Joyce, Weil, and Calhoun (2004) identified 10 applications for simulations in education. While their list was for education in general, there are direct examples of each application in healthcare provider education.

1. Competition – Simulators have been used frequently in healthcare provider education as a means of assessment, which could be considered a form of competition.
2. Cooperation – Teamwork is a critical skill that is frequently featured in healthcare simulation scenarios.
3. Empathy – Realistic simulators that have the ability to speak can allow learners to demonstrate empathy for the simulated patient. Additionally, when conducting

multidisciplinary simulation sessions, empathy can be generated for the roles of other team members.

4. The social system – Team skills in a multidisciplinary team often involve complex social interactions between team members of varying levels of authority and experience.
5. Concepts – Demonstration of concepts such as assessing the simulator to find a diagnosis is a common simulator use.
6. Skills – Many simulation education sessions involve the application of psychomotor skills, such as endotracheal intubation, to be performed.
7. Efficacy – During the simulation, learners have the opportunity to see the effect of their actions and determine if their action achieves the desired effect.
8. Paying the Penalty – Since the simulation will allow for mistakes, consequences of those mistakes can be seen and discussed.
9. The role of chance – While one advantage of simulation is standardization, there is still the element of chance being introduced as an unintended consequence.
10. The ability to think critically – Through the process of reflection (either reflection in action while the simulation scenario is progressing or reflection on action after the simulation is complete), learners develop the skills needed to critically analyze their own actions and develop new strategies.

Gaba (2004b) generated a list of 11 dimensions to be considered in healthcare provider education utilizing patient simulation:

1. The purpose and aims of the simulation – Simulation may have one of several goals that include: education, training, performance assessment, clinical practice rehearsals, testing organizational practices, and investigating human factors performance.

2. The unit of participation in simulation – The simulation may be targeted at a single learner or it may be focused on an entire team. With the single learner the goals of the simulation will be focused on that individual's knowledge and skills. With the team, the focus may shift to coordination of action, teamwork, and communications.
3. The experience level of simulation participants – Simulation has shown its utility in teaching a wide range of clinical healthcare providers – from the novice through the expert. The difficulty of the simulation scenario may need to be adjusted depending on the level of clinical experience.
4. The health care domain in which simulation is applied – Simulations are most practical in medical domains where there is some element of psychomotor skill application or therapeutic intervention. Even in domains where psychomotor skills are not a major part of the skill set required for success, there may be simulation application, such as in communications skills or team management.
5. The health care disciplines of personnel participating in the simulation – Simulations may have a very diverse audience – ranging from high-level clinical providers such as physicians and nurses to lower level providers such as technologists or aides, and may even involve non-clinical personnel such as admitting personnel or administrators.
6. The type of knowledge, skill, attitudes, or behavior addressed in simulation – Depending on what is to be addressed, different types of simulations may be better at addressing what is to be learned. There may also be the need to integrate multiple areas – such as a combination of knowledge and skill – within one simulation to make the experience meaningful.
7. The age of the patient being simulated – While healthcare providers may have a need to provide care from “cradle to grave,” not all potential patient age groups may be appropriately represented by the simulation technology.

8. The technology applicable or required for simulations – Not all simulations require technology. Some situations may be simulated by simple verbal simulations, or, as Gaba defined, asking “what if?” questions. However, some goals such as skills or teamwork integration may require a more hands-on learning environment that will utilize some form of simulation technology.
9. The site of simulation participation – Some simulations may work well being conducted in a simulation learning laboratory or center. Other simulations may require on site, or *in situ*, simulation. While the dedicated simulation center may work well for many simulations, if one of the goals of the simulations is to test processes, it may be better performed in situ in order to test those processes where they will be used.
10. The extent of direct participation in simulation – All learners may not need to directly participate in the simulation in order to learn from it. Observation and participation in the debriefing may be adequate for some situations.
11. The feedback method accompanying simulation – While experience in itself may be valuable, the more substantial learning in simulation comes from feedback. Some simulators – particularly computer-based simulators – provide their own objective feedback information. Other simulators require the instructor or facilitator to provide feedback in the form of a debriefing session with the learner(s), often using the objective feedback information generated by the simulator. This debriefing may be aided by audio/video recordings or objective data recorded by the simulator.

Why Use Simulators?

Patient simulation of all types, including high-fidelity manikin-based patient simulation, is becoming more prevalent in many aspects and levels of healthcare provider education (Good, 2003; J. A. Gordon et al., 2004; Issenberg, McGaghie et al., 1999). The reasons behind the increased use for patient simulation are many and include: the growth of medical knowledge,

changes in medical education, patient safety, improved realism of simulation devices, availability of patients, new demands on student availability, and the ability of simulation to provide standardization and replication. For new healthcare providers it is also important to consider the changing student profile. Mallow and Gilje (1999) point out that today's students are more comfortable with technology.

Issenberg, McGaghie et al. (1999) pointed out several advantages to patient simulators: Unlike patients, simulators do not become embarrassed or stressed; have predictable behavior; are available at any time to fit the curriculum needs; can be programmed to simulate selected findings, conditions, situations, and complications; allow standardized experience for all trainees; can be used repeatedly with fidelity and reproducibility; and can be used to train both for procedures and difficult management situations. (p. 862)

Kneebone (2003) summarized several challenges for learning in healthcare provider students:

How is it possible to safely carry out the sustained, deliberate, goal-directed practice that expertise requires? How is it possible to integrate technical skill with the knowledge upon which it depends? And how can these elements be combined to ensure the development of professionalism? Simulation...presents an attractive solution, at least to some of these issues. It offers a safe, non-clinical environment designed to meet the educational needs of a range of learners. (p. 269)

In an earlier publication, Kneebone stated, "This shift in emphasis from the clinical needs of the patient to the educational needs of the learner is having a profound effect on medical education generally, and on skills training in particular (Kneebone, 1999, p. 571)."

While simulation does represent a viable alternative to healthcare provider education, it should be only considered an adjunct to the curriculum and never as a complete replacement for the patient (Gaba, 2004b). Ewy, et al (1987) commented on simulation in cardiology education stating, "Patient-centered instruction remains the most important part of the curriculum...While the simulator should not replace the patient as a focus for teaching...patient

centered instruction can be enhanced by use of this simulator (p. 743).” Kneebone (1999) commented, “Any simulation in medical training, however, must be seen as a prelude to doing the real thing on a real patient, never as an end to itself (p. 571).” While not referring to medical simulation, Elgood (1990) made these comments regarding where simulation fit into a continuum of learning, “simulation...is intended as an intermediate stage between theoretical instruction (which has obvious limitations) and the real thing (which is too often costly or too dangerous to be attempted) (p. 51).” Flanagan, Nestel, and Joseph (2004) also noted this distinction, but added that an effective curriculum coupled with “skilled and dedicated teachers (p. 57)” was essential.

Growth of medical knowledge

Medical knowledge is always growing. New medical tests, new medications, new technologies all bring about new understandings and knowledge. However, the healthcare provider curriculum is of finite length. Innovation in the curriculum is required in order prepare the next generation of healthcare providers. Issenberg, Gordon, Gordon, Stafford, and Hart (2001) made the following comments:

In the past century, there has been an exponential growth in our knowledge of the human body, its structure, its functions, what can go wrong with it and why...Over the past few decades, medical educators have been quick to embrace new technologies and pedagogical approaches...in an effort to help students deal with the problem of the growing information overload. Medical knowledge, however, has advanced more rapidly than medical education...Simulation technologies are available today that have a positive impact on the acquisition and retention of clinical skills. (p. 16)

Alverson et al. (2005) provided additional comments, stating, “The vast amount of existing and emerging new knowledge in the health related sciences create new challenges in medical education. Furthermore, there are several medical science concepts that are difficult for learners to comprehend and educators to teach (p. 20).” They continued:

Developing methods to determine adequate acquisition, retention, and competence in the application of these concepts and knowledge, as well as attainment of appropriate clinical skills, continues to be a major endeavor in medicine as efforts to decrease medical errors and improve quality of care have reached high levels of public interest. (p. 20)

Changes in Medical Education

Medicine has typically been taught using a lecture/apprenticeship model (McMahon et al., 2005) that is reliant upon observation and repetition (Eder-Van Hook, 2004). As Halamek et al. (2000) stated the traditional model of medical education has three components: the learner performs a reading of the literature, the learner observes others with greater experience, and then the learner develops hands-on experience. This is the traditional medical model of education that has been in use for over 2,000 years (*Current state report on patient simulation in Canada*, 2005). Halamek et al. (2000) identified several problems with the current medical education model:

- While valuable, reading of the literature does not produce competency. More active than passive participation in the learning experience is required.
- Learners may have difficulty determining if their model for observation is a good model or a poor model. Just because the model may be senior, he or she still may not be competent and therefore the learners may observe poor skills as their basis for emulation.
- The variability of experiences in the apprenticeship model is high, meaning learners' experiences will not be equal.
- Many training environments do not fully represent the complexity of the real world resulting in an inability of the learners to adequately practice their decision-making skills in a contextual environment.

Yaeger et al (2004) reinforced these points stating that medical and nursing education rely on two fatally flawed assumptions:

- Assumption 1: All clinical role models are effective and skilled, and all behaviors demonstrated by these role models are worthy of replication.
- Assumption 2: The conclusion of the training period implies that a trainee is competent in all the skills necessary for successful clinical practice. (p. 326)

Yaeger et al. also commented that in the apprenticeship model there is a need for a preceptor. This preceptor may not have the necessary skills to be an effective educator.

Speaking of the traditional model, Issenberg, Gordon, Gordon, Stafford, and Hart (2001) observed, "This process is inefficient and inevitably leads to considerable anxiety on the part of the learner, the mentor, and at times the patient (p 19)." McMahon, Monaghan, Falchuk, Gordon, and Alexander (2005) stated this model "is inefficient in promoting the highest level of learned knowledge, as reflection and metacognition analysis occur independently, often without guidance and only after extended periods of time when students are able to piece together isolated experiences (p. 84-85)."

Traditionally, this format is often referred to as the "See one, do, one, teach one" model of medical learning (Dunn, 2004; Eder-Van Hook, 2004; Gorman, Meier, & Krummel, 2000; Wayne et al., 2006; Yaeger et al., 2004). Referring to the "See one, do, one, teach one" model, Vozenilek, Huff, Reznick, and Gordon (2004) commented:

Medical educators are under considerable societal pressure and budgetary constraints to enhance the quality of medical education and the safety of medical care. The concept of "learning by doing" has become less acceptable, particularly when invasive procedures and high-risk cases are required...Despite the best efforts of educators, some procedures are so rare in clinical practice that they are difficult for trainees to "see and do," let alone teach. (p. 1149)

In their conclusion, they rephrased the traditional model, saying, “see one, simulate many, do one competently, and teach everyone (p. 1153).”

The whole of medical education is in the midst of reform with wide-spread calls for changes (Bradley & Postlethwaite, 2003b; Issenberg, Pringle et al., 2003; S. MacDonald, 1994; A. K. Wong, 2004; Ziv et al., 2003). A. K. Wong (2004) noted the change in medical education, stating:

The landscape of medical education is changing dramatically, shifting from what Carraccio et al. has termed a process and structure-based curriculum to what is known as an “outcome” or competency-based curriculum.” The former curriculum determines learning on the basis of exposure to specified content over a period of time, whereas the latter determines it on the basis of attainment of preset objectives or competencies. (p. 455-456)

Lane, Slavin, and Ziv (2001) reported on several studies that indicated poor outcomes for medical school graduates, stating that reform was required “in part because physicians were graduating from educational programs without adequate skills (p. 308).” As Greenburg, Loyd, and Wesley (2002) noted, “The changing health care environment, adult learning theory, and an emphasis on assessment and accountability has focused attention on teaching and testing clinical knowledge, attitudes, and skills (p. 1109).” Bradley (2006) cited three reasons behind the recent drive for patient simulation. First was the resuscitation education movement started by Laerdal and others in the early 1960s. Second was the development of anesthesia patient simulators starting with SimOne in the late 1960s. Third was the beginning and ongoing reform of medical education as a whole. Within reform he cited several areas where change has been evident:

- The need to respond to the information overload so that basic clinical and communication skills are properly developed.

- Increased emphasis on the development of a more educationally sound curriculum in the postgraduate training of physicians.
- The recognized need for improvements in continuing medical education.
- Increased efforts at revalidating provider competence.

He stated that simulation, particular high-fidelity simulation, is positioned to be an important part of this reform. More so, he sees simulation as “an essential element of an ethically cognizant education (p. 40).”

Looking specifically at the clinical side of medical education in critical care medicine, Grevnvik, Schaefer, DeVita, and Rogers (2004) stated three major changes in medical teaching have occurred in recent years. These changes included increased emphasis on evidenced-based medicine, higher prominence for patient safety in clinical teaching, and the evolution of patient simulation. On this last point, they noted that during the 10-year period from 1994 through 2004, the number of patient simulation centers went from “very few full-scale simulators in the world... [to] more than 1000 simulation centers (p. 234).”

Bradley and Postlethwaite (2003a) noted the problems with the current system of medical education, stating:

Deficiencies in undergraduate programmes and a reliance on serendipity have been recognized as leading to inadequacy in the skills performance of students. These deficiencies often then result in junior doctors being required to perform skills for which they have not been prepared and as a result they perform suboptimally...It has been noted that the clinical experience of students is changing and that opportunities for them to acquire skills is reducing. (p. 6)

Patient Safety

An overriding theme in many discussions of high-fidelity manikin-based simulation is the concept of patient safety. In the education of healthcare providers, there are sometimes conflicting goals. As Friedrich (2002) commented in quoting Atul Gawande, “medicine has long

faced a conflict between 'the imperative to give patients the best possible care and the needs to provide novices with experiences' (p. 2808)." When examining the broader topic of medical simulation in general, the concept of patient safety is a frequently mentioned theme (Abrahamson & Denson, 1969; Blum et al., 2004; Bradley, 2006; Cleave-Hogg & Morgan, 2002; J. B. Cooper, 2004; Deering, Brown et al., 2006; DeVita et al., 2005; Flanagan et al., 2004; Fried et al., 2004; Glavin & Maran, 2003; J. A. Gordon et al., 2001; Grenvik et al., 2004; Hamilton et al., 2001; Hammond, 2004; Haskvitz & Koop, 2004; Kneebone et al., 2005; Leitch, Moses, & Magee, 2002; H. T. Ostergaard, Ostergaard, & Lippert, 2004; Rall, Schaedle, Zieger, Naef, & Weinlich, 2002; Shalala & Herman, 2000; Shapiro et al., 2004; van Meurs, Couto, Couto, Bernardes, & Ayres-de-Campos, 2003; Wright et al., 2005; Wright, Taekman, & Endsley, 2004; Ziv, Ben-David, & Ziv, 2005; Ziv et al., 2000; Ziv et al., 2003).

Much of the stimulus behind this focus on patient safety dates to the Institute of Medicine 2000 report *To Err is Human: Building a Safer Health System* (Kohn, Corrigan, & Donaldson, 2000). This landmark study reported over 44,000 people and possibly up to 98,000 people die each year in United States hospitals from medical errors. The total annual cost of these errors is between \$17 billion and \$29 billion. Even more alarming is this represents only the hospital sector of the healthcare industry. The number of lives affected would be even higher if other parts of the healthcare system were included such as office-based practice, long term care facilities, and Emergency Medical Services. In its summary of recommendations, the report specifically mentions simulation as a possible remedy, stating, "...establish interdisciplinary team training programs for providers that incorporate proven methods of team training, such as simulation (p. 14)." The report further recommended simulation training as an example of injury mitigation activities:

Another example of ways to prevent and to mitigate harm is simulation training.

Simulation is a training and feedback method in which learners practice tasks and processes in lifelike circumstances using models or virtual reality, with feedback from

observers, other team members, and video cameras to assist improvement of skills. Simulation for modeling crisis management (e.g., when a patient goes into anaphylactic shock or a piece of equipment fails) is sometimes called "crew resource management," an analogy with airline cockpit crew simulation. Such an approach carries forward the tradition of disaster drills in which organizations have long participated. In such simulation, small groups that work together—whether in the operating room, intensive care unit, or emergency department—learn to respond to a crisis in an efficient, effective, and coordinated manner.

In the case of the operating room (OR) this means attempting to develop simulation that involves all key players (e.g., anesthesia, surgery, nursing) because many problems occur at the interface between disciplines. Although a full OR simulator has been in operation for some years at the University of Basel (Switzerland), the range of surgical procedures that can be simulated is limited. It will be a great challenge to develop simulation technology and simulators that will allow full, interdisciplinary teams to practice interpersonal and technical skills in a non-jeopardy environment where they can receive meaningful feedback and reinforcement. (p. 176-177)

Another government report from that same year also cited simulation as a valuable tool to improve patient safety. In *Doing What Counts for Patient Safety: Federal Actions to Reduce Medical Errors and Their Impact - Report to the President*, (Shalala & Herman, 2000) made the following recommendations. "Develop and evaluate programs introducing health professionals to errors analysis and the challenges of practicing in a technically complex environment, explore the use and testing of simulators and automation as education tools, support training in errors research and evaluation...(Shalala & Herman, 2000, p. 17)." With this level of governmental comment and public awareness, healthcare professions education at all levels has had to respond to the issue of patient safety.

The level of concern for patient safety is recognized outside the United States. In Canada, it was estimated there were 70,000 preventable adverse events in Canadian hospitals with an estimate of deaths associated with those errors ranging from 9,000 to 24,000 (*Current state report on patient simulation in Canada, 2005*). The Canadian Patient Safety Institute supports the use of simulation as a means of ameliorating patient safety in Canadian hospitals. In the conclusion of its report on patient simulation, The institute stated:

Growing awareness of adverse events in Canadian hospitals, combined with increasing emphasis on patient safety, has changed the traditional “learning by doing” approach to healthcare education. Anecdotal evidence reveals the promising potential of simulation to fundamentally change the way healthcare professionals practice and further hone their skills, interact across disciplines, and manage crisis situations. (*Current state report on patient simulation in Canada, 2005, p. 23*)

One of the strongest statements made regarding this aspect of simulation was presented by Ziv, Wolpe, Small, and Glick (2003). Under the title “Simulation-Based Medical Education: An Ethical Imperative,” the authors presented an argument that not using simulation was more than just an education issue, it was an ethical issue. As they report, there is often an over reliance on vulnerable patient populations to serve as teaching models when other resources exist that would provide adequate – if not superior – replacements. As they stated in their conclusion:

We suggest that the proper and careful development of SBME [Simulation-Based Medical Education] is an ethical imperative. While the actual contributions that SBME can make to improving skills awaits empirical study, there seems little question that, when used in a sophisticated manner, SBME has the potential to decrease the numbers and effects of medical errors, to facilitate open exchange in training situations, to enhance patient safety, and to decrease the reliance on vulnerable patients for training. Moreover, by adopting simulation as a standard of training and certification, health

systems will be viewed as more accountable and ethical by the populations they serve.
(p. 786)

As mentioned, the education of healthcare providers requires a balancing act between providing the best in patient care while also providing learning opportunities for the healthcare professions student (Friedrich, 2002). Often, to protect patient safety actual patient contact is withheld in the healthcare provider learning process to a surprisingly late time period. J. A. Gordon, Wilkerson, Shaffer, and Armstrong (2001) made this observation:

Medical students are usually excluded from the primary management of acutely ill patients, yet such experiences can be vital to the integration of basic and clinical sciences and to the development of basic medical skills. Not until internship do many young doctors experience first-hand the anxiety of being responsible for very sick patients, but by this point the risk of medical error may be unnecessarily high. (p. 470)

Several education institutions have advanced the concept of a simulation-based curriculum as a means of providing a meaningful learning experience for students prior to or concurrent with their introduction to patients in the clinical environment (J. A. Gordon et al., 2004; McLaughlin et al., 2002; McMahon et al., 2005). There are certain times during clinical training where an exceptional learning opportunity may exist, but the severity of the situation precludes the involvement of the student. As Hammond (2004) noted:

Surgery, anesthesiology, and critical care are typified by the need for emergency care. This creates a poor context for learning in real-life situations due to the uncertainty of the process and the patient's responses, the complexity of the problem and possible confounding variables and simultaneous processes, time pressures, and stress. Little teaching takes place in the midst of a crisis, and in an emergency, the student or learner is often moved to an observer role, as the instructor or more experienced clinician takes over. (p. 236)

An important concept in the use of patient simulators in health professions education is the idea of crisis resource management. This topic is frequently mentioned in the literature (Blum et al., 2005; Blum et al., 2004; DeVita et al., 2005; Flanagan et al., 2004; Gaba, Howard, Fish, Smith, & Sowb, 2001; Glavin & Maran, 2003; Howard et al., 1992; Lighthall et al., 2003; O'Donnell, Fletcher, Dixon, & Palmer, 1998; Rall et al., 2002; Reznek et al., 2003; Sica, Barron, Blum, Frenna, & Raemer, 1999). The concept of crisis resource management (CRM) is another area of simulation that has been adopted from the aviation industry. In aviation, CRM started out as Cockpit Resource Management, but later expanded to cover the whole of the airplane crew, thus becoming Crew Resource Management. CRM programs in health professions education started out in anesthesia training but have been adapted to other areas of medicine (Lighthall, 2004; Lighthall et al., 2003; Reznek et al., 2003). An early leading proponent and developer of CRM training in anesthesia was David Gaba at Stanford University (Flanagan et al., 2004; Good, 2003). Many of the medical CRM programs currently in use can trace their origins to Gaba's early work. Interestingly, as a licensed pilot and an anesthesiologist, Gaba provided a special skills set to transition CRM from aviation to healthcare (Good, 2003).

Crisis Resource Management attempts to bridge the gap between knowledge and action. Connecting these two elements is vital. As Maudsley and Strivens (2000) stated, "In common usage, being 'knowledgeable' does not necessarily equate with critical thinking (p. 539)." Gaba, Howard, Fish, Smith, and Sowb (2001) demonstrated this in reviewing their experiences with student clinicians when they found the clinicians often had the knowledge but had difficulty with the interactional skills to effectively use this knowledge. They identified this as a shortcoming in health professions education.

Flanagan, Nestel, and Joseph (2004) described the major components of CRM training:

1. To enhance the participants' stock of precompiled plans for dealing with situations that could occur in their area of practice. That is, a refresher course in relation to the medical management of a number of critical events.

2. To provide exercises that encourage the use of metacognition, situation awareness, and the avoidance of fixation error, the hallmarks of naturalistic decision-making.
3. To provide exercises in specific elements of resource management; managing the resources of the rest of the domain, including leadership, communication, teamwork, workload management, monitoring, and cross-checking. (p. 60)

One of the principle reasons patient simulation is being touted as a partial remedy for the medical errors crisis is its ability to impact on a particularly vulnerable time in the learning process. As Patow (2005) cited, the “learning curve” faced by many healthcare professions students is a source of medical errors. He continued, stating that the realism of many of the currently available simulators is quite high and allows for procedures to be practiced to mastery prior to being tested on real patients. But simulations offer much more than just practice:

Learning procedures using advanced medical simulators is a step forward, but medical errors often result from ineffective processes and communication. After training in simulation centers, teams can stop to reflect on their own performance in detailed debriefing sessions. Reviewing video to discuss and learn from what transpired during a training exercise is an essential element of the learning process That kind of in-depth review is often not possible in real, fast-paced clinical settings. (Patow, 2005, p. 39)

The use of patient simulation in the training of healthcare providers is not limited to new students. There is also a need to maintain education in the health professions and simulation can be utilized effectively in this area as well (Ziv et al., 2000). As in other reports, Ziv, Small and Wolpe (2000) reiterated the shortcomings of the traditional model and explained that simulation was not just for the beginner:

The reality of medical training is still that health professionals, whether novices or experts, are expected to continuously to acquire new knowledge and skills while treating live patients. The mode of training for gaining proficiency at risky procedures, as well as

achieving and maintaining competence in handling rare, complex, and critical problems has been the classic on-the-job apprenticeship model based on *ad hoc* exposure to patients. (p. 489)

These authors feel simulation, when used across the continuum of health professions education, can make an impact on patient safety by removing patients from the risk of being practiced upon for learning purposes.

Gaba (2004b) pointed out there are also many indirect impacts of patient simulation on patient safety. These areas of impact include improvements in recruitment and retention of highly qualified healthcare providers, facilitating cultural change in an organization to one that is more patient safety focused, and enhancing quality and risk management activities.

A final point on patient safety is the ability to let healthcare providers make mistakes in a safe environment. In real patients, preceptors step in prior to the mistake being beyond the point of recoverability or if the mistake occurs (particularly for those healthcare providers who are no longer students), there is a very limited instructive value to the case. As J. A. Gordon, Oriol, and Cooper (2004) commented, this type of instruction instills a valuable lesson:

Consider the issue of patient safety, and imagine a practitioner who makes a clinical mistake; immediately after realizing the error, he or she will experience an emotional reaction that is powerfully instructive – but only for the next patient. What if educators could replicate such cognitive dynamics in a simulated environment, allowing trainees to “live through” a compendium of important cases in a fraction of real-time? At least for some medical students under this paradigm, simulation may allow complex information to be understood and retained more efficiently than would be the case with traditional methods, favoring early development of expertise in the formative years. (p. 24)

Ziv, Ben-David, and Ziv (2005) elaborated further, stating, “Total prevention of mistakes, however, is not feasible because medicine is conducted by human beings who err...[Simulation Based Medical Education] may offer unique ways to cope with this challenge and can be

regarded as a mistake-driven educational method (p. 194).” They continued stating that

Simulation Based Medical Education:

...creates conditions in which making mistakes is not harmful or dangerous to patients but is, rather, a powerful learning experience for students and professionals. They are permitted to err and are provided with the opportunity to practice and receive constructive feedback which, it is hoped, will prevent repetition of such mistakes in real-life patients. (p. 194)

Realism

Learner perceptions of simulation realism have been reported in several studies and have generally been reported as being high (Devitt et al., 2001; Feingold et al., 2004; Reznick et al., 2003). Maintaining a realistic environment is a key requirement for many simulations and an essential component for effective CRM training (Gaba & DeAnda, 1988; Hotchkiss & Mendoza, 2001). This not only means having a manikin device capable of adequately reproducing the patient condition, but also creating a learning environment that looks and feels like the real world. As Flanagan, Nestel, and Joseph (2004) noted, “Installing a simulator in a laboratory or conference room constrains the potential applications for which the device can be used (p. 38).” What is needed is an immersive environment that utilizes real medical equipment to make the simulation as like-like as possible. As described by Gaba and Small (1997) this is “Full Environment” simulation. Here the simulation is much more than just the manikin, as they stated, the simulation utilizes “a computerized surrogate mannequin patient, actual clinical equipment and staffing typical of the clinical environment (para 5).”

