

Comprehensive Healthcare Simulation

Series Editors: Adam I. Levine · Samuel DeMaria Jr.

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Comprehensive Healthcare Simulation: Anesthesiology

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Foreword

The Truth About Simulation: Beyond the Obvious

Readers of this text are perhaps already well-familiar with the ways in which simulation training can improve individual technical skills, nontechnical skills, and team performance. But the as-yet underappreciated truth about simulation training is this: simulation fundamentals are actually leadership fundamentals. The educator or clinician who masters the simulation content in this book will also be a master of difficult communication, institutional change management, emotional intelligence, strategic planning, decision-making, and other core skills identified ubiquitously by authorities on leadership development.

Simulation as Play

Although medical simulation is serious in nature, simulation itself may be viewed as a form of play. Play activities confer many benefits, which may include strengthened relationships, enhanced problem-solving, and heightened creativity, which combine to create more flexible, adaptive, and effective responses to tough situations. As well, simulation activities by nature are a kind of role-play activity, which offers opportunities to experiment with event management or communication styles in low-stress environments. Feedback on these approaches, including an understanding of how others are likely to think and feel, enhances participants' emotional intelligence and therefore prepares participants to respond most effectively, and quickly, during real critical events. Play also strengthens social bond, which is a critical component to resilience and the combat of burnout. In the setting of inter-professional simulation, play builds a stronger sense of community and trust, which benefits healthcare professionals, healthcare organizations, and patients. Finally, improvisation (either during a scenario or as used in a debriefing exercise) fosters mindfulness. One definition of mindfulness is the state of being attentive to and aware of what is happening in the present moment. Clearly, anesthesiology requires vigilant attention and sharp situation awareness, which mirrors the definition of mindfulness exactly. And, improv training is an increasingly popular tool for leadership development.

Simulation as Organizational Change

Many pioneers of simulation education and developers or champions of new simulation centers over the past two decades share a common experience. They identify with the “build it and they will come” evolution of interest and resourcing of their intended activities, physical and logistical needs, and personnel requirements. These leaders faced tough challenges and by necessity have developed great elevator pitches and value propositions. Simulation training is characterized by an often elusive and somewhat intangible return on investment, especially when it is in the early stages of development. But simulation has been studied as a major tool for effecting cultural change (adopting or improving organizational safety culture), including

safety strategies and responses to error or adverse events. The increasing demand for inter-professional and multidisciplinary simulation training that is sweeping medical centers across the nation is indeed the result of early wins by simulation pioneers and subsequent organizational change.

Simulation as Strategic Planning

Designing, building, stocking, and staffing a new clinical care center (whether small outpatient procedure center or major hospital) are no small feat. Simulation allows for provocation of workflow models, internal systems, and environmental vulnerabilities while there is still an opportunity to modify those elements without jeopardizing patient safety. A principle of adaptive leadership (as outlined by Travis Bradberry in *Leadership 2.0*) is *organizational justice*, which includes decision fairness and outcome concern. Simulations for strategic planning inform where and why specific resources should be allocated and prioritized. This not only strengthens the safety and effectiveness of the new clinical care environment but also provides transparency and justification to the organization as a whole. Even if there are groups who are disappointed with the eventual decisions, it will be clear that leaders care about how such decisions and system designs impact the work of everyone involved and have performed highly visible, thoughtful analysis of competing priorities.

Simulation as Communication Training

High-stakes communications occur every day in every operating room, intensive care unit, or pain management clinic setting. Even routine cases are characterized by multiple opportunities for communication failure, and communication failure is noted as a root cause in The Joint Commission's review of sentinel events year after year. Communication challenges are frequent and can be magnified if relationships are threatened or authority gradients exist. Widely adopted debriefing models (such as the "advocacy/inquiry" approach) include an exploration of the "frames" of all participants, mirroring the classic advice from Stephen Covey in *The 7 Habits of Highly Effective People*: "seek first to understand, then to be understood." Many debriefing paradigms also include elements of psychological safety, exploring others' perspectives, and acknowledging that one's own interpretation of observed behavior is augmented (perhaps erroneously) by past experience. These elements are among those featured in Kerry Patterson's *Crucial Conversations: Tools for Talking When Stakes Are High*. As important as understanding these techniques, if not more so, is the repeated opportunity to *practice* language models that facilitate critical communication in time-pressured, high-stakes situations.