As Collins and Harden (1998) commented, “In general, the more realistic the patient representation, the more likely will the examination assess what the student will do in practice. Expecting students to communicate with a simulated patient whom they recognize as simulated may inhibit their performance (p. 517).” In simulation – not just medical simulation but in other simulation arenas as well – the ultimate achievement is the *suspension of disbelief*. It is at this

point the participant becomes so involved in the scenario that it feels real. To achieve this, realism must be high.

However, when that level of simulation is reached, the impact on participants can be quite high. As J. A. Gordon (2004) recounted one of his learner's comments, "Initially I felt awkward being with a mannequin, but I must say, after a while I could really feel my heart pounding – it was a very visceral experience for me (p. 4)."

Another point to consider in regards to realism are the concepts first presented by Tulving and Thomson (1973). Their hypothesis stated that information is best retrieved when the cues for that information are encoded at the same time. Providing information in a setting that is void of the appropriate cues makes recall of the information much more difficult. Simulation-based training in a realistic environment complete with all cues allows the learner to encode both information and cues, thus improving their chances of successful recall later when the situation is presented in real life.

However, limitations in technology may have negative impacts on learner perceptions. Halamek et al. (2000) surveyed 38 physicians after completing a delivery room scenario with neonatal resuscitation. Using a three items scale (disagree, neutral, agree), the authors found a high satisfaction among the learner group. The majority of the negative comments were primarily directed at the lack of fidelity in the neonatal manikin, although they did rate the environment as a whole and the general nature of the simulations very favorably. Gaba and DeAnda (1988) in the introduction of their Comprehensive Anesthesia Simulation Environment (CASE) examined learner perceptions of the simulation in 17 residents and medical students. While learners rated the simulation environment as a whole very realistic, responses concerning the realism of the simulator itself were relatively low (means ranging from 4.4 to 5.6 on a 0 to 10 scale with 0 being *totally unrealistic* to 10 being *indistinguishable from the real thing*). It should be noted both studies (Gaba & DeAnda, 1988; Halamek et al., 2000) utilized simulators that

were very early in development and these limitations were noted by the authors. However, it does point out that lack of realism might be a distracting factor for learners.

Patient Availability

A health professions student's ability to experience cases in the apprenticeship model is dependent on the natural flow of patients through the clinical environment and often becomes simply a matter of chance (J. A. Gordon & Pawlowski, 2002). A goal of any healthcare provider curriculum should be to provide all students with exposure to all types of relevant patients cases (Eder-Van Hook, 2004). Patient availability is not what it once was (Collins & Harden, 1998; Ewy et al., 1987; Kneebone, 2005). As Dent (2001) stated, "It cannot now be presumed that medical students may acquire competence in clinical skills by practising on patients as willing volunteers (p. 483)." Eder-Van Hook (2004) commented, "The trainee only learns from those cases and situations that present themselves within a short period of time a health care provider is in school (p. 6)."

Lane, Slavin, and Ziv (2001) commented on the problems associated with using real patients for basic teaching:

In the clinical setting, there is no guarantee that every trainee will have a uniform clinical experience, see a representative patient mix, and learn all the necessary skills.

Moreover, practicing clinicians who have trainees working with them might not be familiar with the learning goals and objectives or have the knowledge, attitudes, or skills to teach successfully...Simulation offers an alternative to learning with real patients and allows a wide range of skills to be practiced and mastered. Specific learning goals and objectives can be defined, and all learners can successfully fulfill the goals and objectives, because learning takes place using trained instructors in dedicating teaching time rather than patient care time. (p. 298)

Simulation offers an ability to control the programming of the student's experiences. J. A. Gordon and Pawlowski (2002) commented about "the good teaching case" that can be

programmed into a high-fidelity manikin-based patient simulator and be called up on demand by interested students. This function allows students in every clinical rotation to experience the same case that previously would have been limited to just a few students and possibly even a lone student.

Ewy et al. (1987) highlighted several of the problems posed in obtaining access to patients during the cardiology rotation of medical students. As they pointed out, bedside teaching with real patients was limited due to the fairly short time of the typical cardiology rotation, the lack of an adequate patient sample that was diverse enough to present with the range of cases needed, an out-of-balance student to patient ratio, and the general wear-and-tear on patients being exposed to multiple physical examinations for the sake of teaching students.

Additionally, some patient cases that were once relatively common are now exceedingly rare due to improvements in medications, monitoring, and procedures. Yet, they still occur and the clinician must be prepared for rapid and effective intervention (Fallacaro, 2000; Hotchkiss & Mendoza, 2001). As Macedonia, Gherman, and Satin (2003) pointed out, "Simulation offers educators the opportunity to expose trainees to experiences too infrequent or too medically risky to be found in common practice (para 10)."

Fiedor (2004) noted that pediatric cardiopulmonary arrest training can be difficult. Among the reasons she cited for this are differences in anatomy, different primary etiology of cardiac arrests, medication management is weight-based as opposed to the one-size-fits-all approach in adults, and lastly, the opportunity to learn the skills in the clinical arena are not common. As she stated, "Pediatric cardiopulmonary arrest is a relatively rare event, occurring one tenth as often per year as adult cardiopulmonary arrest. Thus, the ability to practice pediatric lifesaving skills in real time is limited (572)."

Student Availability

In medical education there are restrictions on the amount of time students spend in clinical and education activities (Eder-Van Hook, 2004; Greene, Zurakowski, Puder, & Thompson, 2006; Kneebone, Scott, Darzi, & Horrocks, 2004). This creates a new challenge on how to manage an ever-growing knowledge with limited exposure time for students. Dent (2001) commented:

The prolonged apprenticeship-style training of the past is unlikely to be uniformly available for increased student numbers and in any case cannot be relied upon to provide adequate basic clinical skills training. In addition, expanded graduate-entry programmes will have to maximize the effectiveness of the reduced time available for clinical instruction. (p. 483)

Standardization and Replication

With real patients, there is always some degree of variability between patients – even those with the same disease process. For example, in a health professions student rotation, there may be a requirement to examine a congestive heart failure (CHF) patient. But variability in comorbid factors may make one CHF patient very different from another. In assessing student performance it is difficult to evaluate students equally across this variation. Simulation offers the ability to create standardization (Collins & Harden, 1998). Collins and Harden pointed out that through standardization, there is an improvement in the validity and reliability of evaluation techniques. As cited earlier by Lane, Slavin, and Ziv (2001) simulation offers the opportunity to standardize the goals and objectives of each case presentation. And with the ability to be reproducible, with each case being the same from student to student, there is greater equality in managing assessment (Bond & Spillane, 2002).

Along with standardization comes the ability to provide replication. As Hammond (2004) noted, “Simulation offers the advantages of prospective and repeated observations to events of known etiology (p. 325).” With this ability, all students may experience the same patient leading

to equal learning experiences for all or the same students can experience the same patient repeatedly as he or she learns from each experience and builds better knowledge on how to manage this individual patient simulation.

This ability to standardize and replicate is critical in assessment of learner outcomes.

Collins and Harden (1998) made this observation:

In the clinical examination there are three variables: the student, the examiner, and the patient. The aim should be to standardize the examiner and the patient so that the student's performance can be seen as a measure of his or her clinical competence. (p. 509)

With the variable of the patient removed through the standardization and replicability of the simulator, examination processes can be fairer.

Effectiveness of Simulation as a Teaching Tool

Several studies have been conducted that examined how simulation education compared with more traditional education formats, including the apprenticeship model. Studies have been conducted that demonstrated simulation efficacy through one-shot case study designs, one-group pretest/posttest designs, or one-group time series designs (Dobson, Brancati, & Nagel, 2003; Forrest et al., 2002; Hammond et al., 2002; Marshall et al., 2001; McMahon et al., 2005; Morgan & Cleave-Hogg, 2000; Morgan et al., 2006; Rogers et al., 2001; Winston & Szarek, 2005). However, a fair number of studies have been published that used higher-level experimental designs, including randomized pretest/posttest control group experiments. Considering the number of these studies, the focus of this section will be limited to those higher-level experimental designed.

In the first high-fidelity manikin-based patient simulator study published, Abrahamson, Denson, and Wolf (1969) conducted a randomized experiment in which 10 subjects were assigned to one of two groups. The experimental group received endotracheal intubation training on the SimOne patient simulator (described in Chapter 1) while the other group received

its training in the traditional format (operating room time in the apprenticeship model). Through expert observation and chart reviews, both groups were scored on a number of criteria including how long it took (in both days and number of cases) to reach various proficiency levels. Their findings showed significance ($p = .05$) in the number of days it took to reach a proficiency level of 9 out of 10 successful procedures (45.6 days for the simulation group, 77.0 days for the control group).

Mayo, Hackney, Mueck, Ribaud, and Schneider (2004) compared the effectiveness of patient simulation in the acquisition of advanced airway management skills in first-year internal medicine residents. Their study was a randomized experiment that conducted a pretest for all participants, and then assigned individuals to receive programmed advanced airway training using simulation or to go through the normal apprenticeship model of learning. Four weeks after simulation training, all subjects were again tested on advanced airway management skills. The intervention (simulation) group reached levels of significance on 9 out of the 11 factors being tested. This study also examined how the learning model translated to the bedside with real patients. After the delayed posttest was administered, all subjects who had not received simulation training then received simulation training. During the following 10-month period, expert raters scored the subjects responses to advanced airway cases and found that there was a uniformly high success rate at all individual skill points (range from 91% to 100% successful completion of task). The authors concluded this indicated a high transference of the simulation training to the real clinical environment.

Holcomb et al. (2002) reviewed the impact on performance after simulation training in trauma resuscitation in a pretest/posttest study. It should be noted that the study involved several groups receiving the same intervention at different time periods with the results then being combined. The study utilized an expert team as a comparison model. Their results showed that after the simulation intervention, the non-expert teams were able to perform at nearly the same level as the expert team, scoring lower in only 2 of 13 measurements.

Hall et al. (2005) compared paramedic students' ability to perform endotracheal intubations with one group receiving training on a patient simulator and the other group receiving the traditional apprenticeship model of performing the procedure on patients in the operating room. Their results showed that simulator training was as effective as real patient training as neither group performed significantly better than the other ($p = .42$). While this study did not show superiority for simulation, it was equal with a traditional method that utilized real patients for training.

Shapiro et al. (2004) conducted a pretest/posttest study that compared the impact of an emergency department team training course that included an 8-hour simulator session against another group that completed the same training but spent an 8-hour shift in the emergency department. Following the intervention, each group was observed and scored on team behavior. Comparisons between pretest and posttest scores on the level of team behavior showed the simulation group had improved, although the level did not reach significance ($p = .07$), while the group that completed a regular 8-hour shift showed no gains at all ($p = .55$).

Steadman et al. (2006) conducted a randomized experimental study that compared simulation-based training versus problem-based learning with 31 fourth-year medical students. Both groups underwent an initial simulator-based assessment of their clinical skills as a pretest. Subjects then underwent either simulation-based or problem-based learning workshops on managing patients with difficulty breathing (an ACLS-level skill). The groups were then crossed over to an additional workshop on abdominal pain in order to equalize simulator experience. Students were then retested on the management of a patient with difficulty breathing. Expert raters scored results of the pretest and posttest. While both groups had no significant differences in the pretest ($p = .64$), the simulation-based group had a highly significant advantage in performance in the posttest ($p = .0001$).

Ewy et al. (1987) conducted a multi-site pretest/posttest experiment with a control group. 116 medical students were assigned to receive cardiology training that included a high-fidelity

cardiopulmonary assessment patient simulator while 92 received the standard cardiology training. Testing was done with both a multiple-choice examination and practical skills testing. In post testing, the intervention (simulator) group scored significantly higher ($p < .01$) than the control group. The practical skills testing showed the intervention group performed significantly better ($p < .001$) than the control group. This experiment also had the extra dimension of testing transference to practice as expert raters scored the students on assessment of actual patients. Again, the intervention group performed significantly better than the control group ($p < .03$).

Lee et al. (2003) randomly assigned 60 interns to one of two groups in a trauma orientation course in a posttest only control-group design. After completing the same initial component of the course that involved lectures and demonstrations, the subjects were randomly assigned to receive practice on a high-fidelity manikin-based patient simulator or with a live standardized patient with injuries replicated by make-up and moulage that reflected the traditional approach in an Advanced Trauma Life Support course. After this practice session, each group was further randomized to a second practice session with either the simulator or the standardized patient. Expert raters scored their performance. Their results showed the initial simulator-trained subjects performed significantly better than the initial standardized patient subjects ($p = .02$).

Wyatt, Fallows, and Archer (2004) conducted a randomized pretest/posttest control group study that examined the error rate in paramedics comparing simulation-based education with case-study based teaching. Their results showed simulation-based education had a significantly improved outcome greater than that of the case-study based teaching group ($p = .008$). Their study also indicated that error rates were most significantly reduced in the lesser-experienced subjects when compared to more senior subjects ($p = .014$).

Barsuk et al. (2005) conducted a prospective non-randomized quasi-experimental study comparing the outcomes of two groups of post-internship physicians in the management of airway crisis events. The first group was the control group who received the standard training

intervention. The second group was the intervention group that included a simulation session in airway management (an ACLS-level skill). There were 36 subjects in each group. Comparisons between the two groups showed that the simulation group had a significantly reduced error rate ($p < .05$) in three of five clinical actions being examined and nearly reached significance in one other action ($p = .06$). However, in contrast to other studies of this type, Barsuk et al. refined the intervention group's program content based on errors seen in the control group. While this limits the ability of the study to show a group versus group comparison as in a static-group comparison study, it did show that simulation can be an effective tool in correcting errors.

Dalley, Robinson, Weller, and Caldwell (2004) conducted a randomized static-group comparison study of 18 anesthesiology students receiving training on a new anesthesia delivery system. One group received the standard didactic training on the device. The other group received that same training augmented with practical experience in the use of the device with a patient simulator. After training, both groups reported a high degree of confidence in their ability to use the device ($p = .203$). However, when examined in a practical posttest, the group whose training employed the simulator significantly outperformed the control group in two simulation scenarios in which device complications were introduced ($p = .0113$ and $p = .0413$).

Chopra, Gesink et al. (1994) conducted an experimental comparison study with 28 anesthesiologists and anesthesia students in which one group received simulator-based training on malignant hyperthermia while the other group received simulator-based training on anaphylactic shock. Four months later, all subjects were posttested on a malignant hyperthermia scenario. The group that received specific training in this anesthesia crisis event responded significantly better ($p = .01$) than the group who received simulation-based education on another anesthesia crisis and was reliant on actual clinical experience for learning how to manage malignant hyperthermia.

Pittini et al. (2002) conducted a pretest/posttest design study with three cohort groups that varied in level of experience. Their findings showed that while all groups improved in

perinatal care, simulation had the most significant effect on learning in the most inexperienced group. The lowest level experience group made up of medical students and junior residents improved their skills to almost the same level as the more experienced fellows' group.

Problem-based learning has been well established in medical education as a efficacious learning technique (Barrows, 1996). Combining problem-based learning with simulation has significant potential. Euliano and Mahla (1999) reported on a technique to enhance problem-based learning with simulation. They presented a descriptive paper on their experiences detailing the advantages and disadvantages of combining these two learning techniques. Their conclusion indicated that the two learning strategies combined well, especially to fill in the void created between cognitive knowledge and practical application.

However not all studies have shown manikin-based simulation to have a positive impact on learning. McKenzie (2004) conducted an quasi-experimental study (non-randomized) with 38 medical students, with one group receiving pediatric resuscitation training in small-group teaching and the other with small-group teaching integrated with a high-fidelity manikin-based patient simulator. Posttest scores showed no significant difference between the two groups. However, it should be noted knowledge gain was determined by a written test rather than practical skills assessment.

P. J. Morgan, Cleave-Hogg, McIlroy, and Devitt (2002) conducted a randomized pretest/posttest experiment with 144 medical students comparing simulation-assisted education against video-assisted education in the management of patients with myocardial infarction, anaphylaxis, or hypoxemia. A simulator-based pretest was given to establish a benchmark. After the intervention, all subjects were again given the simulator-based scenario as a posttest. Expert raters scored both the pretest and the posttest. Posttest results showed that while there were significant educational gains in both groups, there was no statistical significance between the groups (p ranging from .09 to .92). One area of their study that did show significance

between the groups was in the level of enjoyment of the experience and the perception of value. In these areas the simulator group scored significantly higher than the video group ($p < .001$).

Gilbart, Hutchison, Cusimano, and Regehr (2000) conducted a randomized posttest only control-group design study that involved one group receiving simulator-based education, another group receiving seminar-based education, and a third group receiving no education intervention at all in the management of trauma patients. The outcome measure was a surgical Objective Structured Clinical Examination (OSCE). Their results showed that learners in both the seminar and simulation groups significantly outperformed the no-intervention control group. However, there was no statistical difference between the seminar and simulation groups. The one positive finding for the simulation group was a higher perceived self-confidence.

Nyssen, Larbuisson, Janssens, Pendeville, and Mayne (2002) conducted an experimental comparison study with 40 anesthesiology students in which the intervention group received training with full-scale manikin-based simulation and the control group received training using a screen-based simulation. Their findings showed that while performance improved, there was no significant difference between the two groups. Due to the costs of high-fidelity manikin-based simulators, the authors suggested that there might be more cost-effective methods of providing simulation-based education. However, they did note that full-environment simulations might have impact in other areas that were not tested:

Our results support the contention that screen-based simulators are good devices to acquire technical skills of crisis management. Mannequin-based simulators would probably provide better training for behavioral aspects of crisis management, such as communication, leadership, and interpersonal conflicts, but this was not tested. (p. 1560)

Other forms of simulation, including some with fairly high fidelity, have been studied or reported. These include virtual reality simulation and screen-based simulation (Agazio, Pavlides, Lasome, Flaherty, & Torrance, 2002; Ahlberg, Hultcrantz, Jaramillo, Lindblom, & Arvidsson, 2005; D. Alverson et al., 2005; Caudell et al., 2003; Colt, Crawford, & Galbraith, 2001; Goolsby,

2001; M.S. Gordon et al., 1999; Hikichi et al., 2000; J. Jacobs et al., 2003; Kiegaldie & White, 2006; Kneebone et al., 2003; Liu, Tendick, Cleary, & Kaufmann, 2003; S. MacDonald, 1994; Mangan, 2000; Mayrose, Kesavadas, Chugh, Joshi, & Ellis, 2003; Moorthy, Smith, Brown, Bann, & Darzi, 2003; Reznick, Harter, & Krummel, 2002; Rowe & Cohen, 2002; Saliterman, 1990; Satava, 2001; Schendel, Montgomery, Sorokin, & Lionetti, 2005; Schwid & O'Donnell, 1990, 1992; Schwid, Rooke, Ross, & Sivarajan, 1999; Sedlack & Kolars, 2002; Sohmura et al., 2004; Székely, 2003; Tuggy, 1998). However, while these studies have made a contribution to the knowledge base of simulation, this study is limited to manikin-based simulation.

Simulation and Short Course Programs

Franklin (2004) reported that of all the short-course certification programs such as ACLS, ATLS, PALS, and other similar programs, ACLS has the greatest potential for high-fidelity manikin-based patient simulation use. He said, "As sites gain access to an advanced patient simulator, the training and testing phases of ACLS are becoming more realistic. There are several advantages to the use of this technology, particularly with regard to a course such as ACLS (p. 399)." He continued, "With little effort, this experience can become totally immersive and provide a nearly realistic patient crisis (p. 400)." Schumacher (2004b) also reported that simulation could be an "effective strategy and tool for teaching advanced cardiac life support (p. 174)." Despite the promise of simulation in ACLS, no experimental studies on the use of high-fidelity manikin-based patient simulation in an actual ACLS course have been published. However, one descriptive report of using simulation in an ACLS course has been published (Ferguson et al., 2004).

ACLS-level skills and high-fidelity manikin-based patient simulation have been studied by a number of researchers. As a sampling, specific ACLS skills that have been taught or evaluated using high-fidelity manikin-based simulation included airway management (Barsuk et al., 2005; Hall et al., 2005; Mayo et al., 2004), respiratory compromise (Steadman et al., 2006),

ECG rhythm interpretation and defibrillation (Mueller et al., 2005), and cardiac arrest management (DeVita et al., 2005; Marsch et al., 2005).

Two published reports, both by the same lead author (Wayne et al., 2006; Wayne et al., 2005), covered ACLS course material in a manner that closely resembled an actual ACLS course and each of their studies involved one ACLS Instructor. However, neither study was an actual ACLS course that included all elements of the ACLS course and resulted in issuance of an American Heart Association course completion card. Nonetheless, these two studies warrant closer discussion.

Wayne et al (2005) conducted a randomized pretest/posttest controlled experiment with 38 second year internal medicine residents. Their study featured a crossover design that provided the simulation-based education intervention to the control group after the first posttest. Three comparison measurements were made: baseline, after either the simulation-based intervention (treatment group) or three-months of clinical activity (control group), and after a simulation-based intervention (control group) or three-months of clinical activity (treatment group). The simulation-based education intervention focused on ACLS patient cases and utilized ACLS course materials. Results showed that there was no difference between the groups at the baseline. At the second measurement, the treatment group receiving the simulation-based education intervention performed significantly better on a simulated ACLS patient case than the control group ($p < .0001$). On the final measurement, the control group (which had now received the simulation-based education intervention) performed significantly better than the original treatment group ($p < .05$).

As they described their results, Wayne et al.(2005) noted that based on the second measurement point's results, clinical experience alone was not adequate in comparison to an ACLS-like simulation-based education intervention. The authors noted that there appeared to be very little decay in the original treatment group's score after three months. The mean scores for testing at measurement 2 and measurement 3 were 265.6 and 256.15 respectively. However,

the authors did not submit this finding to a statistical test. Still, this finding is relevant considering other authors have reported rapid degradation of skills after ACLS training (Kaye, Mancini, & Rallis, 1987; Kaye et al., 1985; O'Steen, Kee, & Minick, 1996; Stross, 1983).

Wayne et al. (2006) conducted a one-group pretest/posttest design study with 41 second year internal medicine residents. After baseline testing, the subjects participated in a simulation-based education intervention that mimicked many elements of an actual ACLS course. Subjects received 4 two-hour simulation sessions with ACLS cases, and then were retested. Subjects who did not achieve a minimum passing score were remediated through additional simulation sessions. Remediation times ranged from 15 minutes to 2 hours. Posttest scores improved significantly with the intervention ($p < .0001$). However, as reported earlier in this chapter, low-fidelity manikin-based ACLS programs reported significant improvement as well (Boonmak, Boonmak, Srichaipanha, & Poomsawat, 2004; Marchette et al., 1985; Quan, Shugerman, Kunkel, & Brownlee, 2001; Waisman, Amir, & Mimouni, 2002).

Student perceptions of manikin-based simulation

Numerous studies have examined learner perceptions of manikin-based simulation. Different perceptions were evaluated and included level of satisfaction, improvements in self-confidence, feelings of simulation realism, and overall acceptance of manikin-based simulation as a learning strategy.

Acceptance

Several studies were identified that showed a high degree of acceptance by students of simulation as a learning strategy (Bond et al., 2004; Bond et al., 2001; J. A. Gordon et al., 2001; Hammond et al., 2002; Lighthall et al., 2003; Morgan et al., 2006; J. Weller et al., 2004).

Bond, Kostenbader, and McCarthy (2001) examined the level of satisfaction with using a high-fidelity manikin-based patient simulator in 78 healthcare providers of varying backgrounds. Using a five-point Likert scale (1 equals *disagree completely*, 5 equals *agree completely*), subjects responded to five questions after a simulation session. Results showed a very positive agreement that indicated a high degree of satisfaction with the simulation session. Responses ranged from 4.53 to 4.77. In qualitative comments that were solicited, the most frequent responses referenced the realism of the simulation and the ability to see the results of therapeutic decisions.

Lighthall et al. (2003) surveyed 181 healthcare providers after completion of a CRM course focused on intensive care unit patients. Their results showed participants heavily supported simulation-based education, although medicine and anesthesia residents indicated having a greater liking for the program than surgery residents. During debriefings associated with the scenarios, validity of the program was established as there was uniform agreement that the errors highlighted in the simulation sessions were errors that were commonly seen in hospital-based practice.

Bond et al. (2004) conducted a qualitative assessment of 15 emergency medicine resident physicians after utilizing a high-fidelity manikin-based patient simulator for the

assessment and treatment of a renal failure patient with hyperkalemia. Through a combination of verbal questioning by an ethnographer and a series of survey questions utilizing a Likert-like scale (1 equals *disagree completely*, 5 equals *agree completely*), the authors found that the residents were very favorable to simulation as a learning strategy, ranking it second only to direct patient care in terms of how effective it was educationally. On individual items related to knowledge gain, the subjects rated the simulation highly with a mean range of responses being 4.6 to 4.73. Subdividing the results between second year and third year residents, the authors noted a difference in what was learned. The less experienced physicians tended to state that the knowledge they gained was related to treatment specifics, such as the use of various medications or other therapeutic interventions. The more senior physicians tended to state they learned more about their own cognitive processes in the decision-making in the management of the simulated patient. The authors concluded the simulation sessions were not only valuable in teaching specifics about patient care interventions, but also useful in developing metacognition strategies.

Morgan, Cleave-Hogg, Desousa, and Lam-McCulloch (2006) surveyed 226 medical students on their experience after completing a simulation-based education program. Using their five-point scale (*strongly disagree* to *strongly agree*), the overwhelming majority of students rated the experience highly (either agree or strongly agree in all areas). The learners felt the simulation was realistic, represented the learning objectives, was a valuable learning experience, and helped link theoretical aspects of care to practical applications.

J. A. Gordon, Wilkerson, Shaffer, and Armstrong (2001) conducted a one-shot case study survey of a convenience sample of 27 medical students and 32 medical educators after introducing a high-fidelity manikin-based patient simulator to each group. Both groups responded very favorably to simulation as a learning tool with 85% of students rating the experience as excellent with 89% of the students saying simulation should be a mandatory part

of the curriculum. For the educators, 89% rated the session as good or excellent while 82% stated simulation should be part of the curriculum.