Simulation as Team Management Training

Leaders of clinical emergencies must be facile in timely decision-making, delegation of roles, monitoring of performance, mobilizing resources, and anticipating and planning for future patient states. Simulation allows for practice in each of these areas. Emergency management paradigms (including crisis resource management) include elements of leveraging differences – what can people do, how can we be sure that all necessary items get done, and who is best to do what. These questions inform optimal role assignment, task delegation, and resource management. Although typically not characterized by the same level of urgency, classic leadership skills for managing individuals and teams include optimizing outcomes by understanding and valuing the differences among team members and putting them to best use.

As you read the text, notice these themes. Decision-making, team training, event management, communication, and other major leadership skills are highly represented in every chapter.

Simulation educators not only teach leadership skills but also use those same skills as they navigate difficult debriefing situations, design curricula creatively in low-resource environments, and add value to their institutions by contributing to patient safety initiatives and strategic planning. In every element of simulation training design, implementation, and evaluation, you will see core leadership principles at play.

Simulation fundamentals are leadership fundamentals.

Raleigh, NC, USA

Marjorie Podraza Stiegler, MD

Preface

Simulation technology has been with us for decades, and as early adopters, anesthesiologists have played a major role in integrating this tool not only into our own training and assessment but throughout healthcare pedagogy. A goal of this text was to avoid an over-reliance on an esoteric narrative or descriptive approach to the use of simulation technology in the field of anesthesiology. While those looking to create a report or historical account on this topic may find something of utility in these pages, our intended audience has been, from the outset, *educators*. What we hope to have accomplished, to the extent possible, is the creation of a practical tool for those tasked with implementing a curriculum that is simulation-based or that incorporates simulation. We have, by necessity, included the requisite background information regarding the history of this technology and its associated pedagogy in order to equip the novice simulation educator with baseline knowledge and familiarity. What follows, however, is meant to be practical in its composition, providing our audience with a “how to” manual for integrating simulation into a variety of settings involving anesthesiology education, assessment, and practice.

In this text, you will find insights and tools provided by the leading simulation experts in the field of anesthesiology. In the first section, you will find a tripartite introduction to simulation in anesthesiology consisting of the application of the basics of education theory and practice to simulation, the context in which simulation is applied in the field of anesthesiology, and a review of the modalities through which simulation can be applied. The next section provides a review and a practical guide to the application of simulation to different populations of learners within the field of anesthesiology. In the third section, our authors provide a review and practical guide to simulation in the subspecialties of anesthesiology. The prospective (or experienced) simulationist/anesthesiologist can turn to these pages as a first resource when tasked with creating a curriculum for any level of learner and in any subspecialty of the field. Each chapter provides instructions, examples, and further resources for those looking to incorporate simulation into their educational toolkit.

We have bookended this text with a historic perspective on simulation in the field of anesthesiology and a look into the future of the application of this technology. A strong theme that runs through both chapters is one of the increasing incorporations of simulation into the training, assessment, and even practice of the anesthesiology. It is a privilege to provide you, our readers, with this “first of its kind” practical guide aimed to facilitate education in the field that blazed the trail for the incorporation of simulation in healthcare and seems likely to maintain this role in the future. Like all technology, the past and future of simulation in healthcare is highly dynamic and rapidly evolving, and this text will likely hold a modest shelf life barring future revisions. However, we have provided lessons from experts in the field, so our readers will be unburdened from “recreating the wheel” and will instead have the opportunity to contribute their own novel approaches in the application of this exciting technology to improving the training of tomorrow’s providers and the quality of care our patients receive.

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Bryan Mahoney, MD, FASA: I would like to thank the editors of the original *The Comprehensive Textbook of Healthcare Simulation* who invited us to prepare this text, my coeditors who have joined me on this amazing journey, the Mount Sinai Health System Department of Anesthesiology for its support in time and resources, and my family for its patience with many extra nights and weekends spent preparing this text.