J. Weller (2004) conducted a one-group pretest/posttest survey of 33 medical students participating in an anesthesia workshop. Weller described her study as using a medium-fidelity manikin-based patient simulator; however, she used the same simulator being used in this study (Laerdal SimMan). As discussed in Chapter 1, fidelity is a fairly subjective term that has different meanings depending on the use of the device. Her findings showed that learner self-reported measures of confidence in providing care significantly increased after participation in the workshop ($p < .0001$). Written responses from the students after the workshop indicated enthusiastic acceptance of the simulator as a learning tool and responses indicated students felt the workshop very beneficial. When asked to identify key learning points of the workshop, it was interesting to note that the clinical objectives such as assessment and therapeutic interventions were not the most frequently mentioned. Behavioral issues such as teamwork, leadership, and critical thinking skills were identified as the key learning points of the workshop.

Feingold, Calaluce, and Kallen (2004) surveyed 65 undergraduate nursing students on their views of using simulation as a learning strategy in clinical skills laboratory. Their results showed that learners felt the simulations provided realism sufficient for the skills being taught, and had considerable overall value to the learners' ability to learn new skills and knowledge. About half of the learners felt there was a high degree of transferability of the skills from the simulation laboratory to the real clinical setting. One significant finding discovered in subgroup analysis of their data was that learners with lower self-reported Grade Point Average felt the simulation experience was of greater value than those with higher self-reported GPA.

Confidence

Learner self-reports of confidence in their ability to provide patient care after simulation-based education have been positive (Bearson & Wiker, 2005; Euliano, 2001; Feingold et al.,

2004; Gilbert et al., 2000; Henrichs et al., 2002; Marshall et al., 2001; Meier, Henry, Marine, & Murray, 2005; O'Brien, Haughton, & Flanagan, 2001; Wayne et al., 2006).

Experience plays a significant role in the development of healthcare provider confidence (Morgan & Cleave-Hogg, 2002). Confidence is vital to the clinician taking action. As Maibach, Schieber, and Carroll (1996) noted, even clinicians with adequate knowledge and skills may be reluctant to take appropriate action unless they are confident in their abilities. In reviewing the literature, learner feelings of self-confidence tend to be improved when the learning experience is simulation-based. Euliano (2001) reviewed the results of student evaluations of a simulation-based course that also utilized problem-based learning techniques. Using a pretest/posttest design, learner confidence in their knowledge of the material significantly improved after participation in the simulation program ($p < .0001$). Additionally, learners rated the course with a mean of 4.5 out of 5.0, which rated among the highest rated courses in the medical school where the course was conducted.

Henrichs, Rule, Grady, and Ellis (2002) performed a qualitative study of 12 first year nurse anesthesia students to determine their perceptions about simulation as a learning strategy. Their results identified 11 items that were positively perceived by the learners. This included, in rank order:

1. Improved critical thinking and decision-making skills
2. Ability to learn crisis resource management skills
3. Ability to learn how to administer anesthesia without causing harm
4. Vital part of nurse anesthesia education
5. Simulated reality of anesthesia environment
6. Increased confidence level
7. Evaluation of cognitive and psychomotor skills
8. Ability to learn about rare events or unusual complications
9. Ability to critique actions per videotape of self and classmates

10. Motivation to learn more about a specific topic

11. Improved leadership skills (p. 222)

Henrichs, Rule, Grady, and Ellis also identified several negative perceptions, including learners' lack of knowing what to do in the situation, a tendency to experience fixation errors, increased anxiety, and a lack of reality at all times. As this study was performed with first-year students, some of these negative factors such as anxiety and fixation errors may correlate to their experience level with nurse anesthesia in general.

Wayne et al. (2006) conducted a follow-up survey with 40 second year internal medicine residents after having completed an ACLS-like simulation-based education program. They reported that the subjects were uniformly positive about the ability of the simulation-based education experience to increase their clinical capabilities and improve their confidence to respond to ACLS emergencies in the clinical setting. Subjects also reported they felt they were better team leaders as a result of the intervention.

Even in comparative studies where differences in observed learning between two or more groups was not significant, learners' from the simulation intervention group still had a higher self-reported feeling of confidence. Gilbert, Hutchison, Cusimano, and Regehr (2000) surveyed their study's participants and found that 100% of the simulation group learner felt clinically competent to manage a trauma patient while only 82% of the seminar group felt confident. Griggs (2003) reported increased learner self-reported competency in a randomized pretest/posttest controlled study. However, the reported perceptions of competence had improved for both the control and experimental (simulation) groups and there was no statistical significance between the two.

Learner Satisfaction

Learner satisfaction has been reported as being very positive after manikin-based simulation-based education programs (Block et al., 2002; Cleave-Hogg & Morgan, 2002; Morgan et al., 2002; von Lubitz et al., 2003).

Cleave-Hogg and Morgan (2002) conducted a survey of 145 fourth-year medical students after completion of an anesthesiology rotation in a patient simulation laboratory. Participants completed a seven-item questionnaire with a 5-point Likert-like scale (1 being *strongly disagree*, 5 being *strongly agree*) and answered additional open-ended qualitative questions. The quantitative results showed a significant preference for simulation as a learning model, with most responses being in the agree or strongly agree column. One interesting note on the quantitative results was on the questions related to the participant being “comfortable” in the simulator room. This question had the highest number of strongly disagree and disagree responses of any question. One student commented, “It was too anxiety provoking and overwhelming a situation to actually learn from (p. 25).” Stress or fear as a issue in patient simulation is a factor and has been reported by others (Bond et al., 2004; Henrichs et al., 2002; Kapur & Steadman, 1998). However, this may be a testament to the realism of the simulation session, as stress in real events would be expected to be high as well (Aronson et al., 1997; Kneebone et al., 2002). Qualitative comments showed students responded very favorably to simulations. One student stated, “Realism promoted reinforcement of book-learned concepts...putting knowledge into practice was invaluable (p. 25).” Another commented, “We don’t get much opportunity to run codes [cardiac arrests] in real life. Excellent opportunity to get hands on experience without risk of harming patient. This is almost a ‘real life’ experience (p. 25).”

Block, Lottenberg, Flint, Jakobsen, and Liebnitzky (2002) conducted a one-shot case study of 14 participants in an Advanced Trauma Life Support course. Their survey results showed the students felt the manikin was better than the previous model used in the course (a live anesthetized animal). However, while the patient simulator in this course represented excellent fidelity for the task being taught and tested, it did not represent a full-bodied manikin.

Patient Perceptions

Not all studies have focused on the healthcare learner as their subjects in examining perceptions about simulation. Graber, Wyatt, Kasperek, and Xu (2005) conducted a survey of 151 visitors to an emergency department to determine how simulator use influences patients' perceptions about medical students performing skills in the emergency department. Subjects were asked how many procedures after demonstrating competence on a patient simulator a medical student should do before the subjects would let that student perform the procedure on them. Results were compared with a similar study that did not include the simulator aspect of the question. The results showed that simulator training changed patient perceptions about allowing a medical student to perform procedures on them. Of the nine procedures covered in the survey, results were significantly different ($p < .03$) in six of the procedures, indicating that patients were more accepting of medical students doing procedures on them when the medical student had simulator training.

Limitations of Simulation

While realism has been achieved in many areas of patient simulation, there are still many other areas of patient anatomy and physiology that have yet to be realized. As Hammond (2004) noted, "The major hurdles facing medical education are to expand the fidelity of the modeling and to create a business case for simulation centers (p. 325)." Others have also commented on the lack of realism in some areas, including the feel of the skin, skin color, and skin temperature (Euliano, 2001; Good, 2003; Haskvitz & Koop, 2004). The lack of realism may not just apply to the simulation device. Morton (1997) commented on the ability of the environment to be recreated, saying:

...simulation is constrained by the degree it can mimic reality. The fast-paced, high-stress environment of a critical care unit is difficult to simulate. As a result, there is no assurance that the learner will make a smooth transition of knowledge from the simulated situation to the actual clinical environment. (p. 67)

Kneebone, Scott, Darzi, and Horrocks (2004) warned against an over reliance on simulation as being a replacement for actual clinical experience. Simulation competence may lead to overconfidence on the part of the learner creating a dangerous situation when the learner takes those skills to the clinical arena. They stated, "There is also a danger that simulation may become an end in itself, disconnected from the professional practice for which it purports to be a preparation (p. 1099)." Gilbert, Hutchison, Cusimano, and Regehr (2000) lend credence to this viewpoint as 100% of their simulation-based learners felt confident about their ability to provide care while only 83% of a comparison group felt confident, despite finding there was no significant difference in either group to provide adequate patient care. However, it could not be determined if this was a matter of overconfidence in the simulator group or underconfidence in the comparison group.

One problem with high-fidelity manikin-based patient simulators is that they are mechanical. Breakdowns do occur. Bond, Kostenbader, and McCarthy (2001) and Henrichs, Rule, Grady, and Ellis (2002) noted some dissatisfaction with breakdowns in their studies of healthcare providers' experience with simulation sessions. Bond, Kostenbader, and McCarthy (2001) also showed some dissatisfaction in their subjects' qualitative comments with the simulator making mechanical noises during some assessment procedures.

Cost remains an issue with simulation courses as the purchase of the simulators, equipping the simulation room, providing maintenance, and training faculty and staff still remains relatively high (Dent, 2001; Euliano, 2001; Farnsworth et al., 2000; Good, 2003; Haskvitz & Koop, 2004; Hotchkiss & Mendoza, 2001; Issenberg, McGaghie et al., 1999; Morton, 1997; D. Murray et al., 2002; Nehring et al., 2001; Nyssen et al., 2002; Wang & Vozenilek, 2005).

While there has been a fair amount of research conducted on simulation as a teaching strategy in healthcare provider education, more needs to be done (Bradley, 2006; Hotchkiss & Mendoza, 2001). Just as evidence-based medicine has become an expectation in patient care,

evidence-based education is becoming a higher priority in many healthcare provider curriculums. Once such manifestation of this movement is the Best Evidence Medical Education program (Issenberg et al., 2005). One issue that creates problems for simulation-based education research is the small sample size of many studies (Bradley, 2006). Other authors (Beaubien & Baker, 2004; J. Cooper & Taqueti, 2004) also suggest more research is required, particularly research that shows improvements in patient safety. Another issue regarding simulation research is the inability to establish congruent findings. Gilbert, Hutchison, Cusimano, and Regehr (2000) noted this as they reviewed the literature regarding transference of skills from simulation to the real world clinical environment.

While simulation has been studied in a wide variety of healthcare provider curriculums and is continuing to grow in its use, it is not yet pervasive as an educational tool. J. Cooper and Taqueti (2004) stated the “tipping point” has not yet been reached in simulation in all healthcare fields. One reason they cite for a portion of this problem is the reimbursement problems for healthcare providers and educational organizations. Good (2003) mentioned that simulation may be intimidating to some healthcare provider learners. However, he added that several studies have shown excellent acceptance for simulation as a learning strategy.

Nehring, Ellis, and Lashley (2001) also noted the limited number of learners that could utilize the simulator at one time. Simulation-based education limits activities to small groups or possibly even single learners. Other formats such as lecture, demonstration, or web-based instruction can allow for larger groups or more simultaneous users.

Good (2003) stated that faculty development may be a problem. As in many areas of education, faculty staffing and work requirements are stretched. Teaching with simulation requires a whole new skill set that many faculty members do not currently have. In addition to the teaching techniques required (such as debriefing) there is the technology to learn. While many simulation centers employ simulation technicians to manage this aspect, this is not universal and the faculty member may be called upon to manage the technology. Feingold,

Calaluce, and Kallen (2004) and Nehring, Ellis, and Lashley (2001) also reported faculty concerns that simulation would require additional time and resources beyond their normal teaching responsibilities.

Haskvitz and Koop (2004) noted that learners in a simulation are probably in a state of heightened awareness and anticipation, waiting for something to happen. As they stated, “Students may aggressively tune into the possibility that something is about to happen and become overzealous in treating a situation (p. 184).” This does not represent the real world well as most care may be routine and the clinician may drop his or her guard and be caught unawares of the developing crisis situation. Coupled with the idea that something is going to happen, Henrichs, Rule, Grady, and Ellis (2002) found that students in their study experienced feeling like a “sitting duck (p. 223).” This feeling created a higher level of anxiety than they would have experienced in the real clinical environment.

As mentioned earlier in this chapter, anxiety on the part of the student may be a problem with simulation. While the stresses of learning in the real world clinical situation are well documented, there is a different kind of stress in the simulation setting that must be taken into account, especially in evaluation scenarios. As Kapur and Steadman (1998) stated:

The simulator environment may prove to be intimidating to candidates at first. The presence of video cameras, evaluators, scripted roles for co-actors in the scenes, and limited flexibility of the programmed scenarios to accept alternative therapeutic pathways or thought processes that avoid harm and achieve acceptable results could potentially lead to a false-negative test, in which the candidate could be deemed incompetent in the simulator situation, yet be an entirely acceptable clinical anesthesiologist under less artificial conditions. (p. 1158)

Another drawback noted by Greenberg, Loyd, and Wesley (2002) is that despite technological advances in simulator fidelity, simulators do not convey “humanness (p. 1109).” Simulators are cold and plastic in appearance and even with the capability for a human voice to

be generated via microphone and speaker, there are limits to how real the devices can seem. To counteract this deficit, Greenberg, Loyd, and Wesley devised a program where standardized patients are incorporated into the scenario and utilized up until the point actual procedures start. Kneebone et al. (2002) and Pittini et al. (2002) developed similar systems with part-task simulation.

Issenberg, McGaghie et al. (1999) pointed one other area of concern for simulation technology. They commented that there is some fear that technology will dehumanize health care. Simulation technology removes the health professions student from interacting with the patient and decreases total time spent with real patients. These authors felt that simulation training served the patient's best interest by placing a better prepared clinical student at the bedside. Ziv, Wolpe, Small, and Glick (2003) agreed with this point, stating, "Although overreliance on technological medicine may sometimes be a threat to humanistic care, the proper use of simulation technology has the potential to enhance humanistic training in medicine (p. 786)."

Morton (1997) warned of another potential issue with simulation. She stated that simulations might be heavily oriented to the psychomotor skills. As such, learners develop an emphasis on the technology often associated with those skills. Doing this "deemphasizes human caring...Yet, to become a caring nurse requires a measure of comfort and competence with technology so that technology no longer is the focus of care. Instead, the patient becomes the focus (p. 68)."

Simulation in Nursing Education

High-fidelity manikin-based patient simulation has been conducted with a variety of health professions students and practicing healthcare providers as noted in Chapter 1. While the majority of published studies focus on medical (physician) education, the application and benefits of patient simulation are similar for nursing (Feingold et al., 2004). Peters (2000) and Yaeger et al. (2004) stated that the medical education model and the nursing education model

have many similarities, although both are going through reform. This study used nursing students as subjects. Simulation-based education has frequently been reported in the nursing literature and its uses in nursing education are many (Schumacher, 2004a, 2004b).

While most of the studies on patient simulation have focused on simulation in medical education, nursing represents a significant audience for patient simulation. Many of the same challenges facing medical education are also apparent in nursing education, including the continuing growth of medical knowledge, patient safety, and patient availability. Complicating matters for nursing education is an unprecedented demand for nurses in today's health care market, with nursing shortages expected to reach as high as 20% by 2020 (Eder-Van Hook, 2004). Larew, Lessans, Spunt, Foster, and Covington (2006) noted that simulation in nursing education started with "teaching psychomotor skills and competency testing. Use in nursing curricula has expanded to include development of critical thinking and the practice of skills within the affective domain (p. 17)."

Nehring, Ellis, and Lashley (2001) noted that modern high-fidelity manikin-based patient simulation has great potential in nursing education:

The psychomotor skill laboratories in nursing education have grown from the infamous Mrs. Chase and other crude mannequin-driven laboratory projects of the early part of the last century to the advanced simulation environment of today. This has been accomplished through the integration of medical and nursing education with the emerging and expanding computer technology, such as the HPS [Human Patient Simulator], available throughout the world. This has been done to insert the learner into a more realistic simulation environment where the development and application of knowledge, skills, and the practice of protocols can be enhanced. Opportunities for education, research, and evaluation using the HPS at all levels of nursing education are limitless. (p. 202)

Nehring and Lashley (2004) conducted an international survey of 34 schools of nursing and six simulation centers on the use of high-fidelity manikin-based simulators in use in nursing education. The authors noted that simulation use in nursing education programs was not yet well developed, especially in comparison to simulation use in medical education. They also noted that reports on the use of patient simulation in the nursing literature were very few.

Among their descriptive findings:

- of the 34 nursing schools, 82% were public institutions
- the nursing schools offered a range of degrees from associate to graduate
- 16 were community colleges, 18 were universities
- The simulator was most frequently reported being in use in associate degree programs, with associate degree programs also showing the most hours of use
- Community college use tended to be focused on assessment skills while university use tended towards higher level problem-solving and interventional skills

Bearson and Wiker (2005) conducted a one-shot case study of the impact of a simulation-based education program on post-operative pain management by student nurses in a baccalaureate nursing program. The measurement instrument was a self-administered instrument that evaluated student opinions on the learning experience and their self-efficacy in the management of post-operative pain. Using a Likert-like scale of 1 (*strongly disagree*) to 4 (*strongly agree*), the students responded to four questions. Mean scores ranged from 3.0 to 3.31. The authors concluded that simulation could be a valuable asset to nurse training.

Feingold, Calaluce, and Kallen (2004) conducted a one-shot case study (however, it included two groups from two different semesters that were combined for reporting). Sixty-five baccalaureate degree nursing students were included in the study. Their findings included very high scores for student agreement with the realism of the simulation and its value to learning

(84.6% and 92.3% respectively). Additionally, the participants viewed the simulation as a good test of their clinical skills (83.0% agreement) and their decision-making (87.7% agreement).

Farnsworth, Egan, Johnson, and Westenskow (2000) did a one-group pretest/posttest study with 20 Registered Nurses involved in conscious (moderate) sedation patient interventions. Written pretest and posttest comparisons showed that after simulation-based education, posttest scores improved significantly ($p = .001$). In a simulator-based practical evaluation of the concepts taught in the program, mean practical score was 5.5 out of a possible 6 (with 0 being the lowest possible score).

Haskvitz and Koop (2004) Suggested a model of remediation for nursing students performing at a suboptimal level in clinical rotations. Citing patient safety as a major motivating factor, nursing clinical preceptors and educators have a responsibility to improve the educational outcomes of their students while still protecting patient safety. Through the use of a patient simulator, the authors introduced a program to remediate nursing students who needed additional help in grasping clinical concepts and skills. Their process identified four steps:

- Assessment – Determine what areas need improvement. Not all areas can be effectively remediated with simulation. Issues related to preparation, didactic knowledge, and professionalism may need to be addressed elsewhere. Simulation does lend itself well to problems associated with integrating didactic knowledge into the clinical setting, performing a skill, or implementing a plan of care in prioritized manner.
- Planning – Simulation scenarios need to be developed that address the learner's deficiencies. Objectives should be reviewed with the learner and the preceptor. The learner should be instructed to prepare for the simulation in the same manner in which he or she would in preparing for a clinical day.
- Implementation – The learner interacts with the simulator in the prescriptive scenario. The instructor or preceptor may have the learner repeat the scenario until the desired

level of competence is achieved. The scenario could be interrupted to supply appropriate feedback on actions taken by the learner.

- Evaluation – Once the simulation scenario is complete, debriefing should be performed that summarizes the objectives and includes how the learner achieved each of those objectives. Learners would be encouraged to identify areas where additional improvement may be needed. Lastly, preceptors should monitor learner performance in the actual clinical environment to ensure that the simulation behavior of the learner transfers to the clinical realm.

Bremner, Aduddell, Bennett, and VanGeest (2006) conducted a one-shot case study survey of 41 novice nursing students using a manikin-based patient simulator for performing a patient assessment. Their results showed the vast majority of these novice nursing students felt the simulation was a valuable tool for learning and should be a mandatory part of the curriculum. Sixty-one percent of the learners stated the simulation session gave them greater confidence in performing a patient assessment.

As with simulation in general, not all studies in nursing's use of simulation have demonstrated favorable findings for simulation compared to other learning methodologies. Ravert (2004) conducted a randomized pretest/posttest design with 25 third semester nursing students comparing two types of learning strategies: classroom-based discussion for one group and simulator-based education for the other group. Her findings showed both groups significantly increased their critical thinking skills. Both groups also reported significant gains in self-efficacy. However, neither group significantly outperformed the other in either area.

Alinier, Hunt, Gordon, & Harwood (2006) conducted a randomized pretest/posttest study of 99 diploma-level nursing students. Two groups were tested: one that went through the normal curriculum and another that had their curriculum supplemented by simulation-based education. Upon testing using an Objective Structured Clinical Examination, both groups demonstrated significant increases in their ability to assess patients ($p < .0001$). However no intergroup

differences were noted in learning gains. Additionally, both groups' perceptions of stress and self-confidence scored equally as well.

Simulation and Team Training

Team leadership has long been identified as a problem in ACLS courses and ACLS-level care (Kaye & Mancini, 1986). As Kay and Mancini noted, "During training, assessment of both the patient and the team, and troubleshooting must be explicit and well understood. Optimal assessment and troubleshooting skills of the team leader will maximize the likelihood of a successful resuscitation (p. 103)." Simulation offers an opportunity to more effectively practice and evaluate team leadership as it allows the instructor to step back from the teaching scenario and allow the team to function in a more independent manner.

Another factor affecting team management is the changing role of the physician (Dent, 2001). Rather than the traditional authoritarian role of the physician, physicians are now being seen as team members in multidisciplinary teams with a blurring of boundaries in responsibility and roles. Directly related to patient safety concepts embedded into Crisis Resources Management programs, modern healthcare teams differ greatly from their predecessors.

Reviewing learning teams in general, Kayes, Kayes, and Kolb (2005) summarized several negative behaviors that tended to surface in groups. These included:

- over reliance on a single dominant person as team leader,
- tendencies to resort to groupthink where individual members cede their independent thought to conform to the group, even when the group decision is wrong, such as making riskier or more conservative decisions than individuals would have made alone,
- diffusion of responsibility in which individual members of the group shirk responsibility thinking that someone else will assume that responsibility,

- social loafing where individual group members lose motivation creating a situation in which the group's results are less than what the individual results could have been, and
- the Abeline paradox where individual members consent to group actions against their own judgment, failing to express their opinions.

It is this team approach that must be addressed to have a substantial impact on patient safety and healthcare outcomes. As Hamman (2004a) noted in comparing aviation incidents with adverse medical events, it is typically not a single individual or a piece of equipment that fails. It is more typically a team that fails. Training at this level has to involve more than just focus on the individual. Whole teams must be evaluated. As Hamman observed, in healthcare, training is focused at the individual with the intent of making that individual a better clinician. Henriksen and Moss (2004) stated that, "Health care providers work together, but are trained in separate disciplines. Few receive training in teamwork (p. i1)." Integrating that individual and his or her knowledge into the more complex interactive requirement is not the focus of most healthcare education programs. Hamman (2004a) created a five-step process for developing team simulations in medicine:

1. Identify team topics and subtopics, linking performance indicators to objectives.
2. Select incidents to simulate, preferable from a data set of real events.
3. Identify objectives and the observable behaviors that will indicate their completion as tracked by a validated assessment instrument.
4. Test the simulation scenario with at least two different expert teams and confirm validation of the assessment instrument.
5. Modify and finalize the simulation based on expert team feedback and deliver simulation scenario to its intended audience.

Experiential learning (covered in greater detail later in this chapter) in teams can be credited to Kurt Lewin in his work in the 1940s (Kayes et al., 2005). For teams, reflection is an

important process for improving team function. Kayes, Kayes, and Kolb (2005) cited principles that have they deduced from a review of research on experiential learning in teams in general.

Their three principles were:

- “To learn from their experiences, teams must create a conversational space where members can reflect on and talk about their experiences together (p. 332).”
Objectivity is essential in this conversational space. The team must see itself in a true light. If this is not achieved, the team is “flying blind. (p. 333).”
- “As a team develops from a group of individuals into an effective learning system, members share the functional tasks necessary for team effectiveness (p. 333).”
Team members must develop a shared responsibility. No one person assumes the role of the traditional team leader.
- “Teams develop by following the experiential learning cycle. (p. 333).” This process – concrete experience, reflective observation, abstract conceptualization, and active experimentation – is reviewed later in this chapter.

For teams to learn, some form of intervention is required. Natural development is an unreliable way to improve performance (Kayes et al., 2005). Simulation offers a “programmed team learning experience (Kayes et al., 2005, p. 350)” For experiential learning to work for team development and acquisition of new knowledge, four components must be in place for team members, with one component for each of the four segments of the experiential learning cycle.

Team members must be...

- involved and committed to the team and its purpose and who are creating new knowledge and identifying challenges (concrete experience).
- engaging in reflection and conversation about the team’s experiences and making observations to ensure that all available knowledge has been addressed (reflective observation)

- thinking critically about how the team works and coming up with new theories, devising plans, models, and placing abstract events into coherent and simple explanations (abstract conceptualization)
- making decisions, taking action, and experimenting with various approaches and strategies for problem solving (active experimentation) (Kayes et al., 2005, p. 350)

Ostergaard and colleagues (D. Ostergaard, 2004; H. T. Ostergaard et al., 2004)

discussed the current state of team training in a variety of medical disciplines and presented information on their development of team training programs using simulation. One area on which they focused was ACLS training. Upon reviewing their own hospital's activities, they found that application of treatment guidelines was inconsistent and through focus group interviews found that communication and leadership skills were poor. In response to this information, a specialized training program in ACLS-like course that utilized high-fidelity manikin-based patient simulation was developed. In a one-group pretest/posttest design study, they showed that self-evaluation of communication, cooperation, and leadership improved dramatically from pretest to posttest.

However, there has been contradictory information presented as well. Blum, Raemer, Carroll, Dufresne, and Cooper (2005) noted a key component of effective healthcare team performance is the ability to effectively share information. They conducted a one-group pretest/posttest design study that examined communication sharing. In their study, critical patient information was inserted into the scenario by a role-playing research staff member to one of the team members participating in the scenario. As predicted in their first hypothesis, information sharing between team members was very low with only 27% of the planted information being shared among team members. However, their hypothesis that debriefing and a didactic education session from the Anesthesia Crisis Resource Management (ACRM) course would improve team communication and information sharing failed to show significance during posttest.

Simulation Learning Theory

Patient simulation has become well entrenched in many healthcare provider curriculums. Healthcare educators who have promoted simulation as a learning model are quick to point out many of the advantages patient simulation offers and there are great expectations for simulation. J. A. Gordon, Oriol, and Cooper (2004) discussed this potential:

High-fidelity patient simulations – full-bodied mannequin-robots that breathe, talk, blink, and respond “like a real person” – promise to play a revolutionary role in undergraduate medical education. Allowing students to “practice without risk” on the simulator creates a powerful new framework for the thoughtful integration of basic and clinical science, long a goal of medical educators worldwide. (p. 23)

Considering the hopes that are pinned to simulation as a means of improving healthcare providers’ learning while at the same time increasing patient safety, an exploration of why patient simulation works as a learning strategy is warranted.

In reviewing the simulation literature – both in healthcare simulation and the more general view of simulation – a variety of education theories are presented as supporting simulation’s use. However, no one theory has emerged as being explanatory of the whole field of simulation. Kneebone (2006) commented:

If simulation is to be fit for purpose, we need to elaborate an underpinning ‘theory of simulation.’ As well as establishing the scientific basis of our field, this will provide insight into the theoretical frameworks of related disciplines, helping learners and teachers to select the type of simulation which best meets their needs at a given moment...Without a coherent theory, it is easy to get lost in a confusion of beguiling but disparate fields. (p. 160)

The following section of the literature review will investigate current thinking in learning theories that may help provide a basis on why simulation is an effective tool. A broad spectrum of learning theories is presented with each theory having the potential to influence creation of an

integrated simulation learning theory. While this section does provide some examples of how these theories have applicability in simulation, a more unified presentation of a simulation learning theory that draws upon these viewpoints will be presented in Chapter Five.

Within the healthcare simulation literature, Bradley & Postlethwaite (2003b) provided one of the better overviews of learning theories and their influence on patient simulation. The authors noted that issues related to deficits in the research literature prompted their review:

...there has been criticism of medical education from within the profession of the relative paucity of sound educational research that underpins much of medical education innovation. Medical simulation offers tremendous opportunities for the advancement of our understanding of learning because it is consistent with different ways of conceptualizing learning, and because research in very different paradigms can be accommodated. (p. 1)

Dunn (2004) supplied another overview in the simulation literature that briefly reviewed five leading educational theoretical viewpoints: behaviorist, cognitivist, humanist, social learning, and constructivist. In his introduction, he cited this proposition:

Two underlying hypotheses must be recognized in the context of reviewing education theory relevant to critical care instruction. The first of these is that better learning is associated with improved teaching techniques. The second is that education as a discipline (similar to research and practice domains) has its own tool set (i.e., the knowledge-of-education theory) which, if well applied and adequately studied, can facilitate learner (and perhaps patient) outcomes. (p. 15)

Several education theories and models have been suggested as a means of explaining simulation's effectiveness. Other potentially relevant theories have not been tied directly to manikin-based patient simulation, but deserve investigation. Among the theories and models discussed in the simulation literature are constructivism, experiential learning theory, adult learning theory, and the novice to expert continuum. Other education theories and models that

hold potential in explaining why simulation works include brain-based learning and social cognitive theory.

Constructivism

Constructivism includes several different theories and points of view (Fenwick, 2000; Woolfolk, 2004). Woolfolk cited the influences on constructivist thought to educational theorists and philosophers including John Dewey, Jean Piaget, Lev Vygotsky, and Jerome Brunner. Constructivism places the learner in an active role rebuilding their knowledge based on new experiences.

Delgarno (2001) cited three major principles that guide constructivist learning:

- Each person has his or her own unique experience and knowledge. Delagarno traces this principle from Kant, through Dewey, and most recently to von Glasserfield.
- Learning occurs through active exploration when an individual's knowledge does not fit the current experience. In Piagetian terms, this would be disequilibrium. Using Vygotsky's terminology, this is the zone of proximal development.
- Learning requires interaction within a social context. Referring to Vygotsky, Delgarno stated that this social context is integral to learning.

Fenwick (2000) provided these insights in her definition of constructivism:

The learner reflects on lived experience and then interprets and generalizes this experience to form mental structures. These structures are knowledge, stored in memory as concepts that can be represented, expressed, and transferred to new situations...A learner is believed to construct, through reflection, a personal understanding of relevant structures of meaning derived from his or her action in the world. (para 18 & 19)

Within constructivism there are many viewpoints and there are conflicts related to just how information should be presented. Dalgarno (2001) made these observations:

Radical constructivists claim that learners should be placed within the environment they are learning about and construct their own mental model, with only limited support provided by a teacher or facilitator. More moderate constructivists claim that formal instruction is still appropriate, but that learners should then engage in thought oriented activities to allow them to apply and generalise the information and concepts provided in order to construct their own model of the knowledge. Adding a third dimension is the view that knowledge construction occurs within an environment that allows collaboration between learners, their peers, experts in the field, and teachers. (p. 184-185)

One concept from the constructivist viewpoint that is particularly relevant to patient simulation is the concept of situated learning. As Woolfolk explained, situated learning is “the idea that skills and knowledge are tied to the situation in which they were learned and difficult to apply in new settings (2004, p. 326).” Maudsley and Strivens (2000) commented on situated learning saying, “This perspective claims that ‘learning to do (closely related to knowing how) takes place through solving problems in context (p. 537).” Simulation offers several advantages aimed at overcoming the specificity of the learning context. First, in simulation-based education, the knowledge or skills are presented in context as opposed to being presented in an environment that may not have a real-world implication. Second, simulation-based education emphasizes the function of debriefing after a simulation. This provides the opportunity to review the situation and examine what other contexts the knowledge and skills may be applied. Lastly, through the reflective process of debriefing, simulation-based education instills a critical thought process in the learner that better prepares the learner to transition the knowledge and skills into new situations.

The idea of context is a central concept in constructivist thought. Instead of introducing knowledge and skills in a simplistic manner in a noncontextual environment, constructivism would advocate the use of complex learning environments that mimic the real-world application of the knowledge and skills. This is best represented by Gaba and Small’s (1997) “full

environment” simulation. Here the complex problems associated with the new knowledge or skill are embedded into real-world authentic tasks. Complex learning environment emphasize the ambiguity of many real-world situations and force learners to integrate previous knowledge to the new situation.

Beaubien and Baker (2004) made the recommendation that full mission simulation be conducted with scenarios that generate “ambiguity, time pressure, and stress (p. i54).” In their recommendation, they also suggest another constructivist strategy – the use of scaffolding to help learners progress from one level to the next. This technique is credited to Jerome Brunner (Woolfolk, 2004). Scaffolding involves the teacher or facilitator (or as Beaubien and Baker suggested, an experienced clinician) being involved in the scenario to offer support to the less experienced learners. This support is not directive. The aim with scaffolding is to guide the learner towards the correct response, allowing the learner to make the discoveries. Kneebone (2005) pointed out the problem of providing too much feedback during scaffolding. As Kneebone described, once the learner reaches a level where performance is internalized, additional feedback may become counterproductive.

Kneebone, Scott, Darzi, and Horrocks (2004) discussed Vygotsky’s zone of proximal development and scaffolding. They saw the zone of proximal development (ZPD) as being a particularly well-suited concept for task-based simulation. According to Kneebone, Scott, Darzi, and Horrocks, many elements of the ZPD are present in simulation-based training: the ability to work individually or in a small group or team, the presence of an expert resource in the form of the facilitator or other more experienced and knowledgeable team members, a nurturing and positive leaning environment, instructor support adjusted to the level of expertise of the student, and guided feedback

Another key point of constructivism is that it forces the ownership of learning onto the learner (Woolfolk, 2004). While the teacher still plays a vital role in the education process, the

learner plays a more active part as he or she is the only one who can relate his or her own unique personal knowledge history into the current situation.

The role of the teacher in simulation has some difficulties, or at least potential problems that must be addressed. Kneebone, Scott, Darzi, and Horrocks (2004) stated, "Each person's learning trajectory is unique. Past experience, natural aptitude, motivation, and many other variables combine with contextual barriers and triggers to create a shifting pattern of process and progress in learning (p. 1099)." Burnard (1987) pointed out two problems. First, every learner brings a unique personal experience into the simulation. It is not possible for the teacher to know this experience. Therefore, some actions that may seem logical on the part of the learner based on that personal experience may not be appreciated by the teacher. Second, with each person in the simulation (both learners and teachers) having his or her own personal experience, some form of consensus reality must be shaped in order to apply the new knowledge. Burnard mentions the problem of "multiple realities" that must be fused together to make a meaningful learning experience for all involved.

Peters (2000) explained this further, stating, "In essence, constructivist teaching is mediation. A constructivist teacher works as the interface between curriculum and student to bring the two together in a way that is meaningful to the learner (p. 167)." He continued:

The idea that students discover and construct meaning from their environment suggests a rethinking about how they could teach. A constructivist teacher is one who designs learning experiences that are active, where the learners are "doing," reflecting on and evaluating their learning experiences, and building on previous learning experiences to construct new knowledge and meaning (p. 167-168)

Experiential Learning and Reflective Thought

Beaubien and Baker (2004) commented, "There is an old saying that 'practice makes perfect'. In reality, practice makes behavior more or less permanent. Perfection can only be achieved through practice with feedback (p. i55)." Through practice (simulation) and feedback

(debriefing) learners have the best opportunity for reaching that perfection. One educational theory that embraces this concept (or at least has been embraced by the simulation community) is experiential learning theory.

Experiential learning is a frequently mentioned subject in both the medical and general simulation literature (D. Alverson et al., 2005; D. C. Alverson et al., 2004; Cleave-Hogg & Morgan, 2002; Fallacaro, 2000; J. A. Gordon et al., 2004; Hanna & Fins, 2006; Kneebone, 2003; Kneebone & ApSimon, 2001; Leigh & Spindler, 2004; Makoul, 2006; McMahon et al., 2005; Morgan et al., 2006; Morgan et al., 2002; Watterson et al., 2000; Wilson, Shepherd, Kelly, & Pitzner, 2005). The basis for much thought on why experiential learning in patient simulation is a viable educational tool can be related to John Dewey. As Hammond (2004) summarized from Dewey's 1938 book *Experience and Education*, Dewey "outlined four key concepts of learning: experience, democracy, continuity, and interaction. His premise was that education took place through interplay between objective and internal conditions, and that 'all genuine education comes through experience.' Expertise can only be gained by sustained practice over a period of time (p. 235)."

Hyttén (2000) noted, "Dewey's attitude toward education...is an experiential one. As a pragmatist, he wants us to test out our ideas in practice, so that we can see their consequences in action and modify them in order to bring about better results (p. 459)." She also discussed Dewey's Laboratory School as a place where teachers could experiment with new ideas and see concepts put into practice. While real teaching with real students took place in Dewey's school, one could say the Laboratory School was a highly complex full-environment simulator.

Burnard (1987) discussed three domains of knowledge: propositional knowledge, practical knowledge, and experiential knowledge. While each domain can remain isolated, knowledge is enhanced when there is overlap between the domains and is most effective when all three domains overlap. Propositional knowledge is facts, theories, and models – what Burnard describes as "textbook" knowledge. Practical knowledge is knowledge in action; it is

knowing how to do something, whether it is a psychomotor skills or a mental process (such as conducting a patient interview). Experiential knowledge requires a greater personal relationship with the material to be known. Experiential knowledge adds another dimension to the material or subject that makes for a more complete knowledge. Translating Burnard's thoughts into the simulation arena, experiential knowledge would be related to the metacognitive abilities of the students. It also requires reflection in order to build on the experience. Burnard referred to the works of Pablo Freire and the concept of praxis. As defined by Freire, praxis is "reflection and action upon the world in order to transform it (Freire, 2003, p. 51)." This concept of reflection as a means of improving performance is a oft repeated item in the simulation literature (Bond et al., 2004; Dannefer & Henson, 2004; Flanagan et al., 2004; J. A. Gordon et al., 2004; Kneebone et al., 2002; McMahon et al., 2005; S. W. Roberts & McCowan, 2004; Watterson et al., 2000).

The concept of reflection on experience as a means of improving knowledge and performance is not a new concept to education in general. John Dewey made these observations about experience and reflection in 1916:

When we experience something we act upon it, we do something with it; then we suffer or undergo the consequences. We do something to the thing and then it does something to us in return; such is the peculiar combination. The connection of these two phases of experience measures the fruitfulness or value of the experience. Mere activity does not constitute experience...Experience as trying involves change, but change is meaningless transition unless it is consciously connected with the return wave of consequences which flow from it. When an activity is continued *into* the undergoing of consequences, when the change made by action is reflected back into change made in us, the mere flux is loaded with significance. We learn something. (Dewey, 1916, p. 139)

Experiential learning is more than just "learning by doing." To meet the modern definition of experiential learning, some action must take place after the experience to create a more

integrated meaning for the knowledge gained from the experience. J. Roberts (2002)

commented:

We must move beyond mere “learning by doing” for our fields’ philosophical underpinnings and practical approaches to become more influential in mainstream education. Using only the learning by doing definition, experiential education becomes nothing more than activities and events with little to no significance beyond the initial experience...This was not John Dewey’s vision and it cannot be our lasting legacy (p. 264)

Dewey (1916) saw a significant difference between trial-and-error experience and the use of reflective thought:

No experience having a meaning is possible without some element of thought. But we may contrast two types of experience according to the proportion of reflection found in them. All our experiences have a phase of “cut and try” in them – what psychologists call the method of trial and error. We simply do something, and when it fails, we do something else, and keep on trying till we hit upon something that works, and then we adopt that method as a rule of thumb measure in subsequent procedure...We see *that* a certain way of acting and a certain consequence are connected, but we do not see how they are...In other cases we push our observation farther. We analyze to see just what lies between so as to bind together cause and effect, activity and consequence. This extension of our insight makes foresight more accurate and comprehensive. (p. 145)

Without reflection simulation becomes simply a behavioristic response, or, as Dewey stated, trial and error learning. It is this practice of connecting cause and effect that makes simulation with a subsequent debriefing an effective learning method.

Experiential learning has many connections with constructivism (Quay, 2003). One concept that demonstrated this is the idea that traditional roles in the learning dyad (teacher and student) change substantially. Leigh and Spindler (2004) made this observation:

Traditional approaches position the educator in control of learning with final authority over content and learning processes...In contrast, experiential learning positions the educator in a supportive role and locates the learner at the center of the process. From this position, the educator helps identify opportunities for learning, engages the learner in dialogue with these, and relinquishes authority to direct the learning process....These two positions – traditional teaching and experiential facilitation – require quite different, and at times contradictory, skills and processes. (p. 53)

Of all the experiential education models presented, it is the work of David Kolb that has clearly taken center stage in the simulation literature. Kolb is mentioned often in the simulation literature (Cleave-Hogg & Morgan, 2002; Flanagan et al., 2004; Maudsley & Strivens, 2000). Kolb cited several theorists and educators as his primary influence in creating experiential learning theory (ELT). These primary influences included John Dewey, Kurt Lewin, and Jean Piaget. He credits secondary influences to Carl Jung, Erik Erikson, Carl Rogers, Abraham Maslow, and the gestalt theorists including Fritz Perls (D. A. Kolb, 1983).

Kolb's model lends itself well to simulation. As Cleave-Hogg and Morgan (2002) stated, "Kolb and others maintain that professional education can be improved if students are challenged by active engagement in the learning process that replicates real situations as closely as possible (p. 23)." This recommendation is made to order for patient simulation.

Kolb defined learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience (D. A. Kolb, 1983, p. 41)." Kolb's ELT is frequently represented as a learning cycle with four stages: Concrete experience, observation and reflection, formation of abstract concepts and generalizations, and testing implications of concepts in new situations. However, Kolb (D. A. Kolb, 1983) stated this learning cycle is actually credited to Lewin (see Figure 1). Kolb used Lewin's experiential learning model as a base to build his ELT model (see Figure 2).

Figure 1. A representation of Lewinian experiential learning model (adapted from Kolb, 1983)

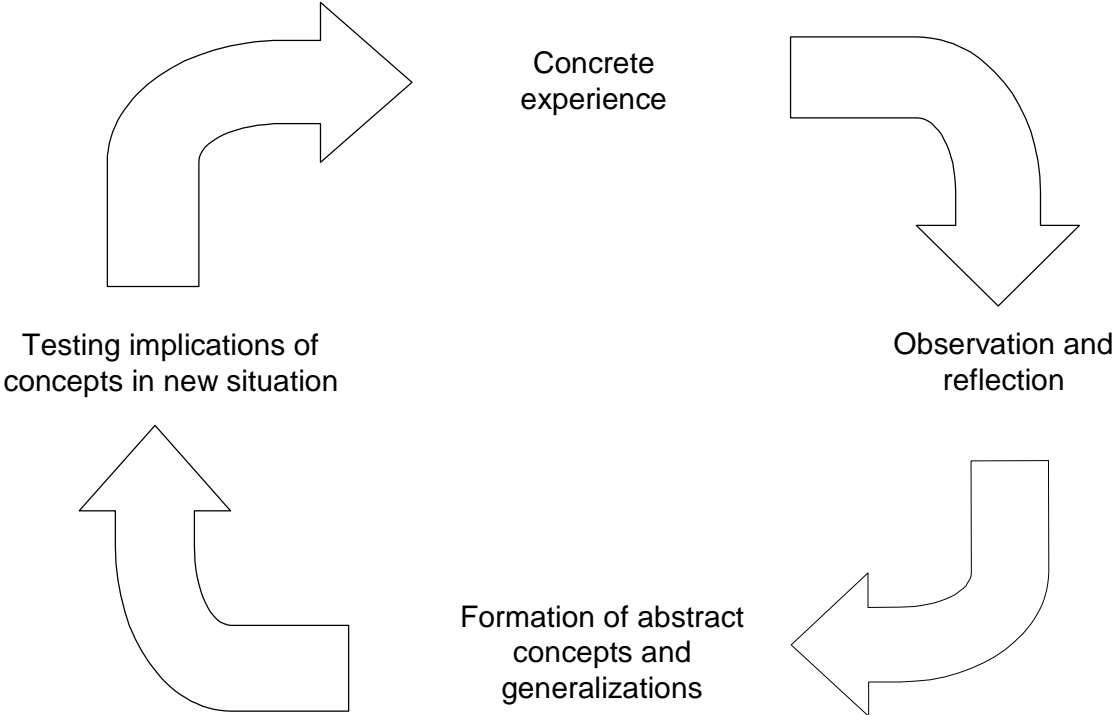
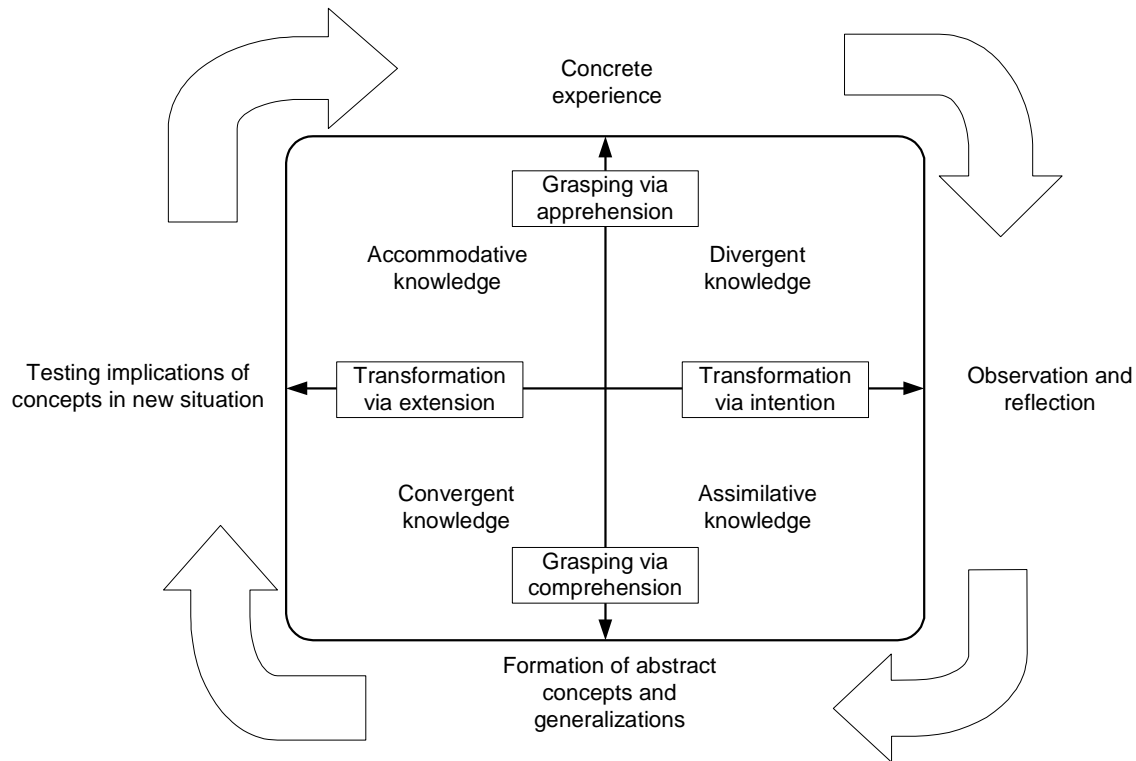


Figure 2. A representation of Kolb's experiential learning model structural dimensions overlaid on Lewinian experiential learning model (adapted from Kolb, 1983)



Lewin's model contains the key features that are most commonly referred to in the simulation literature. Lewin's model is primarily a feedback loop where the learner undergoes a concrete experience (the simulation) and then receives feedback (either in the form of simulator response to interventions or through a reflective debriefing process). As Kolb noted, "This information feedback provides the basis for a continuous process of goal-directed action and evaluation of the consequences of that action (p. 22)." Within this model, learning becomes a process rather than an outcome.

Kolb added additional dimensions to Lewin's model. Kolb bisected Lewin's model with two additional lines. First was a line depicting the "grasping" of knowledge either through apprehension (concrete experience) or through comprehension (abstract conceptualization).

Second was a line depicting the “transformation” of knowledge through intention (reflective observation) or through extension (active experimentation).

Grasping via apprehension means being aware of the experience without much thought. It is simply a matter of experiencing the experience. Grasping via comprehension means being cognitively aware of the experience. Transformation via intention is an integrative step between apprehension and comprehension where the learner internalizes the experience and makes attributions that lead to an understanding of the implications of the experience. Transformation via extension externalizes the understanding so that it can be applied in new situations.

Once separated into quadrants, Kolb inserted four learning styles: divergent, assimilative, convergent, and accommodative. Kolb summarized these learning styles (D. A. Kolb, 1983):

- The *convergent* learning style relies primarily on the dominant learning abilities of abstract conceptualization and active experimentation. The greatest strength of this approach lies in problem solving, decision making, and the practical application of idea.
- The *divergent* learning style has the opposite learning strengths from convergence, emphasizing concrete experience and reflective observation. The greatest strength of this orientation lies in imaginative ability and awareness of meaning and value.
- In *assimilation*, the dominant learning abilities are abstract conceptualization and reflective observation. The greatest strength of this orientation lies in inductive reasoning and the ability to create theoretical models.
- The *accommodative* learning style has the opposite strengths from assimilation, emphasizing concrete experience and active experimentation. The greatest strength of this orientation lies in doing things, in carrying out plans and tasks, and getting involved in new experiences. (p. 77-78)

Kolb and colleagues used this model to develop a learning style inventory assessment to identify individual learning styles (A. Kolb & Kolb, 2005).

Kolb's primary influence on simulation has been through his presentation and modification of Lewin's learning cycle model and the detailed background in the roots of experiential learning that he provided in *Experiential Learning: Experience as the Source of Learning and Development* (D. A. Kolb, 1983). Experiential learning using the models presented by Kolb lends itself well to patient simulation.

Adult Learning Theory

Healthcare provider students are adults. As such, adult learning theory plays an important role in patient simulation and is mentioned often in the simulation literature (Cavanagh, 1990; Feingold et al., 2004; Greenberg et al., 2002; Kneebone, 2002; Maudsley & Strivens, 2000; Yaeger et al., 2004).

Malcolm Knowles is often associated with adult learning theory. However, as Knowles himself described, the lineage of adult learning theory predates his contributions (Knowles, Holton, & Swanson, 1998). The basic tenets of adult education can be traced back to John Dewey. Dewey's influence on adult education is significant because of his association with a contemporary at Columbia University – Eduard Lindemann. Lindemann based many of his thoughts on adult education on principles promoted by Dewey. Dewey and Lindemann shared a common philosophy toward education. Lindemann took many of Dewey's ideas and adapted them to the adult learning. Additionally, Lindeman took concepts and practices from his native Denmark (such as study circles) and incorporated them into his learning theory.

Knowles credits Lindemann as a major influence in the development adult learning theory. Much of Knowles work can trace its origins to Lindemann. Knowles (Knowles et al., 1998) cited several passages from Lindemann's 1926 work *The Meaning of Adult Education*:

- The resource of highest value in adult education is the learner's experience. If education is life, then life is also education. Too much learning consists of

vicarious substitutions of someone else's experience and knowledge...Experience is the adult learner's living textbook. (p. 37)

- Authoritative teaching, examinations which preclude original thinking, rigid pedagogical formulae – all these have no place in adult education...Small groups of aspiring adults who desire to keep their minds fresh and vigorous, who begin to learn by confronting pertinent situations, who dig down into the reservoirs of their experience before resorting to texts and secondary facts, who are led in the discussion by teachers who are also searchers after wisdom and not oracles; this constitutes the setting for adult education. (p. 37-38)

Heavily influenced by the work of Lindemann, Knowles developed the concept of andragogy as being the science of teaching adults. In his andragogical model, Knowles highlighted six assumptions that made andragogy different from pedagogy. Each principle can be demonstrated in patient simulation education (Knowles et al., 1998).

Adults have an intrinsic need to know – Adults need to know why they need to know something. In patient simulation, one of the roles of the facilitator is to set the stage for learning. The realism of high-fidelity manikin-based patient simulation helps establish a need to know as it presents knowledge in context. Learners quickly find out what they do not know in highly complex high-fidelity simulations. Knowles observed, “Even more potent tools for raising the level of awareness of the need to know are real or simulated experiences in which the learners discover for themselves the gaps between where they are now and where they want to be (Knowles et al., 1998, p. 65).”