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Part I

Introduction to Simulation for Anesthesiology

Anesthesia and Simulation: An Historic Relationship

1

Daniel Saddawi-Konefka and Jeffrey B. Cooper

Introduction

While the rise of simulation in healthcare in general appears to be fairly recent, simulation of many forms has actually been used for well over a thousand years. Owen, in his book *Simulation in Healthcare Education: An Extensive History*, goes back to 500 AD for the first documented use of simulation in healthcare education [1]. This was described in the *Sushruta Samhita*, where students were urged to practice incisions on items that resembled parts of the human body (e.g., gourds, leather bags filled with fluid, or dead animals). Students were encouraged to practice “so that they could be quick, which was important when operating on patients without the benefit of anesthesia” [1]. In its long history since, simulation spread across many geographies and disciplines, including surgery, obstetrics and gynecology, ophthalmology, urology, dentistry, trauma, and nursing. What is remarkable is that Owen’s historical textbook of over 400 pages ends its story at about 1950! All of those working in the modern world of simulation who think they have started something new may in fact have much to learn from earlier generations.

Use of simulation in anesthesiology is now widespread, and anesthesiologists are seen as pioneers of the modern era of simulation. Interestingly, however, the term “anesthesia” is mentioned only a few times in Owen’s text, and even then only as it related to practice of intubation (not involving anes-

thesiologists). This may not be too surprising since anesthesiology as an independent field only developed its footing in the early 1900s, and simulation’s first major introduction in anesthesiology did not occur until the 1960s and took over two decades to gain any serious national attention. In telling the story of the now widespread uses of simulation in anesthesiology, we can learn much from why it took so long for this now-obvious patient safety and educational tool to take hold in anesthesiology and the rest of health care. What does it take to spread an idea? It is an inspiring story, but not without some fits and starts. There are pioneers and innovative technologies. There are lessons to be learned that can be applied to the patient safety challenges that still face us. And there is an unfinished story that needs to be continued.

In this chapter, we pick up the story in the 1960s, shortly after Owen left off, focusing on simulation in anesthesiology. Due to anesthesiology’s central place in the development of modern simulation, this history has been discussed in several other writings. We draw on two of these key references more heavily in this chapter and recommend them to interested readers [2, 3]. Because of the foundational role patient safety played in the dissemination of simulation in anesthesiology, we begin by describing the relationship between anesthesiology, simulation, and patient safety.

Chapter Objectives

Readers will learn about the earliest “modern” simulators in anesthesiology and the challenges that these pioneers faced in trying to establish the role of simulation in anesthesiology education. They will also learn about the critical drivers that led to the successful dissemination of simulation in the field. In particular, they will read about the critical role of patient safety to establish a successful value proposition for simulation. Finally, they will learn about the scholars whose work propelled simulation to the central stage it currently holds in anesthesiology.

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Anesthesiology, Simulation, and Patient Safety

Anesthesiology is rooted in patient safety. Because anesthesia is not generally therapeutic by itself, there is even more than the usual motivation to do no harm, or, in the words of the original mission and now vision of the Anesthesia Patient Safety Foundation (APSF), “To ensure that no patient is harmed by anesthesia” [4]. In this chapter, we will trace how those roots are responsible for the leading role that anesthesiology has played in the development and dispersion of simulation in health care.

Anesthesiology simulation, as we have come to know it, grew independently and convergently from the interests of different individuals in both medical education and patient safety. In the 1960s, Dr. Stephen Abrahamson, an educator, led the first relatively modern introduction of full-scale simulation in anesthesiology [5]. His foray into medical education came from his interest in using early-stage computers to enhance the educational experience. It was somewhat serendipitous that he teamed with an anesthesiologist for his simulation project. Their focus was on education, not patient safety, and as a result, they struggled to “find a market” for their work – there was no recognized unmet need.

It was not until the second modern wave of simulation (starting in the mid-1980s) that simulation in healthcare began to take hold. This wave was driven not just to develop physiologic models of anesthesia that could enhance teaching but also from full-scale simulation environments created

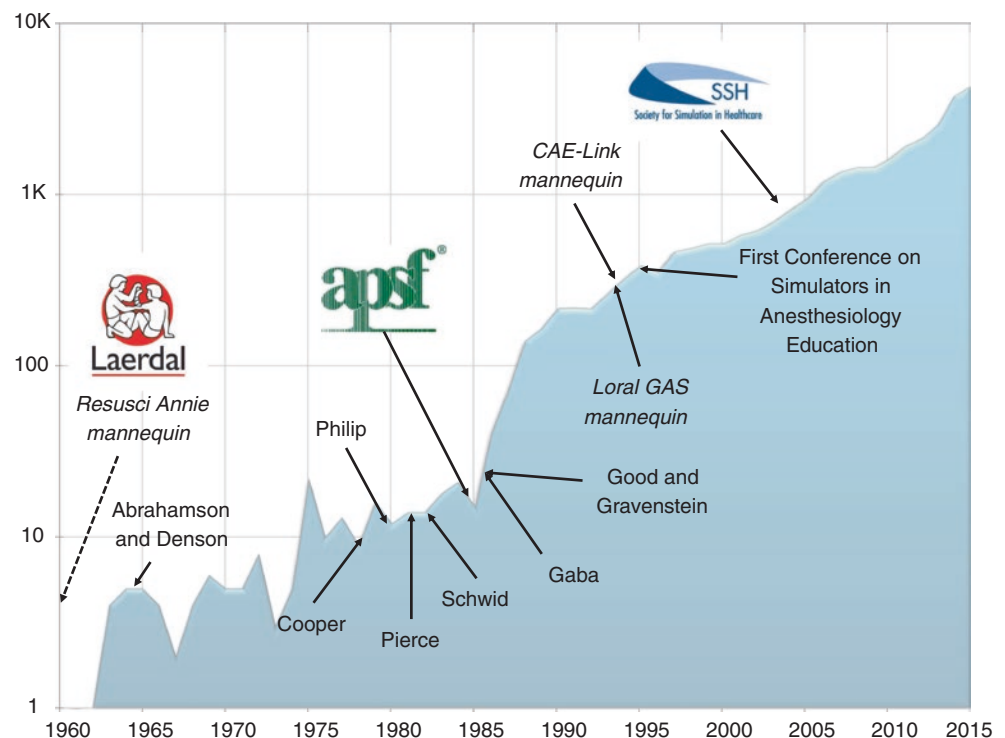
to address patient safety issues. Five simulation pioneers in anesthesiology (each developing some aspect of simulation for different reasons) were James Philip, Howard Schwid, David Gaba, and the mentor/mentee team of J.S. Gravenstein and Michael Good [6–10].

In between these two waves, Jeffrey Cooper and Ellison Pierce championed an increased focus on patient safety [11–13], fertilizing the grounds from which simulation would grow. This focus on patient safety was key to simulation’s success, as simulation became a powerful tool to combat a widely appreciated problem. Figure 1.1 illustrates how some specific landmark events aligned with the growth of interest in anesthesiology (as gauged by the number of peer-reviewed publications on simulation in anesthesiology). The clear inflection that occurred in the 1980s was in large part a result of the research program of the APSF and other activities it promoted to enhance dissemination.

Stephen Abrahamson and Judson Denson: Sim One’s Attempt to Establish a New Educational Paradigm [14]

“Sim One,” the first computer-controlled simulation mannequin, was a remarkably capable device, with features that surpass some of those in technologies found today. It was developed by Drs. Stephen J. Abrahamson and Judson S. Denson at the University of Southern California and publicly revealed in 1967 – only 20 years after the first computer

Fig. 1.1 The graph is a semilog plot showing the number of PubMed-indexed citations for “anesthesia and simulation” or “anesthesiology and simulation” from 1965 through 2015. Overlaid on top of this graph are the approximate years that each of the pioneers in the field first made their work public. Relevant societies are also shown. Major commercial mannequin releases are shown in italics



(ENIAC) was developed. This impressive feat of technology proposed a drastic and expensive change from the teaching paradigm of the day, and this is likely why it received limited acceptance from academic medical education.