Adults have self-responsibility – There is a desire among adult learners to demonstrate that they are self-responsible and self-directed. Simulation puts control of the learning process into the hands of the learner as each learner actively participates in the learning process. Knowles stated learners must make “the transition from dependent to self-directed learners (Knowles et al., 1998, p. 65).” The self-directed nature of patient simulation is a common

reference in the simulation literature (Issenberg, McGaghie et al., 1999; Kneebone, 2002; Kneebone & ApSimon, 2001)

Adults have a lifetime of experiences – Life experiences differ greatly in quantity and quality for the adult learner. As a result, adults will be a heterogeneous group and will require a higher degree of individualization. Adult learners can often be their own resources because of their experiences. Sometimes their experience is good; sometimes it is not. Facilitators of patient simulation must be aware of the unique personal knowledge their learners bring with them and be ready to reinforce or discourage behaviors as appropriate.

Adults have an innate readiness to learn – Once a situation is presented in which the adult learner realizes they need more knowledge; there is a readiness to learn. The key is to not present information until that learner has the need for the information. Simulation allows for events to unfold naturally and creates the situation where the learner must respond. Also, in simulation, the learner can be presented with challenges that are not possible in real life. In scenarios such as this, the learner is ready to move from one developmental stage to the next. It is here in Vygotsky's zone of proximal development where facilitator techniques such as scaffolding can be employed to take advantage of the learner's desire to move to the next level. Again, simulation comes up as a topic with Knowles, as he said, "There are ways to induce readiness through exposure to models of superior performance, career counseling, simulation exercises, and other techniques (Knowles et al., 1998, p. 67)

Adults have a life-centered orientation to learning – Learning must show a relevance to every-day life. It cannot be subject-centered (as it often is in pedagogy). Problems must have real world application. Simulation encourages bringing real problems to the learning environment. Feingold, Calaluce, and Kallen (2004) cited Knowles as an influence in stating, "clinical simulation...relates to real clinical problems (p. 157)." Halamek et al (2000) wrote the most successful simulations reflect real-life events.

Adults have internal motivators – Adults are more responsive to internal motivators rather than extrinsic factors. A goal of adult education is to remove barriers that threaten internal motivators. One barrier that is mentioned in the patient simulation literature is the idea of a safe debriefing environment that does not threaten the learner. Typically referred to in the literature as a nonjudgmental debriefing, there have recently been alternate approaches proposed that allow facilitators to bring errors to the surface in discussion while still maintaining a positive learning environment for the participants (Rudolph, Simon, Dufresne, & Raemer, 2006).

As Knowles developed his theory, he drew upon other forms of education theory, namely constructivist and humanistic theories. According to Peters (2000), adult learning theory and constructivist thought share many common points, and have, as he describes, a “natural affinity.” As he stated, quoting Candy (1989):

The link between the two appears to be one of symbiosis. Indeed, Candy stated that “constructivism is particularly congruent with the notion of self-direction in emphasizing active enquiry, independence in the learning task, and individuality in constructing meaning”...the implicit links between adult learning and constructivism indicate that constructivism may have an important role to play in adult education and research. (168)

The Novice to Expert Continuum

“Novices develop into experts by incrementally acquiring skills that depend on accruing experience,” stated Maudsley and Strivens (2000, p. 539). As they further described, there is an ever changing set of rules that govern performance with these rules changing as experience is gained. Cavanagh (1990) summarized the work of Benner (1984) in explaining the novice to expert continuum as it related to nursing. Novices function with a set of rules that are context-free. Most of their knowledge is, as Burnard (1987) described, propositional or textbook knowledge. When presented with new situations, novices tend to be restricted in their behavior, creating both “limited and inflexible” responses (Burnard, 1987, p. 43). Experts on the other

hand, have more context and are less bound by rules. There is a higher degree of perceptual awareness of the situation, what Cavanagh calls a “gestalt” where the whole of the situation is more easily perceived and individual actions are initiated from deducing what is needed from examining the whole. Simulation lends itself well to defining where individual healthcare providers are on the novice to expert continuum. With its replication capability, simulation can be used as a measuring stick for defining where each provider stacks up in comparison to others or can track one learner’s progress over time.

High-fidelity manikin-based patient simulation has been used extensively in testing of students’ ability to meet learning objectives. Devitt, Kurrek, Cohen, and Cleave- Hogg (2001) demonstrated the construct validity of using patient simulation as an evaluation tool. In their study, they reviewed the ability of a group of 142 physicians and students with a wide range of experience (from practicing anesthesiologist to final-year medical students) in their ability to manage a simulated anesthesia case. Their scoring mechanism was able to discriminate between expert and novice user. This approach has been used in several other patient simulation studies to gauge novice versus expert performance (DeAnda & Gaba, 1991; Delson, Koussa, Hastings, & Weinger, 2003; Gisoni et al., 2004; Larew et al., 2006; Moorthy et al., 2003; Morgan & Cleave-Hogg, 2002; Pittini et al., 2002; Pugh, 2001)

While Benner is frequently cited in the healthcare simulation literature, especially in regards to nursing simulation (Benner, 1984; Detty Oswaks, 2002; Larew et al., 2006; C. Martin, 2002), Benner’s work is based on the model first proposed by Dreyfus and Dreyfus (H. L. Dreyfus & Dreyfus, 1986; S. E. Dreyfus & Dreyfus, 1980). The Dreyfus model of skill acquisition contains five levels:

- Stage 1 – Novice: At this stage facts and skills are understood only in a context free manner. The learner may know how to put an oxygen mask on a patient, but does not fully understand the reasons for doing so.

- Stage 2 – Advanced beginner: The learner at this level begins to become situationally aware and see how facts and skills learned earlier may be adopted in certain situations, The rules for this integration are rather simplistic and complex problems are not yet able to be solved. In a simulation example, the learner may now know that the patient is having respiratory distress and requires oxygen, but fails to understand the complicating factors that affect the oxygen delivery such as the presence of chronic obstructive pulmonary disease.
- Stage 3 – Competence: Through experience, a hierarchical process of decision-making is developed. Prioritization is possible. In the medical simulation this would be seen during the assessment of a trauma victim as the practitioner may quickly move past a seemingly spectacular injury that is superficial to treat a less noticeable, but life threatening condition.
- Stage 4 – Proficiency: Up to this point, decision-making is primarily rule-based. At this level, intuition develops and the practitioner begins to anticipate. Rules still play an important part for the proficient provider, but they are modified based on experience.
- Stage 5 – Expertise: Conscious thought about actions disappears. The expert practitioner simply does what is needed, able to unconsciously appraise the situation and make intuitive actions without regard for thinking through rules. As Dreyfus and Dreyfus (1986) stated, “An expert generally knows what to do based on mature and practiced understanding (p. 30).”

In their original report, Dreyfus and Dreyfus (1980) also referred to a mastery level in which the expert performer goes beyond mere expert performance. They stated,

The expert is capable of experiencing moments of intense absorption in his work, during which his performance transcends even its usual high level...we note that this masterful

performance only takes place when the expert, who no longer needs principles, can cease to pay conscious attention to his performance and can let all the mental energy previously used in monitoring his performance go into producing almost instantaneously the appropriate perspective and its associated action. (p. 14)

In Schon's (1983) description, this is the point of professional artistry.

As summarized by King and Appleton (1997), intuition was a significant factor that distinguished expert nurses from novice and advanced beginner nurses, although some levels of intuition were present in all levels of skill acquisition. With intuition, healthcare practitioners are able to move beyond simple problem identification and grasp a larger sense of the situation, much in the same manner as Cavanagh's (1990) gestalt. King and Appleton stated, "It must be recognized that intuition occurs in response to knowledge, is a trigger for nursing action and/or reflection and thus has a direct bearing on analytical processes in patient/client care (1997, p. 201)." They also surmised that healthcare education uses a predominantly linear approach to care with very little educational effort focused on using intuition in decision-making. High-fidelity, full-environment simulation could be a remedy for this deficit as it allows for an immersive experience that tests more than just knowledge and clinical skills.

Some authors have noted there is a predictable element present in the ability to identify expert performers – deliberate practice (Issenberg et al., 2002; Issenberg, McGaghie et al., 1999; Kneebone, 1999, 2005; Kneebone & ApSimon, 2001; Wayne et al., 2006). Using sports as an analogy, Issenberg, McGaghie, et al (1999) made these comments concerning deliberate practice:

The most important identifiable factor separating the elite performer from others is the amount of "deliberate practice." This includes practice undertaken over a long period of time to attain excellence as well as the amount of ongoing effort required to maintain it. Deliberate practice has been defined as the opportunity to tackle "a well-defined task

with appropriate difficulty level for the particular individual, informative feedback, and opportunities for repetition and correction of errors.” (p. 862)

Kneebone (2005) elaborated further, “Practice should therefore focus on a well-defined area, be supported by detailed immediate feedback, and provide opportunities for gradual improvement of the same or similar tasks (p. 550).”

As Dreyfus and Dreyfus (1986) stated, just because a person achieves a certain level of expertise does not mean he or she will automatically maintain that level: “Practice is required for maintaining know-how. It can be lost through inactivity (p. 17).” For this reason simulation offers an excellent tool for not only teaching and perfecting new skills but also for maintaining skills. This is especially true for healthcare providers who may have achieved expertise but now are working in areas where practicing what they were expert in is reduced. For example, an anesthesiologist may have become expert at managing a patient with malignant hyperthermia. But, owing to the reduced frequency of seeing this crisis event due to improved anesthesia medications and monitoring, has not had the opportunity to practice the skills needed to quickly respond to this emergent event. When presented with this case, the anesthesiologist may revert back to rule-based decision making rather than the intuitive thought process that guided his or her earlier expertise.

Brain-Based Learning

One of the more recent lines of thought in education theory has been the development of brain-based learning (Caine & Caine, 1991; Jenson, 1996). However, the healthcare simulation literature has not explored this area well despite its potential to impact simulation-based education learning theory. Only one study was identified in this literature search that referenced brain-based learning principles in medical simulation education (Wortock, 2002).

Two of the most prominent researchers in brain-based learning are Renate and Geoffrey Caine. They presented three essential elements for learning and 12 principles for brain/mind learning. The three essential elements are:

- Relaxed alertness – Defined as a state of low threat and high challenge, having the learner in this state creates the ideal emotional state for learning. The learner feels competent, confident, interested, and motivated. The learning environment should not be intimidating or fear producing. Based on the work of MacLean (1973, 1978) in introducing the concept of the triune brain, Caine and Caine pointed out when fear is present in learning there is interference in long-term memory encoding, making lasting learning difficult. Jenson (1996) also stated that when challenge is present, the mind is more engaged and receptive to learning, but when a threat to self is perceived, learning is inhibited. Hart (1983) referred to this as *downshifting*.
- Orchestrated immersion in complex experiences – The teacher creates an immersive learning environment that involves as many learner senses as possible. New experiences are related to old experiences (much in the same manner as in constructivism). This element requires knowledge to go beyond just knowing. Something must be done with the knowledge so the learner can “own” that knowledge. This element also instills a questioning and decision pathway in the learning as the learner explores the new knowledge and becomes an active integrator of the new knowledge.
- Active processing of experience – Performance is self-assessed in the midst of the experience as the learner actively engages the teacher, other learners and utilizes feedback to analyze the situation and make decisions based on how new information is integrated into his or her existing knowledge.

Caine and Caine (1990, 1991, 2006) also presented 12 principles that can be transitioned into the simulation learning environment:

1. All learning engages the entire physiology: Learning involves more than just the brain. The entire person – both in body and mind – is involved in the learning process. Factors such as stress and nutrition will impact an individual’s ability to

- learn. The implications of this in simulation are providing an immersive environment and low stress learning in which the fear of failure is removed. Facilitators should provide a supportive learning environment that engages more than just the brain, but rather includes opportunities for involvement of the whole person and on his or her senses.
2. The brain/mind is social: Humans have a natural urge for social contact. Learning is more effective when learners are engaged in processes that permit relationships that allow them to be recognized and have their contributions acknowledged. The simulation-based CRM training emphasizes social structure and communications.
 3. The search for meaning is innate: There is a balance between the learner working with the familiar and searching for new knowledge and can be described as a survival mechanism. In simulation, providing learning in a contextual basis in which the learner is rooted in a familiar environment will enhance the learner's ability to look for new knowledge.
 4. The search for meaning occurs through patterning: The brain does not learn isolated facts well. There needs to be some logical connection, or pattern, to previously learned knowledge. The learner is actively searching for these connections. Simulation offers the opportunity for the learner to recognize patterns where new knowledge can be integrated with previous knowledge.
 5. Emotions are critical to patterning: Learning is not a purely cognitive function. Emotions play a significant role in encoding and retrieving information. The realism of simulation allows the learner to associate emotions with certain areas of knowledge, such as when the learner in an obstetrics simulation associates the decreased tone of the fetal heart monitor with an emotional need to react.
 6. The brain/mind processes parts and wholes simultaneously: As the learner processes information, he or she is examining information both in parts and in the

- whole simultaneously. As the learner breaks down the skills of a medical procedure (such as endotracheal intubation), the learner must not only examine each part of the skill, but also keep the end result in focus (in the case of endotracheal intubation, patient ventilation).
7. Learning involves both focused attention and peripheral perception: While focus may be on an individual skill, attention is still be directed to the big picture view of the situation. Simulation provides the opportunity for practice of individual skills while creating a need for monitoring the overall patient condition.
 8. Learning is both conscious and unconscious: As individuals learn, they are receiving both overt knowledge and covert knowledge. In overt knowledge, the content of the lesson is managed and transmitted. In covert knowledge, an underlying message is being generated about this knowledge. Covert knowledge may be intentional on the part of the teacher or may be an unintended consequence. In simulation, presenting information in a positive manner that manages the covert message is important in instilling the appropriate response in the learner. For instance, a vitally important skill must be presented in a manner that conveys that importance to the learner. If the teacher presents it in a nonchalant manner, the learner may encode this information as not being important even if the teacher says it is.
 9. There are at least two approaches to memory: There are two sets of memory systems. The spatial memory system and a set of systems for rote learning. In spatial memory, recall just happens. Learners do not have to think about what a tree is; they just know it. Recall is automatic and is improved by novelty. Facts and skills that represent isolated ideas and concepts are not processed through by the spatial memory system. These concepts require some degree of organization to create retrieval systems. Simulation plays a role in this by supplying practice in context to help train the brain to retrieve information needed for the clinical scenario.

10. Learning is developmental: All learners do not progress at the same rate. There are individual differences in which each person falls in a novice to expert continuum. Education programs must recognize this and avoid categorizing all learners in the same group. Simulation can be used as a means to discriminate where learners fall on the novice to expert continuum and if the simulation is scalable in its objectives, the simulation can be adjusted to accommodate the appropriate level for each individual learner.
11. Complex learning is enhanced by challenge and inhibited by threat associated with helplessness and fatigue: When fear – including fear of failure – is present, the brain downshifts into a more primitive function and encoding into long term memory becomes problematic. While some stressors in a realistic simulation session are beneficial and help with encoding, fear is a complicating factor. That is one reason why debriefing sessions are done in a non-punitive manner, so individual learners do not fear being criticized, ridiculed, or embarrassed at the conclusion of the simulation.
12. Each brain is uniquely organized: While constructivism establishes that each person has a unique experience, Caine and Caine stated that each learner also has a unique system for learning. Individual learning styles must be addressed whether it is a relatively simplistic approach such as the VAK learning style set (visual, auditory, kinesthetic) or more complex learning styles sets such as Gardner’s multiple intelligences (Gardner, 1983). Simulation invokes a variety of senses as it presents material and as such, it offers multiple ways for the learner to access information.

Complexity is an underlying issue in Caine and Caine’s work. They stated, “Brain research establishes and confirms that multiple complex and concrete experiences are essential for meaningful learning and teaching (Caine & Caine, 1991, p. 5).” As they further explained, “content is inseparable from context (p. 5).” In simulation this has great impact as all learning is

contextual. Immersion (a word Caine and Caine use) is one means of engrossing the learner in the experience. Simulation is an immersive strategy, especially in full-environment simulations.

Social Cognitive Theory

First presented as social learning theory by Albert Bandura, social cognitive theory expands on the behavioristic model of learning (Woolfolk, 2004). Several components of social cognitive theory have relevance with patient simulation. First is the concept of enactive learning. Different from the simple stimulus and response mechanism of behaviorism, enactive learning proposes that each consequence has a deeper role in learning as the consequence should provide information that will be used by the learner in subsequent actions. Second is the concept of vicarious learning by which people learn through observation. Through both participation and debriefing in patient simulation scenarios, all team members have the ability to watch and analyze the performance of other team members. Gaba (2004b) mentioned this aspect in his review of the dimensions of simulation. In a related concept, vicarious reinforcement is another means by which team members can learn by watching other team members be rewarded for their successes. Practice is a vital factor in social cognitive theory. Practice can be mental rehearsals (in itself a form of simulation) or actual hands-on practice. Through practice, combined with feedback and coaching, performance can be improved.

Motivation

“Motivation is the natural human capacity to direct energy in the pursuit of a goal,” according to Wlodkowski (1999, p. 7-8). Motivation is a critical component in teaching. Without it, maintaining attention and interest is difficult (Woolfolk, 2004). Motivation can be intrinsic or extrinsic. Intrinsic motivation is the internal driver that pushes learners to accomplish goals and objectives. Extrinsic motivation is the external influences such as good grades for students or increased pay for practicing clinicians.

Motivation is a complex concept and has been addressed by other authors in detail in the general education literature (Theall, 1999; Woolfolk, 2004). In the medical simulation

literature, motivation has been seen as a key topic and is discussed in several studies (Feingold et al., 2004; J. A. Gordon et al., 2001; Kneebone, 2005; Ravert, 2004)

In general, the medical simulation literature sees high-fidelity simulation as a motivating factor for learners to not only learn more in the session they are currently enrolled, but as a motivating factor for learning more once the course is complete. Through qualitative surveys of students' response to simulation, Cleave-Hogg and Morgan (2002) demonstrated a motivating factor in their study. One student commented, "I learned to integrate various pieces of knowledge into a very realistic scenario. It encouraged me to study and learn more about other scenarios (p. 25)."

While the bulk of the motivation literature concentrates on differentiating between intrinsic and extrinsic motivation, motivation can be represented in another way. Trait and state motivation are terms to describe the focus of the motivation. State motivation – as defined by Rubin, Palmgreen, and Sypher (1994) – is a "temporary condition in which individuals direct high levels of concentration toward the competent completion of a task (p. 343)." They continue, "Whereas trait motivation can be defined as a relatively enduring predisposition towards school or learning, state motivation refers to students' attitudes towards a particular class or subject (p. 343)."

Simulation offers several ways to enhance motivation at all levels. One area is through practice and the ability to achieve success or mastery through the support of teachers or facilitators. Kneebone (2005) suggested that through practice, motivation would be enhanced:

Perhaps, most important of all, is motivation. Simple repetition of a task is not enough, but must be underpinned by a determination to improve. Such a determination underpins the continual striving toward improvement that is a sine qua non for achieving expertise. (p. 550)

J. A. Gordon, Wilkerson, Shaffer, and Armstrong (2001), commented, “[The medical students] felt that the experience promoted critical thinking and active learning, and that it allowed them to build confidence and practice skills in a supportive environment (p. 472).”

The active role the learner plays in the learning process with simulation also contributes to motivation. Feingold, Calaluce, and Kallen (2004) wrote, “As a teaching strategy, simulated clinical experiences are consistent with adult learning theory. Data indicate that active learning increases motivation and interest in learning (p. 161).” Ravert (2004) had similar conclusion. The simulation-based education group in Ravert’s study indicated a greater degree of motivation to learn more. “The HPS [Human Patient Simulator] group was more enthused about learning and expressed a desire for further sessions. The HPS group said ‘learning by doing’ was helpful and felt more confident in caring for patients (p. iv & v).”

Another area where simulation provides an influence on motivation is in the practice of learning in context. J. MacDonald (1999) pointed out that each discipline has its own learning climate that relates to how it meets its objectives. For some disciplines, that climate may primarily involve cognitive exercises and a traditional classroom format may be well suited to the needs of the learners in performing in the climate. However in healthcare, the eventual climate is at the patient’s side. Simulation provides learning in context that allows learners to attribute more significant meaning to what is being learned. By seeing knowledge in action, motivation may be enhanced.

There are several theories behind motivation. As demonstrated in this literature review, cognitive and constructivist theories dominate the literature in medical simulation. As opposed to the behaviorist point of view for motivation that is primarily extrinsically driven, cognitive theory approaches suggest there is a greater degree of intrinsic motivation. Two approaches to motivation that fall in with the cognitive viewpoint are attribution theory and expectancy value theory. In attribution theory there are three dimensions that contribute to success or failure (Woolfolk, 2004). Locus determines if the cause is internal or external to the learner. Stability

determines if the cause is stable or can change over time. Controllability is whether the learner has command over the cause. How these dimensions are influenced in simulation-based education is critical to their impact on motivation. Simulation places a significant amount of control of the learning process in the hands of the learner as he or she explores the simulation environment. Through the debriefing process, deficits in knowledge and performance can be identified and corrected in a supportive and nonjudgmental manner. Learners can be placed into the same simulation again and see that improvement is possible.

Expectancy value theory combines the behavioristic viewpoint of reward or expectation with the cognitivist viewpoint of internal valuing (Woolfolk, 2004). For the best potential for motivation, a learner needs to have an expectation for success and that expectation must have a high value (Paulson & Feldman, 1999). There are a variety of motivators in healthcare education. Some are external such as promotions, increases in pay, and decreases in malpractice insurance for practicing healthcare providers. For healthcare students, motivators can be grades or improved opportunity for successful job placement. Some are internal such as the innate desire to learn more and become better practitioners so that patient care can be its best. Simulation offers an opportunity to put learning content into practice and an arena for teachers to instill value in the learners' perceptions of the content.

The manner in which knowledge is presented to the learner has the ability to influence several factors including motivation. In a randomized comparison group posttest study of learners using either lecture, video, or interactive multi-media that included screen-based simulations, Rodgers and Withrow-Thornton (2005) found that the interactive multi-media with screen-based simulations enhanced motivation by providing higher levels of learner attention, relevance, confidence, and satisfaction with the course material. Built on the ARCS model of motivation (Keller, 1987a, 1987b, 1999), the interactivity present in the screen-based interplay between learner and content provided multiple opportunities for learners to build on successes

with the interactions and required a continued contact with the material. Manikin-based simulation offers this same opportunity.

Simulation in team-based training offers additional opportunities for improving motivation. Team-based simulation allows cooperative learning to take place as team members share information in a developing simulation scenario. Panitz (1999) reviewed several studies and found that cooperative learning leads to high degrees of motivation in learners as team members work together to achieve goals. This also results in higher degrees of individual learner self-esteem and satisfaction with the learning experience. When cooperative learning is promoted in teams, higher order thinking skills are developed. And, because cooperative learning requires active participation, learning is enhanced as the learners become engrossed in the content. Simulation-based team learning engenders all these possibilities.

Affective Domain

Bloom (Bloom, Engelhart, Frost, Hill, & Krathwohl, 1956; Krathwohl, Bloom, & Bertram, 1973; Woolfolk, 2004) identified three domains for learning. The cognitive domain involves mental skills and concentrates on knowledge. The psychomotor domain involves manual skills and physical manipulation. The affective domain involves emotions, feelings, and attitudes. In simulation-based education, as with education in general, most work concentrates on the cognitive and psychomotor domain. As demonstrated in this literature review, many simulation-based studies focus on written examinations to test cognitive abilities and expert rater scored practical examinations to test psychomotor abilities. Teaching and testing of the affective domain is not common. As B. L. Martin and Briggs (1986) observed, "What has received relatively little attention by instructional technologist and designers is the development of instruction that incorporates affective goals, objectives, and strategies into educational programs and practices (p. xi)." One of the few courses of instruction that included simulation that specifically targeted the affective domain was conducted by L. M. Jacobs et al (2003); however, this course did not use manikin-based simulation.

Affect in learning deals with the learner's attitudes towards the course material and can be represented in his or her feelings, emotions, and behaviors in how the course knowledge is integrated into the learner's daily life. Affect also has a considerable influence on motivation (Paulson & Feldman, 1999). Affect is described by Rubin, Palmgreen, and Sypher (1994):

Affect is operationalized to include lower-order levels of students' attitudes towards (a) course, (b) subject matter, and (c) instructor, as well as higher-order levels of students' behavioral intentions of, (d) engaging in behaviors taught in the class, and (e) taking additional classes in the subject matter. (p. 81)

B. L. Martin and Briggs (1986) identified several problems explaining why research on the affective domain lags behind the volume of research on the cognitive and psychomotor domains:

...affective behaviors are difficult to conceptualize and evaluate. Because of this, the most effort and time have gone into thinking about, studying, evaluating, and teaching the cognitive aspects of behavior. Cognitive behaviors are easier to specify, operationalize, and measure than are affective behaviors...The affective domain poses a unique set of problems for educators. First, the definition of the domain and the concepts that comprise it are so broad and often unfocused that all aspects of behaviors not clearly cognitive or psychomotor are lumped together in a category called the affective domain...The definitional problem is further compounded when one looks within and between disciplines for clarification. Some psychologists define affect as a psychological or biological state; educators and other psychologists interested in behavior changes define affect as a cognitive type process. (p. 12-13)

As B. L. Martin and Briggs state there are problems with the definition of affect. Beane (1990) concurred with this view, simply stating, "The meaning of affect is still somewhat ambiguous (p. ix)." Still, Beane did offer a definition:

In sum, we may now define affect as an aspect of human thought and behavior that has a number of constitutive elements. It refers to a broad range of dimensions such as emotion, preference, choice, and feeling. These are based on beliefs, aspirations, attitudes, and appreciations regarding what are desired and desirable in personal development and social relationships. Both of these are connected to thinking or cognition...Finally, affect is connected to behavior as both an antecedent and a consequence. Thus it is both a constitutive aspect of learning and an appropriate object of educational efforts. (p. 6)

Woolfolk (2004) described Bloom's original work as a continuum that ranges from a low level of affect to a high level of affect. She listed five points along this continuum:

1. Receiving – The ability of the learner to pay attention to the course matter and respect the role of the teacher and other learners.
2. Responding – The learner provides some sort of response to the course material such as asking questions or participating in course discussions.
3. Valuing – The learner begins to make a commitment to the course material and might follow-up after the course with independent reading or additional courses in the subject.
4. Organization – The learner integrates the knowledge into his or her own value system and places a priority on this knowledge.
5. Characterization by value – The learner has internalized the course content and now actively demonstrates the value of the knowledge in his or her actions.

The broader Emergency Cardiovascular Care literature has identified problems with teaching the affective domain. In recent literature reviews conducted for the 2005 consensus conference for International Liaison Committee on Resuscitation 2005 Consensus on Emergency Cardiovascular Care and CPR Science and Treatment Recommendations, several studies were identified that stated individuals who were trained in performing CPR often fail to

act when presented with an emergency situation ("Worksheet ID - Are people who are trained in CPR willing to perform it? (Chest compression only) (A)," 2005; "Worksheet ID - Are people who are trained in CPR willing to perform it? (Chest compression only) (B)," 2005). While the skills of ACLS are advanced level skills and the responders typically have a duty to act, there are still issues with assuring the affective domain has been addressed effectively.

Simulation offers new opportunities to address issues such as learning in the affective domain that often cannot be adequately dealt with in the clinical environment. Kneebone (2005) stated that the affective domain is often ignored in traditional teaching. Kneebone added that in the clinical setting, learning is a by-product of patient care. In the clinical setting, patient care is the focus. In simulation, the priorities can be reversed with the learner now being the focus of attention. With the control offered by a simulation-based learning experience, simulation has the potential to enhance the affective aspect of patient care.

Kneebone (2003) referred to Bloom's affective domain by stating, "Attitudes relate to how knowledge and skill are combined in the care of patients. This area includes clinical judgment, decision-making, the values of professional behavior and the range of vital but intangible qualities that go to make up the competent clinician (p. 268)." Kneebone sees simulation as a possible solution to improving attitudes, or affect, in healthcare professionals. Through processes such as teamwork training in simulation, attitudes can be changed or refined.

Kneebone, Scott, Darzi, & Horrocks (2004) stated that the simulation learning environment should reflect a positive attitude as a means of increasing the chances of learners being able to develop the appropriate affective attitudes needed in healthcare. They said that past learning experiences – either positive or negative – exert a "powerful influence" on how learners approach a learning situation.

The regulating body for physician residency programs in the United States is the Accreditation Council for Graduate Medical Education (ACGME). The ACGME has a required competency in professionalism and defines this competency by stating:

Residents must demonstrate a commitment to carrying out professional responsibilities, adherence to ethical principles, and sensitivity to a diverse patient population. Residents are expected to:

- demonstrate respect, compassion, and integrity; a responsiveness to the needs of patients and society that supersedes self-interest; accountability to patients, society, and the profession; and a commitment to excellence and on-going professional development
- demonstrate a commitment to ethical principles pertaining to provision or withholding of clinical care, confidentiality of patient information, informed consent, and business practices
- demonstrate sensitivity and responsiveness to patients' culture, age, gender, and disabilities ("ACGME outcome project," 2006)

The professionalism competency contains several affective behaviors and forces a valuing process. Gisondi, Smith-Coggins, Harter, Soltysik, and Yarnold (2004) conducted a one-shot case study of 27 emergency medicine residents enrolled in a course designed to evaluate professionalism. Through the use of simulation scenarios, Gisondi and colleagues were able to test residents' ability to demonstrate compliance with this competency. While this study did not attempt to provide additional education in meeting the competency, demonstrating the ability to evaluate the competency lends credibility to the concept of teaching it, especially with the use of reflective debriefing processes.

Summary

The introduction of high-fidelity manikin-based simulation into the healthcare provider education curriculum represents a significant shift in healthcare provider education. While the use of

simulation in more primitive forms has been found in healthcare education for many years, recent improvements in technology have created highly realistic simulators capable of very high levels of fidelity – to the point that it is often possible to “suspend disbelief” in the learning environment, making the situation appear to be quite real.

There are many drivers currently in place that are pushing the use of simulation in the learning environment. These include:

- The growth of medical knowledge – The ever increasing body of medical knowledge presents new challenges to curriculum planners. Educators must find new ways of accommodating this volume of knowledge in the curriculum.
- Changes in medical education – Calls for increased accountability and outcomes measurement are being voiced in medical, nursing, and allied health education. Education practices and curricula that have been in place for decades must change to meet new demands for improving learner outcomes.
- Patient safety – It is no longer acceptable to use patients as primary learning models for healthcare provider students. Simulation offers a suitable alternative to allow student learning and initial demonstrations of competence to take place in a patient-free environment.
- Realism – Technology has advanced to the point where simulation at relatively high levels of fidelity has become affordable for many healthcare education organizations.
- Patient availability – Improvements in care in the clinical environment have reduced the numbers of many types of patient cases making what were once commonly seen diseases or events much more rare. This has led to a reduced opportunity for students to be exposed to these patient conditions during clinical

training. Simulation can serve as a replacement for many of these conditions and augment the clinical experience.

- Student availability – Increasing learning demands combined with schedule restrictions have limited the availability for many student populations. Simulation offers an opportunity to program a student's learning activity with greater efficiency.
- Standardization and replication – With the pressures for improved learner outcome measurements, simulation offers the capability to create standardization in evaluation by providing consistent replication of patient cases.

While the body of peer-reviewed literature evidence on the efficacy of high-fidelity manikin-based simulation is still relatively young, what has been reported has demonstrated that simulation is a viable learning strategy in healthcare provider education. However, much of this data is limited to knowledge and skill acquisition in the learning environment. There is still relatively very little data available on how well manikin-based simulation learning transfers to the clinical environment. Still, based on research showing the ability of students to meet learning objectives with higher degrees of success with manikin-based patient simulation, simulation has considerable face validity.

Other research has shown high-fidelity manikin-based patient simulation has been received well by learners. Research has demonstrated simulation has high degrees of acceptance among learners and that learners have felt highly satisfied with their simulation learning experience, even more so than learners who did not have simulation available for use. Learners' confidence in their ability is also higher when the learning environment includes high-fidelity patient simulation.

While no one theory can explain or predict outcomes in patient simulation, as a learning strategy, high-fidelity manikin-based simulation is bolstered by several learning theories.

Education theories that have a role in explaining how simulation works include:

- Constructivism – Originating with the works of John Dewey and moving forward to other theorists such as Piaget and Vygotsky, the basic premise of constructivism is that learners each have a unique knowledge base and rebuild that knowledge based on new information. Three tenets of constructivism that have relevance to simulation are:
 - Each person brings his or her own unique experience and knowledge set to the situation. Simulation allows learners to pull from their own frame of reference and apply themselves to the situation. Each learner has the potential to approach the situation in their own manner.
 - Learning occurs through active exploration when an individual's knowledge does not fit the current experience. Simulation offers the opportunity to push learners past their current knowledge level and see new areas where knowledge may be lacking.
 - Learning requires interaction within a social context. A fundamental function of manikin-based simulation is the team approach to patient care. Whether it is a single- or multi-disciplinary team in the simulation, effective interaction with team members is often a requirement for success in simulation.
- Experiential Learning – Based on concepts presented by Kurt Lewin and David Kolb, experiential learning theory (ELT) is frequently mentioned in the simulation literature as a leading learning theory that supports simulation learning. There are two primary components for ELT to be effective. First is an active experience in which the learner

interacts with the learning environment. Simulation provides this immersive experience very well. However, the experience itself is not where the learning occurs. Learning happens in the second component, a reflective process that reviews the actions of the experience and identifies areas for improvement. The process then continues in a cycle that builds on each experience and reflective action.

- Adult Learning Theory – Developed from concepts presented by Eduard Lindemann and Malcolm Knowles, adult learning theory centers on six assumptions that make andragogy (the teaching of adults) different from pedagogy (the teaching of children). All six assumptions can be observed in patient simulation. These assumptions are:
 - Adults have an intrinsic need to know
 - Adults have self-responsibility
 - Adults have a lifetime of experiences
 - Adults have an innate readiness to learn
 - Adults have a life-centered orientation to learning
 - Adults have internal motivators
- Brain-based Learning – One relatively new learning theory that has received very little attention in the simulation literature is brain-based learning (BBL). This learning theory examines how the brain learns. Several theorists are still actively contributing to building this learning theory. One BBL concept that is very applicable to patient simulation is Renate and Geoffrey Caine's three essential elements for learning. They stated three elements were necessary for learning:
 - Relaxed alertness – Learners must be alert to new challenges, but not so much so that fear (including fear of failure) interferes with the learning

process. Simulation represents a safe environment for learners to face new challenges without the fear of patient harm.

- Orchestrated immersion in complex experiences – The instructor creates an immersive simulation experience with specific objectives.
- Active processing of experience – Similar to the reflective thought process found in experiential learning, learners must process the experience to identify areas for improvement.

High-fidelity manikin-based patient simulation is an essential learning tool in healthcare provider education at all levels. With a combination of multiple drivers and a growing body of evidence showing positive learner outcomes, patient simulation will be a key part of the healthcare provider education curriculum. However, as simulation technology advances, users must be cautious to use the technology as part of a coordinated curriculum that emphasizes learning outcomes and not just the use of technology.

REFERENCES

- Abrahamson, S. (1997). Sim One: A patient simulator ahead of its time. *Caduceus*, 13(2), 29-41.
- Abrahamson, S., & Denson, J. S. (1969). A computer-based patient simulator for training anesthesiologists. *Educational Technology*, 9(10), 55-59.
- Abrahamson, S., Denson, J. S., & Wolf, R. M. (1969). Effectiveness of a simulator in training anesthesiology residents. *Journal of Medical Education*, 44, 515-519.
- ACGME outcome project. (2006). Retrieved Sept. 1, 2006, from <http://www.acgme.org/outcome/comp/compFull.asp#5>
- Agazio, J. B., Pavlides, C. C., Lasome, C. E., Flaherty, N. J., & Torrance, R. J. (2002). Evaluation of a virtual reality simulator in sustainment training. *Military Medicine*, 167(11), 893-897.
- Ahlberg, G., Hultcrantz, R., Jaramillo, E., Lindblom, A., & Arvidsson, D. (2005). Virtual reality colonoscopy simulation: A compulsory practice for the future colonoscopist? *Endoscopy*, 37(12), 1198-1204.
- Alinier, G., Hunt, B., Gordon, R., & Harwood, C. (2006). Effectiveness of intermediate-fidelity simulation training technology in undergraduate nursing education. *Journal of Advanced Nursing*, 54(3), 359-369.
- Alverson, D., Saiki, S., Caudell, T., Summers, K. L., Panaiotis, S., Sherstyuk, A., et al. (2005). Distributed immersive virtual reality simulation development for medical education. *Journal of the International Association of Medical Science Educators* 15, 19-30.
- Alverson, D. C., Saiki, S. M., Jr., Jacobs, J., Saland, L., Keep, M. F., Norenberg, J., et al. (2004). Distributed interactive virtual environments for collaborative experiential learning and training independent of distance over Internet. *Studies in Health Technology and Informatics*, 98, 7-12.
- Aronson, B. S., Rosa, J. M., Anfinson, J., & Light, N. (1997). Teaching tools. A simulated clinical problem-solving experience. *Nurse Educator*, 22(6), 17-19.
- Barrows, H. S. (1996). Problem-Based Learning in Medicine and Beyond: A Brief Overview. In L. Wilkerson & W. Gijsselaers (Eds.), *Bringing problem-based learning to higher education: Theory and practice*. San Francisco, CA: Jossey-Bass.

- Barsuk, D., Ziv, A., Lin, G., Blumenfeld, A., Rubin, O., Keidan, I., et al. (2005). Using advanced simulation for recognition and correction of gaps in airway and breathing management skills in prehospital trauma care. *Anesthesia and Analgesia*, *100*(3), 803-809.
- Beane, J. A. (1990). *Affect in the curriculum: Toward democracy, dignity, and diversity*. New York: Teachers College Press.
- Bearnson, C. S., & Wiker, K. M. (2005). Human patient simulators: A new face in baccalaureate nursing education at Brigham Young University. *Journal of Nursing Education*, *44*(9), 421-425.
- Beaubien, J. M., & Baker, D. (2004). The use of simulation for training for teamwork skills in health care: How low can you go? *Quality and Safety in Health Care*, *13* (Suppl. 1), i51-i56.
- Benner, P. (1984). *From novice to expert: Excellence and power in clinical nursing practice*. Menlo Park, CA: Addison-Wesley Publishing Company.
- Berkenstadt, H., Ziv, A., Barsuk, D., Levine, I., Cohen, A., & Vardi, A. (2003). The use of advanced simulation in the training of anesthesiologists to treat chemical warfare casualties. *Anesthesia and Analgesia*, *96*(6), 1739-1742.
- Block, E. F., Lottenberg, L., Flint, L., Jakobsen, J., & Liebnitzky, D. (2002). Use of a human patient simulator for the Advanced Trauma Life Support course. *American Surgeon*, *68*(7), 648-651.
- Bloom, B. S., Engelhart, M. D., Frost, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives, Handbook I: The cognitive domain*. New York: David McKay Co Inc.
- Blum, R. H., Raemer, D. B., Carroll, J. S., Dufresne, R. L., & Cooper, J. B. (2005). A method for measuring the effectiveness of simulation-based team training for improving communication skills. *Anesthesia and Analgesia*, *100*(5), 1375-1380, table of contents.
- Blum, R. H., Raemer, D. B., Carroll, J. S., Sunder, N., Felstein, D. M., & Cooper, J. B. (2004). Crisis resource management training for an anaesthesia faculty: A new approach to continuing education. *Medical Education*, *38*(1), 45-55.
- Bond, W. F., Deitrick, L. M., Arnold, D. C., Kostenbader, M., Barr, G. C., Kimmel, S. R., et al. (2004). Using simulation to instruct emergency medicine residents in cognitive forcing strategies. *Academic Medicine*, *79*(5), 438-446.

- Bond, W. F., Deitrick, L. M., Eberhardt, M., Barr, G. C., Kane, B. G., WorriLOW, C. C., et al. (2006). Cognitive versus technical debriefing after simulation training. *Academic Emergency Medicine*, 13(3), 276-283.
- Bond, W. F., Kostenbader, M., & McCarthy, J. F. (2001). Prehospital and hospital-based health care providers' experience with a human patient simulator. *Prehospital Emergency Care*, 5(3), 284-287.
- Bond, W. F., & Spillane, L. (2002). The use of simulation for emergency medicine resident assessment. *Academic Emergency Medicine*, 9(11), 1295-1299.
- Bonin, B., & Posner, G. D. (2004). Simulation in obstetrics and gynecology. In G. E. Loyd, C. L. Lake & R. B. Greenburg (Eds.), *Practical health care simulations* (pp. 405-434). Philadelphia, PA: Elsevier/Mosby.
- Boonmak, P., Boonmak, S., Srichaipanha, S., & Poomsawat, S. (2004). Knowledge and skill after brief ACLS training. *Journal of the Medical Association of Thailand*, 87(11), 1311-1314.
- Bowyer, M. W., Rawn, L., Hanson, J., Pimentel, E. A., Flanagan, A., Ritter, E. M., et al. (2006). Combining high-fidelity human patient simulators with a standardized family member: A novel approach to teaching breaking bad news. *Studies in Health Technology and Informatics*, 119, 67-72.
- Bradley, P. (2006). The history of simulation in medical education and possible future directions. *Medical Education*, 40(3), 254-262.
- Bradley, P., & Postlethwaite, K. (2003a). Setting up a clinical skills learning facility. *Medical Education*, 37(Suppl. 1), 6-13.
- Bradley, P., & Postlethwaite, K. (2003b). Simulation in clinical learning. *Medical Education*, 37 (Suppl. 1), 1-5.
- Bremner, M. N., Aduddell, K., Bennett, D. N., & VanGeest, J. B. (2006). The use of human patient simulators: Best practices with novice nursing students. *Nurse Educator*, 31(4), 170-174.
- Burnard, P. (1987). Towards an epistemological basis for experiential learning in nurse education. *Journal of Advanced Nursing*, 12(2), 189-193.
- Byrick, R., Cleave-Hogg, D., & McKnight, D. (1998). A crisis management program for residents in anesthesia. *Academic Medicine*, 73(5), 592.

- Caine, R., & Caine, G. (1990). Understanding a brain-based approach to learning and teaching. *Educational Leadership*, 48(2), 66-70.
- Caine, R., & Caine, G. (1991). *Making connections: Teaching and the human brain*. Alexandria, VA: Association for Supervision and Curriculum Development,.
- Caine, R., & Caine, G. (2006). What is brain/mind learning [Internet Website]. Retrieved Aug. 26, 2006, from www.cainelearning.com/principles.html
- Candy, P. C. (1989). Constructivism and the study of of self-direction in adult learning. *Studies in the Education of Adults*, 21, 95-116.
- Carey, M. A. (2006, Feb. 13). Reining In Medicare Costs. *CQ Weekly*, 64, 417.
- Caudell, T. P., Summers, K. L., Holten, J. t., Hakamata, T., Mowafi, M., Jacobs, J., et al. (2003). Virtual patient simulator for distributed collaborative medical education. *The Anatomical Record Part B: The New Anatomist*, 270(1), 23-29.
- Cavanagh, S. J. (1990). Educational aspects of cardiopulmonary resuscitation (CPR) training. *Intensive Care Nurse*, 6(1), 38-44.
- Chopra, V., Engbers, F. H., Geerts, M. J., Filet, W. R., Bovill, J. G., & Spierdijk, J. (1994). The Leiden anaesthesia simulator. *British Journal of Anaesthesia*, 73(3), 287-292.
- Chopra, V., Gesink, B. J., de Jong, J., Bovill, J. G., Spierdijk, J., & Brand, R. (1994). Does training on an anaesthesia simulator lead to improvement in performance? *British Journal of Anaesthesia*, 73(3), 293-297.
- Cleave-Hogg, D., & Morgan, P. J. (2002). Experiential learning in an anaesthesia simulation centre: Analysis of students' comments. *Medical Teacher*, 24(1), 23-26.
- Collins, J. P., & Harden, R. M. (1998). AMEE Medical Education Guide No. 13: Real patients, simulated patients and simulators in clinical examinations. *Medical Teacher*, 20(6), 508-521.
- Colt, H. G., Crawford, S. W., & Galbraith, O., 3rd. (2001). Virtual reality bronchoscopy simulation: A revolution in procedural training. *Chest*, 120(4), 1333-1339.
- Connecticut nursing history vignettes. (2004, Sept.). *Nursing Councils' News: A Publication for the Hartford Hospital Community*, 6, 1-4.

- Cooper, J., & Taqueti, V. R. (2004). A brief history of the development of mannequin simulators for clinical education and training [Electronic Version]. *Quality and Safety in Health Care, 13*, 11-18.
- Cooper, J. B. (2004). The role of simulation in patient safety. In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 20-24). Des Plaines, IL: Society of Critical Care Medicine.
- Coopmans, V. C. (2005). *Certified registered nurse anesthetist performance and perceptions: Use of a handheld, computerized, decision making aid during critical events in a high-fidelity human simulation environment*. Unpublished doctoral dissertation, Virginia Commonwealth University, Virginia.
- Current state report on patient simulation in Canada*. (2005). Edmonton, AB, Canada: Canadian Patient Safety Institute. (Document Number)
- Dalgarno, B. (2001). Interpretations of constructivism and consequences for computer assisted learning. *British Journal of Educational Technology, 32*(2), 183-194.
- Dalley, P., Robinson, B., Weller, J., & Caldwell, C. (2004). The use of high-fidelity human patient simulation and the introduction of new anesthesia delivery systems. *Anesthesia and Analgesia, 99*(6), 1737-1741.
- Dannefer, E. F., & Henson, L. C. (2004). Refocusing the role of simulation in medical education: Training reflective practitioners. In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 25-28). Des Plaines, IL: Society of Critical Care Medicine.
- DeAnda, A., & Gaba, D. (1991). Role of experience in the response to simulated critical incidents. *Anesthesia and Analgesia, 72*(3), 308-315.
- Deering, S., Brown, J., Hodor, J., & Satin, A. J. (2006). Simulation training and resident performance of Singleton vaginal breech delivery. *Obstetrics & Gynecology, 107*(1), 86-89.
- Deering, S., Hodor, J., Wylan, M., Poggi, S., Nielsen, P., & Satin, A. J. (2006). Additional training with an obstetric simulator improves medical student comfort with basic procedures. *Simulation in Healthcare, 1*(1), 32-34.
- Deering, S., Poggi, S., Macedonia, C., Gherman, R., & Satin, A. J. (2004). Improving resident competency in the management of shoulder dystocia with simulation training. *Obstetrics & Gynecology, 103*(6), 1224-1228.

- Delson, N. J., Koussa, N., Hastings, R. H., & Weinger, M. B. (2003). Quantifying expert vs. novice skill in vivo for development of a laryngoscopy simulator. *Studies in Health Technology and Informatics*, 94, 45-51.
- Denson, J. S., & Abrahamson, S. (1969). A computer-controlled patient simulator. *Journal of the American Medical Association*, 208(3), 504-508.
- Dent, J. A. (2001). Current trends and future implications in the developing role of clinical skills centres. *Medical Teacher*, 23(5), 483-489.
- Detty Oswaks, J. S. (2002). *The use of simulated clinical experiences to improve competency in the novice anesthesia provider*. Unpublished doctoral dissertation, The University of Tennessee Health Science Center, Tennessee.
- DeVita, M. A., Schaefer, J., Lutz, J., Wang, H., & Dongilli, T. (2005). Improving medical emergency team (MET) performance using a novel curriculum and a computerized human patient simulator. *Quality and Safety in Health Care*, 14(5), 326-331.
- Devitt, J. H., Kurrek, M. M., Cohen, M. M., & Cleave-Hogg, D. (2001). The validity of performance assessments using simulation. *Anesthesiology*, 95(1), 36-42.
- Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*. New York: The Free Press.
- Dickler, R., & Shaw, G. (2000). The Balanced Budget Act of 1997: Its impact on U.S. teaching hospitals. *Annals of Internal Medicine*, 132(10), 820-824.
- Diefenbeck, C. A., Plowfield, L. A., & Herrman, J. W. (2006). Clinical immersion: A residency model for nursing education. *Nursing Education Perspectives*, 27(2), 72-79.
- Dobson, J. V., Brancati, D. S., & Nagel, R. (2003). Pediatric resuscitation: Evaluation of a clinical curriculum. *Medical Education Online [serial online]*, 8(15), Available from <http://www.med-ed-online.org/res00075.htm>.
- Dreyfus, H. L., & Dreyfus, S. E. (1986). *Mind Over machine: The power of human intuition and expertise in the era of the computer*. New York: The Free Press.

- Dreyfus, S. E., & Dreyfus, H. L. (1980). *A five-stage model of the mental activities involved in directed skill acquisition* (No. Contract # F49620-79-C-0063). Berkeley: Air Force Office of Scientific Research, University of California, Berkeley. Document Number)
- Dunn, W. F. (2004). Education theory: Does simulation really fit? In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 15-19). Des Plaines, IL: Society of Critical Care Medicine.
- Dupuis, O., Silveira, R., Zentner, A., Dittmar, A., Gaucherand, P., Cucherat, M., et al. (2005). Birth simulator: Reliability of transvaginal assessment of fetal head station as defined by the American College of Obstetricians and Gynecologists classification. *American Journal of Obstetrics and Gynecology*, 192(3), 868-874.
- Dutta, S., Gaba, D., & Krummel, T. (2006). To simulate or not to simulate. *Annals of Surgery*, 242(3), 301-303.
- Eder-Van Hook, J. (2004). *Building a national agenda for simulation-based medical education* (No. W81XWH-04-0-0583). Washington, DC: Telemedicine and Advanced Technology Research Center. Document Number)
- Elgood, C. (1990). *Using management games*. Aldershot, UK: Gower.
- Ellis, C., & Hughes, G. (1999). Use of human patient simulation to teach emergency medicine trainees advanced airway skills. *Journal of Accident and Emergency Medicine*, 16(6), 395-399.
- Euliano, T. (2000). Teaching respiratory physiology: Clinical correlation with a human patient simulator. *Journal of Clinical Monitoring and Computers*, 16(5-6), 465-470.
- Euliano, T. (2001). Small group teaching: Clinical correlation with a human patient simulator. *Advances in Physiology Education*, 25(1-4), 36-43.
- Euliano, T., Caton, D., van Meurs, W., & Good, M. L. (1997). Modeling obstetric cardiovascular physiology on a full-scale patient simulator. *Journal of Clinical Monitoring* 13(5), 293-297.
- Euliano, T., & Good, M. L. (1997). Simulator training in anesthesia growing rapidly: LORAL model born in Florida. *Journal of Clinical Monitoring*, 13(1), 53-57.
- Euliano, T., Lamptang, S., & Hardcastle, J. F. (1995). Patient simulator identifies faulty H-cylinder. *Journal of Clinical Monitoring*, 11(6), 394-395.

- Euliano, T., & Mahla, M. E. (1999). Problem-based learning in residency education: A novel implementation using a simulator. *Journal of Clinical Monitoring and Computers*, 15(3/4), 227-232.
- Euliano, T., Mahla, M. E., & Banner, M. J. (1998). Clinically relevant discovery recognized during simulator training session: Free-standing peep valve solves problem of incompetent exhalation unidirectional valve in an anesthesia circle breathing system. *Journal of Clinical Monitoring and Computers*, 14(3), 191-194.
- Ewy, G. A., Felner, J. M., Juul, D., Mayer, J. W., Sajid, A. W., & Waugh, R. A. (1987). Test of a cardiology patient simulator with students in fourth-year electives. *Journal of Medical Education*, 62(9), 738-743.
- Fallacaro, M. D. (2000). Untoward pathophysiological events: Simulation as an experiential learning option to prepare anesthesia providers. *CRNA*, 11(3), 138-143.
- Farnsworth, S. T., Egan, T. D., Johnson, S. E., & Westenskow, D. (2000). Teaching sedation and analgesia with simulation. *Journal of Clinical Monitoring and Computers*, 16(4), 273-285.
- Feingold, C. E., Calaluce, M., & Kallen, M. A. (2004). Computerized patient model and simulated clinical experiences: Evaluation with baccalaureate nursing students. *Journal of Nursing Education*, 43(4), 156-163.
- Fenwick, T. J. (2000). Expanding conceptions of experiential learning: A review of the five contemporary perspectives on cognition [Electronic Version]. *Adult Education Quarterly*, 50(4), 243-272.
- Ferguson, S., Beerma, L., Eichorn, M., Jaramillo, Y., & Wright, M. C. (2004). Simulation in nursing education: High-fidelity simulation across clinical final settings and educational levels. In G. E. Loyd, C. L. Lake & R. B. Greenburg (Eds.), *Practical health care simulations* (pp. 184-204). Philadelphia, PA: Elsevier/Mosby.
- Fiedor, M. L. (2004). Pediatric simulation: A valuable tool for pediatric medical education. *Critical Care Medicine*, 32(Suppl. 2), S72-74.
- Flanagan, B., Nestel, D., & Joseph, M. (2004). Making patient safety the focus: Crisis resource management in the undergraduate curriculum. *Medical Education*, 38(1), 56-66.