Abrahamson earned his Ph.D. in Education from New York University in 1951 with post-doctoral work concentrating on evaluation. In 1952, he joined the faculty at the University of Buffalo and soon became the head of the Education Research Center. In 1963, he was recruited by the University of Southern California to lead its Department of Medical Education. One of his early charges was to partner with an engineer, Tullio Ronzoni, to explore uses for computing in medical education. Typical uses for computers in medicine at the time were for data storage, retrieval, and some analysis. Using a computer for simulation or interactive scenarios was uncommon, if done at all, but that is exactly what they set out to do. More specifically, their idea was to use computers to present anesthesiology trainees with simulated data reflecting what they might see during a typical anesthetic (e.g., pulse, respiratory rate), and have them react to that data. The operator of the simulator could manipulate the data in real time, and trainees would then have to decide what actions to take in response.

Because he had essentially no knowledge of anesthesia, Abrahamson approached Dr. Judson “Sam” Denson, the chief anesthesiologist at Los Angeles County Hospital. Over time, the idea grew, and they decided to mock up an entire body, “life-like and life-size,” complete with plastic skin that could become cyanotic, chest wall and diaphragm movement for breathing, heart sounds, palpable pulses (temporal and radial), teeth that could be broken with laryngoscopy, eyes that closed with variable force, pupils that constricted, and more. They used variably magnetized needles with flow sensors to identify which “drugs” were being injected into the simulator and in what quantities. Despite multiple failures to obtain funding from the NIH, Abrahamson was ultimately able to secure a grant of \$272,000 from the US Office of Education’s Cooperative Research Project to fund a 2-year feasibility study. Abrahamson developed measurement and assessment tools for performance and ultimately compared trainees who had used the simulator versus those who had not [5, 15].

Though several lay publications reported on Sim One [16], the medical community strongly resisted adopting this model for training. It is likely that the cost and limitations of the rudimentary computer technology made it impractical for replication at the time. It is also likely that the technology threatened to undermine traditional education methods that were widely accepted and in use. This is supported by anecdotal reports that the reaction to Sim One was at times viscerally unfavorable. For example, when being moved from one location to another, someone deliberately and unnecessarily cut off one of Sim One’s arms, which contained much

of its electronics, to fit the simulator through a doorway. It has been suggested that Sim One was simply a disruptive technology far ahead of its time [3].

Ellison “Jeep” Pierce and Jeffrey Cooper: Galvanizing the Focus on Patient Safety in Anesthesiology

The Patient Safety Movement in healthcare began years before the oft-cited 1999 publication of the influential Institute of Medicine report “To Err is Human”, which catalyzed a widespread Patient Safety Movement in the USA and throughout the world. Early work in anesthesiology started in 1978, with a publication by Dr. Jeffrey Cooper (an engineer) and colleagues that brought attention to the role of human error in preventable adverse outcomes [11]. His later publication in 1984 expanded on that work [17].

Jeff Cooper completed his Bachelor’s in Chemical Engineering and Master’s in Biomedical Engineering from Drexel University before completing a Ph.D. in Chemical Engineering at the University of Missouri. In 1972, he joined the Anesthesia Bioengineering Unit of the Department of Anesthesia at the Massachusetts General Hospital (MGH). In 1974, leading an interdisciplinary team, he set out to learn about how errors in using anesthesia equipment contributed to adverse outcomes. In so doing, his team stumbled onto the “critical incident” technique and used it to learn about the broader topic of errors in anesthesiology, with a focus on human factors [11, 17, 18].

The work of the MGH team shifted the focus to human error. Coupled with relatively high malpractice insurance premiums and some media attention about anesthesia-related deaths, this work created fertile ground for change and innovation. But, an effective clinical leader was still needed to make the topic visible and palatable. Dr. Ellison C. Pierce, Jr. was that leader. At the time, he was the Chair of the Department of Anesthesia at the Deaconess Hospital. Affectionately called by his nickname “Jeep” by all his colleagues, Pierce met with Cooper when he volunteered his department for participation in the critical incident studies. Pierce and Cooper found common ground in their interest in preventing accidental deaths and serious injuries related to anesthesia. As President of the American Society of Anesthesiologists in 1983, Pierce spoke about the importance of injury prevention as the best way to address the malpractice crisis.