- Fletcher, J. L. (1995). Update for nurse anesthetists - Anesthesia simulation: A tool for learning and research. *AANA Journal*, 63(1), 61-67.
- Fontaine, D. K., & Norton, C. (2001). Beyond the essentials. Teaching critical care to undergraduate and graduate students in nursing. *Critical Care Nursing Clinics North America*, 13(1), 13-24.
- Forrest, F. C., Taylor, M. A., Postlethwaite, K., & Aspinall, R. (2002). Use of a high-fidelity simulator to develop testing of the technical performance of novice anaesthetists. *British Journal of Anaesthesia*, 88(3), 338-344.
- Franklin, G. A. (2004). Simulation in life support protocols. In G. E. Loyd, C. L. Lake & R. B. Greenburg (Eds.), *Practical health care simulations* (pp. 393-404). Philadelphia, PA: Elsevier/Mosby.
- Freire, P. (2003). *Pedagogy of the oppressed* (30th Anniversary ed.). London: Continuum International Publishing Group.
- Fried, M. P., Satava, R., Weghorst, S., Gallagher, A. G., Sasaki, C., Ross, D., et al. (2004). Identifying and reducing errors with surgical simulation. *Quality and Safety in Health Care*, 13 (Suppl. 1), i19-26.
- Friedrich, M. J. (2002). Practice makes perfect: Risk-free medical training with patient simulators. *Journal of the American Medical Association*, 288(22), 2808, 2811-2812.
- Gaba, D. (2004a). A Brief History of Mannequin-Based Simulation & Application. In W. F. Dunn (Ed.), *Simulators in Critical Care and Beyond* (pp. 7-14). Des Plaines, IL: Society of Critical Care Medicine.
- Gaba, D. (2004b). The future vision of simulation in health care. *Quality and Safety in Health Care*, 13 (Suppl. 1), i2-i10.
- Gaba, D. (2006). What's in a name: A mannequin by any other name would work as well. *Simulation in Healthcare*, 1(2), 64-65.
- Gaba, D., & DeAnda, A. (1988). A comprehensive anesthesia simulation environment: Re-creating the operating room for research and training. *Anesthesiology*, 69(3), 387-394.
- Gaba, D., Howard, S., Fish, K. J., Smith, B., & Sowb, Y. (2001). Simulation-based training in anesthesia crisis resource management (ACRM): A decade of experience. *Simulation & Gaming*, 32(2), 175-193.

- Gaba, D., & Small, S. (1997). How can full environment-realistic patient simulators be used for performance assessment [Electronic Version]? *ASA Newsletter*, 61(10), Retrieved June 12, 2006 from http://www.asahq.org/Newsletters/1997/2010_2097/HowCan_1097.html.
- Gardner, H. (1983). *Frames of mind: Theory of multiple intelligences* New York: Basic Books.
- Gilbart, M. K., Hutchison, C. R., Cusimano, M. D., & Regehr, G. (2000). A computer-based trauma simulator for teaching trauma management skills. *American Journal of Surgery*, 179(3), 223-228.
- Gisondi, M. A., Smith-Coggins, R., Harter, P. M., Soltysik, R. C., & Yarnold, P. R. (2004). Assessment of resident professionalism using high-fidelity simulation of ethical dilemmas. *Academic Emergency Medicine*, 11(9), 931-937.
- Glavin, R. J., & Maran, N. J. (2003). Integrating human factors into the medical curriculum. *Medical Education*, 37 (Suppl. 1), 59-64.
- Good, M. L. (2003). Patient simulation for training basic and advanced clinical skills. *Medical Education*, 37 (Suppl. 1), 14-21.
- Goodrow, M. S., Rosen, K. R., & Wood, J. (2005). Using cardiovascular and pulmonary simulation to teach undergraduate medical students: Cases from two schools. *Seminars in Cardiothoracic & Vascular Anesthesia*, 9(4), 275-289.
- Goodwin, J. A., van Meurs, W. L., Sa Couto, C. D., Beneken, J. E., & Graves, S. A. (2004). A model for educational simulation of infant cardiovascular physiology. *Anesthesia and Analgesia*, 99(6), 1655-1664.
- Goolsby, M. J. (2001). The role of computer-assisted simulation in nurse practitioner education. *Journal of the American Academy of Nurse Practitioners*, 13(2), 90-97.
- Gordan, J. A. (2004). High-fidelity patient simulation: A revolution in medical education. In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 3-6). Des Plaines, IL: Society of Critical Care Medicine.
- Gordon, J. A. (2002). A simulator-based medical education service. *Academic Emergency Medicine*, 9(8), 865.
- Gordon, J. A., Oriol, N. E., & Cooper, J. B. (2004). Bringing good teaching cases "to life": A simulator-based medical education service. *Academic Medicine*, 79(1), 23-27.

- Gordon, J. A., & Pawlowski, J. (2002). Education on-demand: The development of a simulator-based medical education service [Abstract]. *Academic Medicine*, 77(7), 751-752.
- Gordon, J. A., Wilkerson, W. M., Shaffer, D. W., & Armstrong, E. G. (2001). "Practicing" medicine without risk: Students' and educators' responses to high-fidelity patient simulation. *Academic Medicine*, 76(5), 469-472.
- Gordon, M. S., Ewy, G. A., DeLeon, A. C., Jr., Waugh, R. A., Felner, J. M., Forker, A. D., et al. (1980). "Harvey," the cardiology patient simulator: Pilot studies on teaching effectiveness. *American Journal of Cardiology*, 45(4), 791-796.
- Gordon, M. S., Ewy, G. A., Felner, J. M., Forker, A. D., Gessner, I., McGuire, C., et al. (1980). Teaching bedside cardiologic examination skills using "Harvey", the cardiology patient simulator. *Medical Clinics North America*, 64(2), 305-313.
- Gordon, M. S., Ewy, G. A., Felner, J. M., Forker, A. D., Gessner, I. H., Juul, D., et al. (1981). A cardiology patient simulator for continuing education of family physicians. *Journal of Family Practice*, 13(3), 353-356.
- Gordon, M. S., Issenberg, S. B., Mayer, J. W., & Felner, J. M. (1999). Developments in the use of simulators and multimedia computer systems in medical education. *Medical Teacher*, 21(1), 32-36.
- Gorman, P. J., Meier, A. H., & Krummel, T. M. (2000). Computer-assisted training and learning in surgery. *Computer Aided Surgery*, 5(2), 120-130.
- Graber, M. A., Wyatt, C., Kasperek, L., & Xu, Y. (2005). Does simulator training for medical students change patient opinions and attitudes toward medical student procedures in the emergency department? *Academic Emergency Medicine*, 12(7), 635-639.
- Grant, W. D. (2002). Addition of anesthesia patient simulator is an improvement to evaluation process. *Anesthesia and Analgesia*, 95(3), 786-787.
- Graydon, E., Blum, R., Cooper, J., Feinstein, D., Lowenstein, E., Malov, S. S., et al. (2000, January). *Does participating in realistic simulation prior to anesthesia residency increase the perception of comfort and performance? [Abstract]*. Paper presented at the Society For Technology in Anesthesia Conference, Orlando, FL.

- Greenberg, R., Loyd, G., & Wesley, G. (2002). Integrated simulation experiences to enhance clinical education [Abstract]. *Medical Education*, 36(11), 1109-1110.
- Greene, A. K., Zurakowski, D., Puder, M., & Thompson, K. (2006). Determining the need for simulated training of invasive procedures. *Advances in Health Sciences Education Theory*, 11(1), 41-49.
- Grenvik, A., Schaefer, J. J., 3rd, DeVita, M. A., & Rogers, P. (2004). New aspects on critical care medicine training. *Current Opinions in Critical Care*, 10(4), 233-237.
- Griggs, R. R. (2003). *The effects of the use of a human patient simulator on the acquisition of nursing knowledge in undergraduate nursing students at a university in Illinois*. Unpublished doctoral dissertation, Southern Illinois University at Carbondale, Carbondale, IL.
- Gurewitsch, E. D., Kim, E. J., Yang, J. H., Outland, K. E., McDonald, M. K., & Allen, R. H. (2005). Comparing McRoberts' and Rubin's maneuvers for initial management of shoulder dystocia: An objective evaluation. *American Journal of Obstetrics and Gynecology*, 192(1), 153-160.
- Halamek, L. P., Kaegi, D. M., Gaba, D., Sowb, Y. A., Smith, B. C., Smith, B. E., et al. (2000). Time for a new paradigm in pediatric medical education: Teaching neonatal resuscitation in a simulated delivery room environment [Electronic Version]. *Pediatrics*, 106(4), E45.
- Hall, R. E., Plant, J. R., Bands, C. J., Wall, A. R., Kang, J., & Hall, C. A. (2005). Human patient simulation is effective for teaching paramedic students endotracheal intubation. *Academic Emergency Medicine*, 12(9), 850-855.
- Hamilton, E. C., Scott, D. J., Kapoor, A., Nwariaku, F., Bergen, P. C., Rege, R. V., et al. (2001). Improving operative performance using a laparoscopic hernia simulator. *American Journal of Surgery*, 182(6), 725-728.
- Hamman, W. R. (2004a). The complexity of team training: What we have learned from aviation and its applications to medicine. *Quality and Safety in Health Care*, 13 (Suppl. 1), i72-i79.
- Hamman, W. R. (2004b). Will simulation fly in medicine as it has in aviation? *Quality and Safety in Health Care*, 13(13), 397-399.
- Hammond, J. (2004). Simulation in critical care and trauma education and training. *Current Opinions in Critical Care*, 10(5), 325-329.

- Hammond, J., Bermann, M., Chen, B., & Kushins, L. (2002). Incorporation of a computerized human patient simulator in critical care training: A preliminary report. *Journal of Trauma Injury, Infection and Critical Care*, 53(6), 1064-1067.
- Hanna, M., & Fins, J. J. (2006). Power and communication: Why simulation training ought to be complemented by experiential and humanist learning. *Academic Medicine*, 81(3), 265-270.
- Hart, L. (1983). *Human brain, human learning*. Longman: New York.
- Haskvitz, L. M., & Koop, E. C. (2004). Students struggling in clinical? A new role for the patient simulator. *Journal of Nursing Education*, 43(4), 181-184.
- Hendrickse, A. D., Ellis, A. M., & Morris, R. W. (2001). Use of simulation technology in Australian Defense Force resuscitation training. *Journal of the Royal Army Medical Corps*, 147(2), 173-178.
- Henrichs, B., Rule, A., Grady, M., & Ellis, W. (2002). Nurse anesthesia students' perceptions of the anesthesia patient simulator: A qualitative study. *AANA Journal*, 70(3), 219-225.
- Henriksen, K., & Moss, F. (2004). From the runway to the airway and beyond. *Quality and Safety in Health Care*, 13(Suppl. 1), i1.
- Hikichi, T., Yoshida, A., Igarashi, S., Mukai, N., Harada, M., Muroi, K., et al. (2000). Vitreous surgery simulator. *Archives of Ophthalmology*, 118(12), 1679-1681.
- Hoffman, K. I., & Abrahamson, S. (1975). The "cost-effectiveness" of Sim One. *Journal of Medical Education*, 50(12 Part 1), 1127-1128.
- Hogan, G. T., Jr. (2004). *The effect of simulator training on nurse anesthesia students' anxiety in their first semester of patient care*. Unpublished doctoral dissertation, The University of Tennessee Health Science Center, Tennessee.
- Holcomb, J. B., Dumire, R. D., Crommett, J. W., Stamateris, C. E., Fagert, M. A., Cleveland, J. A., et al. (2002). Evaluation of trauma team performance using an advanced human patient simulator for resuscitation training. *Journal of Trauma Injury, Infection and Critical Care*, 52(6), 1078-1085.
- Hotchkiss, M. A., & Mendoza, S. N. (2001). Full-body patient simulation technology: Gaining experience using a malignant hyperthermia model. *AANA Journal*, 69(1), 59-65.
- Hotvedt, M. O., & Laskowski, R. J. (2002). Establishing priorities for hospital education. *Journal of Continuing Education in the Health Professions*, 22(3), 181-186.

- Howard, S. K., Gaba, D., Fish, K. J., Yang, G., & Sarnquist, F. H. (1992). Anesthesia crisis resource management training: Teaching anesthesiologists to handle critical incidents. *Aviation, Space, and Environmental Medicine*, 63(9), 763-770.
- Hravnak, M., Tuite, P., & Baldisseri, M. (2005). Expanding acute care nurse practitioner and clinical nurse specialist education: Invasive procedure training and human simulation in critical care. *AACN Clinical Issues*, 16(1), 89-104.
- Hytten, K. (2000). The resurgence of Dewey: Are his educational ideas still relevant? *Journal of Curriculum Studies*, 32(3), 453-466.
- Issenberg, S. B., Gordon, M. S., Gordon, D. L., Safford, R. E., & Hart, I. R. (2001). Simulation and new learning technologies. *Medical Teacher*, 23(1), 16-23.
- Issenberg, S. B., Gordon, M. S., & Greber, A. A. (2003). Bedside cardiology skills training for the osteopathic internist using simulation technology. *Journal of the American Osteopathic Association*, 103(12), 603-607.
- Issenberg, S. B., McGaghie, W. C., Gordon, D. L., Symes, S., Petrusa, E. R., Hart, I. R., et al. (2002). Effectiveness of a cardiology review course for internal medicine residents using simulation technology and deliberate practice. *Teaching & Learning in Medicine*, 14(4), 223-228.
- Issenberg, S. B., McGaghie, W. C., Hart, I. R., Mayer, J. W., Felner, J. M., Petrusa, E. R., et al. (1999). Simulation technology for health care professional skills training and assessment. *Journal of the American Medical Association*, 282(9), 861-866.
- Issenberg, S. B., McGaghie, W. C., Petrusa, E. R., Lee Gordon, D., & Scalese, R. J. (2005). Features and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review. *Medical Teacher*, 27(1), 10-28.
- Issenberg, S. B., Petrusa, E. R., McGaghie, W. C., Felner, J. M., Waugh, R. A., Nash, I. S., et al. (1999). Effectiveness of a computer-based system to teach bedside cardiology. *Acad Med*, 74(10 Suppl), S93-95.
- Issenberg, S. B., Pringle, S., Harden, R. M., Khogali, S., & Gordon, M. S. (2003). Adoption and integration of simulation-based learning technologies into the curriculum of a UK undergraduate education programme. *Medical Education*, 37 (Suppl. 1), 42-49.

- Jacobs, J., Caudell, T., Wilks, D., Keep, M. F., Mitchell, S., Buchanan, H., et al. (2003). Integration of advanced technologies to enhance problem-based learning over distance: Project TOUCH. *The Anatomical Record Part B: The New Anatomist*, 270(1), 16-22.
- Jacobs, L. M., Burns, K. J., Kaban, J. M., Gross, R. I., Cortes, V., Brautigam, R. T., et al. (2003). Development and evaluation of the advanced trauma operative management course. *Journal of Trauma*, 55(3), 471-479.
- Jenson, E. (1996). *Brain-based learning*. Del Mar, CA: Turning Point Publishing.
- Jones, J. S., Hunt, S. J., Carlson, S. A., & Seamon, J. P. (1997). Assessing bedside cardiologic examination skills using "Harvey," a cardiology patient simulator. *Academic Emergency Medicine*, 4(10), 980-985.
- Joyce, B., Weil, M., & Calhoun, E. (2004). *Models of Teaching* (7th ed.). Boston, MA: Allyn and Bacon.
- Kapur, P. A., & Steadman, R. H. (1998). Patient simulator competency testing: Ready for takeoff? *Anesthesia and Analgesia*, 86(6), 1157-1159.
- Karnath, B., Thornton, W., & Frye, A. W. (2002). Teaching and testing physical examination skills without the use of patients [Abstract]. *Academic Medicine*, 77(7), 753.
- Kaye, W., & Mancini, M. E. (1986). Use of the Mega Code to evaluate team leader performance during Advanced Cardiac Life Support. *Critical Care Medicine*, 14(2), 99-104.
- Kaye, W., Mancini, M. E., & Rallis, S. F. (1987). Advanced Cardiac Life Support refresher course using standardized objective-based Mega Code testing. *Critical Care Medicine*, 15(1), 55-60.
- Kaye, W., Mancini, M. E., Rallis, S. F., Linhares, K. C., Angell, M. L., Donovan, D. S., et al. (1985). Can better basic and Advanced Cardiac Life Support improve outcome from cardiac arrest? *Critical Care Medicine*, 13(11), 916-920.
- Kayes, A. B., Kayes, D. C., & Kolb, D. A. (2005). Experiential learning in Teams. *Simulation & Gaming*, 36(3), 330-354.
- Keller, J. (1987a). Strategies for stimulating the motivation to learn. *Performance and Instruction*, 26(8), 1-7.
- Keller, J. (1987b). The systematic process of motivational design. *Performance and Instruction*, 26(9), 1-9.

- Keller, J. (1999). Using the ARCS motivational process in computer-based instruction and distance education. In M. Theall (Ed.), *Motivation from within: Approaches for encouraging faculty and students to excel* (pp. 39-47). San Francisco: Jossey-Bass Publishers.
- Kiegaldie, D., & White, G. (2006). "The virtual patient" - Development, implementation and evaluation of an innovative computer simulation for postgraduate nursing students. *Journal of Educational Multimedia and Hypermedia*, 15(1), 31-47.
- King, L., & Appleton, J. (1997). Intuition: A critical review of the research and rhetoric. *Journal of Advanced Nursing*, 26, 194-202.
- Kneebone, R. (1999). Twelve tips on teaching basic surgical skills using simulation and multimedia. *Medical Teacher*, 21(6), 571-575.
- Kneebone, R. (2002). *Teaching and learning basic surgical skills using multimedia and models: An exploration of a new approach to training*. Unpublished doctoral dissertation, University of Bath United Kingdom.
- Kneebone, R. (2003). Simulation in surgical training: Educational issues and practical implications. *Medical Education*, 37(3), 267-277.
- Kneebone, R. (2005). Evaluating clinical simulations for learning procedural skills: A theory-based approach. *Academic Medicine*, 80(6), 549-553.
- Kneebone, R. (2006). Crossing the line: Simulation and boundary areas. *Simulation in Healthcare*, 1(3), 160-163.
- Kneebone, R., & ApSimon, D. (2001). Surgical skills training: simulation and multimedia combined. *Medical Education*, 35(9), 909-915.
- Kneebone, R., Kidd, J., Nestel, D., Asvall, S., Paraskeva, P., & Darzi, A. (2002). An innovative model for teaching and learning clinical procedures. *Medical Education*, 36(7), 628-634.
- Kneebone, R., Kidd, J., Nestel, D., Barnet, A., Lo, B., King, R., et al. (2005). Blurring the boundaries: Scenario-based simulation in a clinical setting. *Medical Education*, 39(6), 580-587.
- Kneebone, R., Nestel, D., Moorthy, K., Taylor, P., Bann, S., Munz, Y., et al. (2003). Learning the skills of flexible sigmoidoscopy - The wider perspective. *Medical Education*, 37(Suppl. 1), 50-58.

- Kneebone, R., Scott, W., Darzi, A., & Horrocks, M. (2004). Simulation and clinical practice: Strengthening the relationship. *Medical Education*, 38(10), 1095-1102.
- Knowles, M., Holton, E., III, & Swanson, R. (1998). *The adult learner* (5th ed.). Woburn, MA: Butterworth-Heinemann.
- Kobayashi, L., Shapiro, M. J., Sucov, A., Woolard, R., Boss, R. M., 3rd, Dunbar, J., et al. (2006). Portable advanced medical simulation for new emergency department testing and orientation. *Academic Emergency Medicine*, 13(6), 691-695.
- Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (Eds.). (2000). *To err is human: Building a safer health system*. Washington, DC: Committee on Quality of Health Care in America, Institute of Medicine, National Academy Press.
- Kolb, A., & Kolb, D. A. (2005). *The Kolb Learning Style Inventory - Version 3.1 - 2005 technical specifications*: Experience Based Learning Systems, Inc. (Hay Resources Direct, Boston, MA)o. Document Number)
- Kolb, D. A. (1983). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Financial Times Prentice Hall.
- Krathwohl, D. R., Bloom, B. S., & Bertram, B. M. (1973). *Taxonomy of Educational Objectives, the Classification of Educational Goals. Handbook II: Affective Domain*. New York: David McKay Co., Inc. .
- Lane, J. L., Slavin, S., & Ziv, A. (2001). Simulation in medical education: A review. *Simulation & Gaming*, 32(3), 297-314.
- Larew, C., Lessans, S., Spunt, D., Foster, D., & Covington, B. G. (2006). Innovations in clinical simulation: Application of Benner's theory in an interactive patient care simulation. *Nursing Education Perspectives*, 27(1), 16-21.
- Lasater, K. (2005). *The impact of high fidelity simulation on the development of clinical judgment in nursing students: An exploratory study*. Unpublished doctoral dissertation, Portland State University, Oregon.

- LeBlanc, V. R., MacDonald, R. D., McArthur, B., King, K., & Lepine, T. (2005). Paramedic performance in calculating drug dosages following stressful scenarios in a human patient simulator. *Prehospital Emergency Care*, 9(4), 439-444.
- Lederman, D. (2005, July 12). Training tomorrow's doctors, for now. *Inside Higher Education [Internet Journal]*, available at <http://www.insidehighered.com/news/2005/2007/2012/health>.
- Lee, S. K., Pardo, M., Gaba, D., Sowb, Y., Dicker, R., Straus, E. M., et al. (2003). Trauma assessment training with a patient simulator: A prospective, randomized study. *Journal of Trauma Injury, Infection and Critical Care*, 55(4), 651-657.
- Leigh, E., & Spindler, L. (2004). Simulations and games as chaotic learning contexts. *Simulation & Gaming*, 35(1), 53-69.
- Leitch, R. A., Moses, G. R., & Magee, H. (2002). Simulation and the future of military medicine. *Military Medicine*, 167(4), 350-354.
- Lighthall, G. K. (2004). The IMPES Course: Towards better outcomes through simulation-based multidisciplinary team training. In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 54-60). Des Plaines, IL: Society of Critical Care Medicine.
- Lighthall, G. K., Barr, J., Howard, S., Gellar, E., Sowb, Y., Bertacini, E., et al. (2003). Use of a fully simulated intensive care unit environment for critical event management training for internal medicine residents. *Critical Care Medicine*, 31(10), 2437-2443.
- Liu, A., Tendick, F., Cleary, K., & Kaufmann, C. (2003). A survey of surgical simulation: Applications, technology, and education. *Presence: Teleoperators & Virtual Environments*, 12(6), 599-614.
- Loyd, G. E. (2004). A course for anaesthesiology residents using simulation. *Medical Education*, 38(5), 571-572.
- Lupien, A. E. (2004). Simulation in nursing education: Nurse anesthesia education. In G. E. Loyd, C. L. Lake & R. B. Greenburg (Eds.), *Practical health care simulations* (pp. 176-183). Philadelphia, PA: Elsevier/Mosby.
- MacDonald, J. (1999). Motivation for higher-order learning. In M. Theall (Ed.), *Motivation from within: Approaches for encouraging faculty and students to excel* (pp. 27-35). San Francisco: Jossey-Bass Publishers.

- MacDonald, S. (1994, June 25-30). *A knowledge-based learning and testing system for medical education* [ERIC Document # ED288269]. Paper presented at the World Conference on Educational Multimedia and Hypermedia, Vancouver, BC, Canada.
- Macedonia, C. R., Gherman, R. B., & Satin, A. J. (2003). Simulation laboratories for training in obstetrics and gynecology. *Obstetrics & Gynecology*, *102*(2), 388-392.
- MacLean, P. D. (1973). *A triune concept of the brain and behaviour*. Toronto, Canada: University of Toronto Press.
- MacLean, P. D. (1978). A mind of three minds: Educating the triune brain. In J. Chall & A. Mirsky (Eds.), *Education and the Brain* (pp. 308-343). Chicago: University of Chicago Press.
- Maibach, E. W., Schieber, R. A., & Carroll, M. F. (1996). Self-efficacy in pediatric resuscitation: Implications for education and performance. *Pediatrics*, *97*(1), 94-99.
- Makoul, G. (2006). Communication skills: How simulation training supplements experiential and humanist learning. *Academic Medicine*, *81*(3), 271-274.
- Mallow, G. E., & Gilje, F. (1999). Technology-based nursing education: Overview and call for further dialogue. *Journal of Nursing Education*, *38*(6), 248-251.
- Mangan, K. A. (2000, Feb. 25). Teaching surgery without a patient. *Chronicle of Higher Education*, *46* A49-A50.
- Maran, N. J., & Glavin, R. J. (2003). Low- to high-fidelity simulation - A continuum of medical education? *Medical Education*, *37* (Suppl. 1), 22-28.
- Marchette, L., Jones, S., Bagg, A., Cohen, A., Palau, D., & Thaw, P. (1985). The effect of an Advanced Cardiac Life Support course on advanced cardiac life support ability. *Heart & Lung*, *14*(6), 594-598.
- Marsch, S. C., Tschan, F., Semmer, N., Spychiger, M., Breuer, M., & Hunziker, P. R. (2005). Performance of first responders in simulated cardiac arrests. *Critical Care Medicine*, *33*(5), 963-967.
- Marshall, R. L., Smith, J. S., Gorman, P. J., Krummel, T. M., Haluck, R. S., & Cooney, R. N. (2001). Use of a human patient simulator in the development of resident trauma management skills. *Journal of Trauma Injury, Infection and Critical Care*, *51*(1), 17-21.