In 1984, Pierce, Cooper, and Richard J. Kitz, Chairman of the Anesthesia Department at the MGH, organized the International Symposium on Preventable Anesthesia Mortality and Morbidity in 1984 [18]. During the conference, Pierce conceived the idea of a foundation dedicated to preventing adverse outcomes. Working with a few colleagues,

he founded the APSF in 1986 to accomplish this goal [12, 19]. Cooper, seeing the need for funding to support patient safety research, instigated the creation of the APSF's research program. In its first 3 years, 1987–1989, APSF awarded four grants for work that involved simulation by three of the pioneers whom we highlight below. Later, the APSF sponsored conferences to explore and support the use of simulation throughout anesthesiology.

James Philip: Development of a Digital Pharmacokinetic Simulator [20, 21]

Dr. James “Jim” Philip earned Bachelor’s and Master’s Degrees in Electrical Engineering from Cornell University before completing medical school at SUNY in Syracuse. He completed his anesthesiology residency and then joined the faculty at the Peter Bent Brigham Hospital (now the Brigham and Women’s Hospital, or BWH) in 1978. Because his contributions to simulation have been limited to anesthesiology (and more specifically to digital simulation of volatile anesthetic kinetics), he is not often mentioned in general simulation history texts. As this book is devoted to the history of simulation in anesthesiology, Jim Philip’s contributions are certainly relevant. In 1978, when he was first on faculty, his department chair, Leroy D. Vandam, M.D., challenged him to become an expert in inhalation anesthetic agent kinetics and teach it to their residents; Philip accepted the challenge (Fig. 1.2).

To this end, he assembled a device composed of tubing sections and containers to simulate the lungs, cardiac output, tissues, etc. By adjusting stopcocks and roller clamps, he could dynamically alter each variable (e.g., decrease venous return by partially closing one of the roller clamps). Infusing colored liquids into the system completed the effect; he had created a dynamic, tangible simulation of inhaled anesthetic agent



Fig. 1.2 James Philip (right) and Roger Russell with early version of Gasman, 1991

kinetics. This model was met with wonderful reviews from faculty and residents. After accidentally spilling a copious quantity of the blue dyed liquid on his shirt, he realized that he needed a much more convenient and sustainable model.

Philip turned to computers for a solution. In August of 1980, he successfully applied for a grant from the Apple Educational Foundation to use Apple II computers to graphically display the compartment model of inhaled anesthetic agent kinetics. Through incredible dedication, he was able to design, code, and test the program, which he ultimately called “Gas Man™.” Gas Man™ received positive reviews at the 1982 American Society of Anesthesiologists Annual Meeting and won a Special Award for Innovation at the New York State Society of Anesthesiologists Post Graduate Assembly.

Over the next few years, Philip successfully obtained the full title to Gas Man™ and published his work with Addison-Wesley. Though this was commercially fairly successful, Addison-Wesley dropped its entire medical publishing division in 1986, including Gas Man™. In 1991, Philip contracted with H. M. Franklin Associates (HMFA) to perform all further programming and updates to Gas Man™; that relationship has continued. Currently, this form of educational simulation is being used to teach inhaled anesthetic agent uptake and distribution at over 100 institutions including anesthesiology residency programs, medical schools, manufacturers, and veterinary schools. Philip was one of the founding members of the Society for Technology in Anesthesia (STA) and served as its President from 1999 to 2000.

Howard Schwid: Moving Physiology Simulation to the Personal Computer

In the 1970s, Dr. N. Ty Smith and Dr. Yasuhiro Fukui developed computerized models to simulate physiology and its response to medications [22]. This work would form the foundation for Dr. Howard A. Schwid’s contributions to simulation [3]. After developing an early interest in computer programming and artificial intelligence, Schwid studied biomedical engineering at the University of Wisconsin-Madison. He spent much of his elective time in computer and electrical engineering, with a special interest in mathematical modeling of physiological processes, including those earlier developed by Fukui. During medical school at the University of Washington, he found physiology classes (that included lectures and a dog lab) much less satisfying than the complete mathematical models he could seamlessly manipulate during his engineering days. Though his clinical years would teach him that “physicians are seldom able to measure everything,” [3] he maintained his passion for modeling physiological processes with computers (Fig. 1.3).