- Martin, B. L., & Briggs, L. J. (1986). *The affective and cognitive domains: Integration for instruction and research*. Englewood Cliffs, NJ: Educational Technology Publications.
- Martin, C. (2002). The theory of critical thinking of nursing. *Nursing Education Perspectives*, 23(5), 243-247.
- Maudsley, G., & Strivens, J. (2000). Promoting professional knowledge, experiential learning and critical thinking for medical students. *Medical Education*, 34(7), 535-544.
- Mayo, P. H., Hackney, J. E., Mueck, J. T., Ribaud, V., & Schneider, R. F. (2004). Achieving house staff competence in emergency airway management: Results of a teaching program using a computerized patient simulator. *Critical Care Medicine*, 32(12), 2422-2427.
- Mayrose, J., Kesavadas, T., Chugh, K., Joshi, D., & Ellis, D. G. (2003). Utilization of virtual reality for endotracheal intubation training. *Resuscitation*, 59(1), 133-138.
- McKenzie, L. S. (2004). *Traditional versus simulator-based small group teaching: A comparative study with third-year undergraduate medical students*. Unpublished Master's thesis, University of Calgary, Canada.
- McLaughlin, S. A., Doezema, D., & Sklar, D. P. (2002). Human simulation in emergency medicine training: A model curriculum. *Academic Emergency Medicine*, 9(11), 1310-1318.
- McMahon, G. T., Monaghan, C., Falchuk, K., Gordon, J. A., & Alexander, E. K. (2005). A simulator-based curriculum to promote comparative and reflective analysis in an internal medicine clerkship. *Academic Medicine*, 80(1), 84-89.
- Meier, A. H., Henry, J., Marine, R., & Murray, W. B. (2005). Implementation of a Web- and simulation-based curriculum to ease the transition from medical school to surgical internship. *American Journal of Surgery*, 190(1), 137-140.
- Miller, M. D. (1987). Simulations in medical education: A review. *Medical Teacher*, 9(1), 35-41.
- Monti, E. J., Wren, K., Haas, R., & Lupien, A. E. (1998). The use of an anesthesia simulator in graduate and undergraduate education. *CRNA*, 9(2), 59-66.
- Moorthy, K., Smith, S., Brown, T., Bann, S., & Darzi, A. (2003). Evaluation of virtual reality bronchoscopy as a learning and assessment tool. *Respiration*, 70(2), 195-199.

- Morgan, P. J., & Cleave-Hogg, D. (1999). Evaluation of medical students' performances using the anesthesia simulator. *Academic Medicine*, 74(2), 202.
- Morgan, P. J., & Cleave-Hogg, D. (2000). Evaluation of medical students' performances using the anesthesia simulator. *Medical Education*, 34, 42-45.
- Morgan, P. J., & Cleave-Hogg, D. (2002). Comparison between medical students' experience, confidence and competence. *Medical Education*, 36(6), 534-539.
- Morgan, P. J., Cleave-Hogg, D., Desousa, S., & Lam-McCulloch, J. (2006). Applying theory to practice in undergraduate education using high fidelity simulation *Medical Teacher*, 28(1), 10-15.
- Morgan, P. J., Cleave-Hogg, D., Mcllroy, J., & Devitt, J. H. (2002). Simulation technology: A comparison of experiential and visual learning for undergraduate medical students. *Anesthesiology*, 96(1), 10-16.
- Morgan, P. J., Cleave-Hogg, D. M., Guest, C. B., & Herold, J. (2001). Validity and reliability of undergraduate performance assessments in an anesthesia simulator. *Canadian Journal of Anaesthesia*, 48(3), 225-233.
- Morton, P. G. (1997). Using a critical care simulation laboratory to teach students. *Critical Care Nurse*, 17(6), 66-69.
- Mueller, M. P., Christ, T., Dobrev, D., Nitsche, I., Stehr, S. N., Ravens, U., et al. (2005). Teaching antiarrhythmic therapy and ECG in simulator-based interdisciplinary undergraduate medical education. *British Journal of Anaesthesia*, 95(3), 300-304.
- Murray, D., Boulet, J., Ziv, A., Woodhouse, J., Kras, J., & McAllister, J. (2002). An acute care skills evaluation for graduating medical students: A pilot study using clinical simulation. *Medical Education*, 36(9), 833-841.
- Murray, W. B., Good, M. L., Gravenstein, J. S., van Oostrom, J. H., & Brasfield, W. G. (2002). Learning about new anesthetics using a model driven, full human simulator. *Journal of Clinical Monitoring and Computers*, 17(5), 293-300.
- Murray, W. B., & Schneider, A. J. L. (1997). Using simulators for education and training in anesthesiology [Electronic Version]. *ASA Newsletter*, 61(10), Retrieved June 12, 2006 from http://www.asahq.org/Newsletters/1997/2010_2097/Simulators_1097.html.

- Nehring, W. M., Ellis, W. E., & Lashley, F. R. (2001). Human patient simulators in nursing education: An overview. *Simulation & Gaming, 32*(2), 194-204.
- Nehring, W. M., & Lashley, F. R. (2004). Current use and opinions regarding human patient simulators in nursing education: An international survey. *Nursing Education Perspectives, 25*(5), 244-248.
- Norman, J., & Wilkins, D. (1996). Simulators for anesthesia. *Journal of Clinical Monitoring, 12*(1), 91-99.
- Nyssen, A.-S., Larbuisson, R., Janssens, M., Pendeville, P., & Mayne, A. (2002). A comparison of the training value of two types of anesthesia simulators: Computer screen-based and mannequin-based simulators. *Anesthesia and Analgesia, 94*, 1560-1565.
- O'Brien, G., Haughton, A., & Flanagan, B. (2001). Interns' perceptions of performance and confidence in participating in and managing simulated and real cardiac arrest situations. *Medical Teacher, 23*(4), 389-395.
- O'Donnell, J., Fletcher, J., Dixon, B., & Palmer, L. (1998). Planning and implementing an anesthesia crisis resource management course for student nurse anesthetists. *CRNA, 9*(2), 50-58.
- O'Steen, D. S., Kee, C. C., & Minick, M. P. (1996). The retention of Advanced Cardiac Life Support knowledge among registered nurses. *Journal of Nursing Staff Development, 12*(2), 66-72.
- Ostergaard, D. (2004). National medical simulation training program in Denmark. *Critical Care Medicine, 32*(Suppl. 2), S58-60.
- Ostergaard, H. T., Ostergaard, D., & Lippert, A. (2004). Implementation of team training in medical education in Denmark. *Quality and Safety in Health Care, 13* (Suppl. 1), i91-95.
- Palmisano, J. M., Akingbola, O. A., Moler, F. W., & Custer, J. R. (1994). Simulated pediatric cardiopulmonary resuscitation: Initial events and response times of a hospital arrest team. *Respiratory Care, 39*(7), 725-729.
- Panitz, T. (1999). The motivational benefits of cooperative learning. In M. Theall (Ed.), *Motivation from within: Approaches for encouraging faculty and students to excel* (pp. 59-67). San Francisco: Jossey-Bass Publishers.
- Patow, C. A. (2005, Dec). Medical simulation makes medical education better and safer. *Health Management Technology, 26*, 40.

- Paulson, M., & Feldman, K. (1999). Student motivation and epistemological beliefs. In M. Theall (Ed.), *Motivation from within: Approaches for encouraging faculty and students to excel* (pp. 17-25). San Francisco: Jossey-Bass Publishers.
- Peters, M. (2000). Does constructivist epistemology have a place in nurse education? *Journal of Nursing Education* 39(4), 166-172.
- Phillips Jr., R. L., Fryer, G. E., Chen, F. M., Morgan, S. E., Green, L. A., Valente, E., et al. (2004). The Balanced Budget Act of 1997 and the financial health of teaching hospitals. *Annals of Family Medicine*, 2(1), 71-78.
- Pittini, R., Oepkes, D., Macrury, K., Reznick, R., Beyene, J., & Windrim, R. (2002). Teaching invasive perinatal procedures: Assessment of a high fidelity simulator-based curriculum. *Ultrasound in Obstetrics and Gynecology*, 19(5), 478-483.
- Pugh, C. M. (2001). *Evaluating simulators for medical training: The case of the pelvic exam model*. Unpublished doctoral dissertation, Stanford University, California.
- Quan, L., Shugerman, R. P., Kunkel, N. C., & Brownlee, C. J. (2001). Evaluation of resuscitation skills in new residents before and after pediatric advanced life support course. *Pediatrics*, 108(6), E110.
- Quay, J. (2003). Experience and participation: Relating theories and learning. *Journal of Experiential Learning*, 26(2), 105-112.
- Raemer, D. B., & Barron, D. M. (1997). Uses of simulators for education and training in nonanesthesia health care domains. *ASA Newsletter*, 61(10), Retrieved Jan. 1, 2003 from http://www.asahq.org/Newsletters/1997/2010_2097/UsesOf_1097.html.
- Rall, M., Schaedle, B., Zieger, J., Naef, W., & Weinlich, M. (2002). [Innovative training for enhancing patient safety: Safety culture and integrated concepts]. *Unfallchirurg*, 105(11), 1033-1042.
- Rauen, C. A. (2001). Using simulation to teach critical thinking skills. You can't just throw the book at them. *Critical Care Nursing Clinics North America*, 13(1), 93-103.
- Rauen, C. A. (2004). Simulation as a teaching strategy for nursing education and orientation in cardiac surgery. *Critical Care Nurse*, 24(3), 45-51.

- Ravert, P. K. M. (2004). *Use of a human patient simulator with undergraduate nursing students: A prototype evaluation of critical thinking and self-efficacy*. Unpublished doctoral dissertation, The University of Utah, Utah.
- Register, M., Graham-Garcia, J., & Haas, R. (2003). The use of simulation to demonstrate hemodynamic response to varying degrees of intrapulmonary shunt. *AANA Journal*, 71(4), 277-284.
- Rehmann, A., Mitman, R., & Reynolds, M. (1995). *A handbook of flight simulation fidelity requirements for human factors research* (No. DOT/FAA/CT-TN95/46). Wright-Patterson AFB, OH: Crew Systems Ergonomics Information Analysis Center. Document Number)
- Reznek, M., Harter, P., & Krummel, T. (2002). Virtual reality and simulation: Training the future emergency physician. *Academic Emergency Medicine*, 9(1), 78-87.
- Reznek, M., Smith-Coggins, R., Howard, S., Kiran, K., Harter, P., Sowb, Y., et al. (2003). Emergency Medicine Crisis Resource Management (EMCRM): Pilot study of a simulation-based crisis management course for emergency medicine. *Academic Emergency Medicine*, 10(4), 386-389.
- Roberts, J. (2002). Beyond learning by doing: The brain compatible approach. *The Journal of Experiential Education*, 25(2), 281-285.
- Roberts, S. W., & McCowan, R. J. (2004). The effectiveness of infant simulators. *Adolescence*, 39(155), 475-487.
- Robertson, B. (2006). An obstetric simulation experience in an undergraduate nursing curriculum. *Nurse Educator*, 31(2), 74-78.
- Rodgers, D. L., & Withrow-Thornton, B. (2005). The effect of instructional media on learner motivation. *International Journal of Instructional Media*, 32(4), 333-342.
- Rogers, P. L., Jacob, H., Rashwan, A. S., & Pinsky, M. R. (2001). Quantifying learning in medical students during a critical care medicine elective: A comparison of three evaluation instruments. *Critical Care Medicine*, 29(6), 1268-1273.
- Rosen, K. R. (2004). The history of medical simulation. In G. E. Loyd, C. L. Lake & R. B. Greenburg (Eds.), *Practical health care simulations* (pp. 3-26). Philadelphia, PA: Elsevier/Mosby.

- Rosenblatt, M. A., & Abrams, K. J. (2002). The use of a human patient simulator in the evaluation of and development of a remedial prescription for an anesthesiologist with lapsed medical skills. *Anesthesia and Analgesia*, *94*(1), 149-153.
- Rowe, R., & Cohen, R. A. (2002). An evaluation of a virtual reality airway simulator. *Anesthesia and Analgesia*, *95*(1), 62-66, table of contents.
- Rubin, R., Palmgreen, P., & Sypher, H. (Eds.). (1994). *Communication research measures: A sourcebook*. New York: The Guilford Press.
- Rudolph, J., Simon, R., Dufresne, R. L., & Raemer, D. B. (2006). There's no such thing as "nonjudgmental debriefing: A theory and method for debriefing with good judgment. *Simulation in Healthcare*, *1*(1), 49-55.
- Rupp, G. (1996). The president's report: The academic medical center. Retrieved July 22, 2006, from <http://www.columbia.edu/cu/president/report96/contents.html>
- Salas, E., & Burke, C. S. (2002). Simulation for training is effective when... *Quality and Safety in Health Care*, *11*(2), 119-120.
- Saliterman, S. S. (1990). A computerized simulator for critical-care training: New technology for medical education. *Mayo Clinic Proceedings*, *65*(7), 968-978.
- Sanders, J., Haas, R. E., Geisler, M., & Lupien, A. E. (1998). Using the human patient simulator to test the efficacy of an experimental emergency percutaneous transtracheal airway. *Military Medicine*, *163*(8), 544-551.
- Satava, R. M. (2001). Surgical education and surgical simulation. *World Journal of Surgery*, *25*(11), 1484-1489.
- Savoldelli, G. L., Naik, V. N., Joo, H. S., Houston, P. L., Graham, M., Yee, B., et al. (2006). Evaluation of patient simulator performance as an adjunct to the oral examination for senior anesthesia residents. *Anesthesiology*, *104*(3), 475-481.
- Schendel, S., Montgomery, K., Sorokin, A., & Lionetti, G. (2005). A surgical simulator for planning and performing repair of cleft lips. *Journal of Craniomaxillofacial Surgery*, *33*(4), 223-228.

- Scherer, Y. K., Bruce, S. A., Graves, B. T., & Erdley, W. S. (2003). Acute care nurse practitioner education: Enhancing performance through the use of clinical simulation. *AACN Clinical Issues*, 14(3), 331-341.
- Schon, D. A. (1983). *The reflective practitioner: How professionals think in action*. Aldershot, UK: Ashgate Arena.
- Schumacher, L. (2004a). Simulation in critical care nursing education: Conceptual & practical perspectives. In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 114-118). Des Plaines, IL: Society of Critical Care Medicine.
- Schumacher, L. (2004b). Simulation in nursing education: Nursing in a learning resource center. In G. E. Loyd, C. L. Lake & R. B. Greenburg (Eds.), *Practical health care simulations* (pp. 169-175). Philadelphia, PA: Elsevier/Mosby.
- Schwid, H. A., & O'Donnell, D. (1990). The anesthesia simulator-recorder: A device to train and evaluate anesthesiologists' responses to critical incidents. *Anesthesiology*, 72(1), 191-197.
- Schwid, H. A., & O'Donnell, D. (1992). Anesthesiologists' management of simulated critical incidents. *Anesthesiology*, 76(4), 495-501.
- Schwid, H. A., Rooke, G. A., Carline, J., Steadman, R. H., Murray, W. B., Olympio, M., et al. (2002). Evaluation of anesthesia residents using mannequin-based simulation: A multiinstitutional study. *Anesthesiology*, 97(6), 1434-1444.
- Schwid, H. A., Rooke, G. A., Ross, B. K., & Sivarajan, M. (1999). Use of a computerized Advanced Cardiac Life Support simulator improves retention of Advanced Cardiac Life Support guidelines better than a textbook review. *Critical Care Medicine*, 27(4), 821-824.
- Sedlack, R. E., & Kolars, J. C. (2002). Colonoscopy curriculum development and performance-based assessment criteria on a computer-based endoscopy simulator [Abstract]. *Academic Medicine*, 77(7), 750-751.
- Shaffer, D. W., Dawson, S. L., Meglan, D., S., C., Ferrell, M., Norbash, A., et al. (2001). Design principles for the use of simulation as an aid in interventional cardiology training. *Minimally Invasive Therapy & Allied Technologies*, 10(2), 75-82.

- Shalala, D., & Herman, A. (2000). *Doing what counts for patient safety: Federal actions to reduce medical errors and their impact - Report to the President*. Washington, DC: Report of the Quality Interagency Coordination Task Force (QuIC)o. Document Number)
- Shapiro, M. J., Morey, J. C., Small, S. D., Langford, V., Kaylor, C. J., Jagminas, L., et al. (2004). Simulation based teamwork training for emergency department staff: Does it improve clinical team performance when added to an existing didactic teamwork curriculum? *Quality and Safety in Health Care*, 13(6), 417-421.
- Sica, G. T., Barron, D. M., Blum, R., Frenna, T. H., & Raemer, D. B. (1999). Computerized realistic simulation: A teaching module for crisis management in radiology. *American Journal of Roentgenology*, 172(2), 301-304.
- Sinz, E. (2004). Partial-task-trainers & simulation in critical care medicine. In W. F. Dunn (Ed.), *Simulators in critical care and beyond* (pp. 33-41). Des Plaines, IL: Society of Critical Care Medicine.
- Sinz, E. (2005). Simulation-based education for cardiac, thoracic, and vascular anesthesiology. *Seminars in Cardiothoracic and Vascular Anesthesia*, 9(4), 291-307.
- Sohmura, T., Hojo, H., Nakajima, M., Wakabayashi, K., Nagao, M., Iida, S., et al. (2004). Prototype of simulation of orthognathic surgery using a virtual reality haptic device. *International Journal of Oral and Maxillofacial Surgery*, 33(8), 740-750.
- Sorenson, J. L. (2002). *The use of simulated clinical experiences to improve competency in the novice anesthesia provider*. Unpublished doctoral dissertation, The University of Tennessee Health Science Center, Tennessee.
- Spunt, D., Foster, D., & Adams, K. (2004). Mock code: A clinical simulation module. *Nurse Educator*, 29(5), 192-194.
- St Clair, E. W., Oddone, E. Z., Waugh, R. A., Corey, G. R., & Feussner, J. R. (1992). Assessing house staff diagnostic skills using a cardiology patient simulator. *Annals of Internal Medicine*, 117(9), 751-756.
- Steadman, R. H., Coates, W. C., Huang, Y. M., Matevosian, R., Larmon, B. R., McCullough, L., et al. (2006). Simulation-based training is superior to problem-based learning for the acquisition of critical assessment and management skills. *Critical Care Medicine*, 34(1), 151-157.

- Stross, J. K. (1983). Maintaining competency in Advanced Cardiac Life Support skills. *Journal of the American Medical Association*, 249(24), 3339-3341.
- Székely, G. (2003). Surgical simulators. *Minimally Invasive Therapy & Allied Technologies*, 12(1/2), 14-18.
- Tan, G. M., Ti, L. K., Suresh, S., Ho, B. S., & Lee, T. L. (2002). Teaching first-year medical students physiology: Does the human patient simulator allow for more effective teaching? *Singapore Medical Journal*, 43(5), 238-242.
- Theall, M. (1999). *Motivation from within: Approaches for encouraging faculty and students to excel*. San Francisco: Jossey-Bass Publishers.
- Treadwell, I., & Grobler, S. (2001). Students' perceptions on skills training in simulation. *Medical Teacher*, 23(5), 476-482.
- Treloar, D., Hawayek, J., Montgomery, J. R., & Russell, W. (2001). On-site and distance education of emergency medicine personnel with a human patient simulator. *Military Medicine*, 166(11), 1003-1006.
- Tsai, T.-C., Harasym, P. H., Nijssen-Jordan, C., Jennett, P., & Powell, G. (2003). The quality of a simulation examination using a high-fidelity child manikin. *Medical Education*, 37(Suppl 1), 72-78.
- Tuggy, M. L. (1998). Virtual reality flexible sigmoidoscopy simulator training: Impact on resident performance. *Journal of the American Board of Family Practice*, 11(6), 426-433.
- Tulving, E., & Thomson, D. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychology Review*, 80, 352-373.
- van Meurs, W. L., Couto, P. M., Couto, C. D., Bernardes, J. F., & Ayres-de-Campos, D. (2003). Development of foetal and neonatal simulators at the University of Porto. *Medical Education*, 37 (Suppl. 1), 29-33.
- Via, D. K., Kyle, R. R., Trask, J. D., Shields, C. H., & Mongan, P. D. (2004). Using high-fidelity patient simulation and an advanced distance education network to teach pharmacology to second-year medical students. *Journal of Clinical Anesthesia*, 16(2), 144-151.

- von Lubitz, D. K., Carrasco, B., Gabrielli, F., Ludwig, T., Levine, H., Patricelli, F., et al. (2003). Transatlantic medical education: Preliminary data on distance-based high-fidelity human patient simulation training. *Studies in Health Technology and Informatics*, 94, 379-385.
- Vozenilek, J., Huff, J. S., Rezek, M., & Gordon, J. A. (2004). See one, do one, teach one: Advanced technology in medical education. *Academic Emergency Medicine*, 11(11), 1149-1154.
- Vozenilek, J., Wang, E., Kharasch, M., Anderson, B., & Kalaria, A. (2006). Simulation-based morbidity and mortality conference: New technologies augmenting traditional case-based presentations. *Academic Emergency Medicine*, 13(1), 48-53.
- Wackett, A., Anderson, K., & Thode, H. (2005). Bullard laryngoscopy by naive operators in the cervical spine immobilized patient. *Journal of Emergency Medicine*, 29(3), 253-257.
- Waisman, Y., Amir, L., & Mimouni, M. (2002). Does the Pediatric Advanced Life Support course improve knowledge of pediatric resuscitation? *Pediatric Emergency Care*, 18(3), 168-170.
- Wang, E. E., & Vozenilek, J. A. (2005). Addressing the systems-based practice core competency: A simulation-based curriculum. *Academic Emergency Medicine*, 12(12), 1191-1194.
- Watterson, L., Flanagan, B., Donovan, B., & Robinson, B. (2000). Anaesthetic simulators: Training for the broader health-care profession. *Australian and New Zealand Journal of Surgery*, 70(10), 735-737.
- Wayne, D. B., Butter, J., Siddal, V. J., Fudala, M. J., Wade, L. D., Feinglass, J., et al. (2006). Mastery learning of Advanced Cardiac Life Support skills by Internal Medicine residents using simulation technology and deliberate practice. *Journal of General Internal Medicine*, 21(2), 251.
- Wayne, D. B., Butter, J., Siddall, V. J., Fudala, M. J., Linqvist, L. A., Feinglass, J., et al. (2005). Simulation-based training of internal medicine residents in Advanced Cardiac Life Support protocols: A randomized trial. *Teaching and Learning in Medicine*, 17(3), 202-208.
- Weller, J. (2004). Simulation in undergraduate medical education: Bridging the gap between theory and practice. *Medical Education*, 38(1), 32-38.
- Weller, J., Bloch, M., Young, S., Maze, M., Oyesola, S., Wyner, J., et al. (2003). Evaluation of high fidelity patient simulator in assessment of performance of anaesthetists. *British Journal of Anaesthesia*, 90(1), 43-47.

- Weller, J., Dowell, A., Kljakovic, M., & Robinson, B. (2005). Simulation training for medical emergencies in general practice. *Medical Education*, 39(11), 1154.
- Weller, J., Robinson, B., Larsen, P., & Caldwell, C. (2004). Simulation-based training to improve acute care skills in medical undergraduates [Abstract]. *New Zealand Medical Journal*, 117(1204), U1119.
- Wilson, M., Shepherd, I., Kelly, C., & Pitzner, J. (2005). Assessment of a low-fidelity human patient simulator for the acquisition of nursing skills. *Nurse Education Today*, 25(1), 56-67.
- Winston, I., & Szarek, J. L. (2005). Problem-based learning using a human patient simulator. *Medical Education*, 39(5), 526-527.
- Wlodkowski, R. (1999). Motivation and diversity: A framework for teaching. In M. Theall (Ed.), *Motivation from within: Approaches for encouraging faculty and students to excel* (pp. 7-16). San Francisco: Josey-Bass Publishers.
- Wong, A. K. (2004). Full scale computer simulators in anesthesia training and evaluation. *Canadian Journal of Anaesthesia*, 51(5), 455-464.
- Wong, S. H., Ng, K. F., & Chen, P. P. (2002). The application of clinical simulation in crisis management training. *Hong Kong Medical Journal*, 8(2), 131-135.
- Woolfolk, A. (2004). *Educational psychology* (9th ed.). Boston, MA: Allyn and Bacon.
- Woollicroft, J. O., Calhoun, J. G., TenHaken, J. D., & Judge, R. D. (1987). Harvey: The Impact of a cardiovascular teaching simulator on student skill acquisition. *Medical Teacher*, 9(1), 53-57.
- Worksheet ID - Are people who are trained in CPR willing to perform it? (Chest compression only) (A). (2005). Retrieved Sept. 1, 2006, from <http://www.americanheart.org/presenter.jhtml?identifier=3027885>
- Worksheet ID - Are people who are trained in CPR willing to perform it? (Chest compression only) (B). (2005). Retrieved Sept. 1, 2006, from <http://www.americanheart.org/presenter.jhtml?identifier=3027886>
- Wortock, J. M. M. (2002). *Brain-based learning principles applied to the teaching of basic cardiac code to associate degree nursing students using the Human Patient Simulator*. Unpublished doctoral dissertation, University of South Florida, United States -- Florida.

- Wright, M. C., Taekman, J. M., Barber, L., Hobbs, G., Newman, M. F., & Stafford-Smith, M. (2005). The use of high-fidelity human patient simulation as an evaluative tool in the development of clinical research protocols and procedures. *Contemporary Clinical Trials*, 26(6), 646-659.
- Wright, M. C., Taekman, J. M., & Endsley, M. R. (2004). Objective measures of situation awareness in a simulated medical environment. *Quality and Safety in Health Care*, 13 (Suppl. 1), i65-71.
- Wyatt, A., Fallows, B., & Archer, F. (2004). Do clinical simulations using a human patient simulator in the education of paramedics in trauma care reduce error rates in preclinical performance [Abstract]? *Prehospital Emergency Care*, 8(4), 435-436.
- Yaeger, K. A., Halamek, L. P., Coyle, M., Murphy, A., Anderson, J., Boyle, K., et al. (2004). High-fidelity simulation-based training in neonatal nursing. *Advances in Neonatal Care*, 4(6), 326-331.
- Yee, B., Naik, V. N., Joo, H. S., Savoldelli, G. L., Chung, D. Y., Houston, P. L., et al. (2005). Nontechnical skills in anesthesia crisis management with repeated exposure to simulation-based education. *Anesthesiology*, 103(2), 241-248.
- Ziv, A., Ben-David, S., & Ziv, M. (2005). Simulation based medical education: An opportunity to learn from errors. *Medical Teacher*, 27(3), 193-199.
- Ziv, A., Small, S. D., & Wolpe, P. R. (2000). Patient safety and simulation-based medical education. *Medical Teacher*, 22(5), 489-495.
- Ziv, A., Wolpe, P. R., Small, S. D., & Glick, S. (2003). Simulation-based medical education: An ethical imperative. *Academic Medicine*, 78(8), 783-788.