Schwid was drawn to anesthesiology because of its emphasis on monitors, data, physiology, and pharmacology. In 1982, during his final year in medical school, he began the development of a computerized model of inhalational anesthetic agent uptake and distribution using the computer programming language Fortran. He continued his work during his anesthesiology residency, adding the cardiovascular system and capability of simulating the pharmacokinetic and dynamic responses to intravenous agents as well. This robust system could reasonably predict responses to many anesthetic agents under several pathophysiological conditions.

After completing the computer modeling system, Schwid turned his attention to developing a physical complement to make it seem real. He joined Dr. N. Ty Smith at the University of California San Diego as a fellow and began working with a flight simulator company (Rediffusion Simulation Incorporated) to develop a simulator on a Sun workstation. Though this simulator was met with some interest (it won the “Best Instructional Exhibit” at the 1985 New York State Society of Anesthesiologists Postgraduate Assembly), it did not become a commercial success. That was likely due in part to its requiring an expensive workstation. Also, as with Sim One, the field was not yet ready to accept computers over traditional models of training. Indeed, Schwid commented that when he was applying for full time positions where he could further his work, “most believed there was no future in medical simulation, and some even went so far as to counsel me to do something else with my career.”

He was given a chance to pursue this passion by Dr. Tom Hornbein at the University of Washington, and he joined the faculty in 1986. He advanced the computer modeling of his simulator and published numerous articles on various aspects of it [9, 10, 23–27]. Since Schwid was unable to secure sufficient funding to further develop his simulation ideas, he formed his own company with the aim of dis-

seminating his training concepts. He recognized that for the product to be practical for individual clinicians to use themselves, it would have to run on personal computers. He thus developed a program that ran on DOS machines. Further developments (including a scoring and debriefing tool) were developed using profits from his company and a grant from the APSF. This offering was eventually sold under the name “Anesthesia Simulator” through the company he founded in 1987, Anesoft. Interestingly, though Schwid had assumed that sales of his program would be driven by educational demand, residency programs and medical schools were the smallest fraction of purchasers, whereas private practice groups comprised the largest market. It was eventually folded into the CAE-Link Patient Simulator (which is discussed in the “Dissemination since 1990” section below).

David Gaba: Simulation for Crisis Resource Management and the Study of Human Performance

Dr. David Gaba’s interest in simulation grew from a passion for patient safety [3]. Gaba’s undergraduate education was in biomedical engineering. He had a keen interest in what he termed “intelligent responsive systems.” Being drawn to the clinical aspects of biomedical engineering, he pursued medicine and found a natural home for his passions in anesthesiology, ultimately taking a faculty position at Stanford University (Fig. 1.4).

In a memoir, Gaba wrote that the book *Normal Accidents: Living with High-Risk Technologies* by Charles Perrow transformed the way he viewed patient safety in anesthesiology [28]. The book detailed the Three Mile Island nuclear power plant accident (among other famous accidents), suggesting that some accidents are unavoidable because of the “tight coupling” in complex systems. In 1987, Gaba applied



Fig. 1.3 Howard Schwid and Dan O'Donnell with Anesoft Anesthesia Simulator, 1989



Fig. 1.4 David Gaba, Abe DeAnda, and Mary Maxwell, with pre-prototype simulator (CASE 0.5), 1986

Perrow's principles to anesthesiology in a landmark paper, "Breaking the Chain of Accident Evolution in Anesthesia" [29]. Gaba set about creating a laboratory in which he could subject anesthesiologists to critical situations and study how they responded. He believed that simulating critical events could also help train clinicians, improve their decision-making, and avoid some errors.

With no commercially available simulators at the time, Gaba and his team developed their own technology. Initially, they did so by combining an airway intubation trainer with an endotracheal tube (to serve as the extension of the simulated trachea) that was connected to a reservoir bag (to simulate the lungs). They used virtual devices to produce pulse oximeter, EKG, and blood pressure readings. Finally, they developed a scenario – a pneumothorax, which was simulated by altering the displayed vital signs and partially clamping the simulated trachea to increase airway pressures. To test the scenario, an anesthesiologist unaware of the scenario participated while Gaba recorded and analyzed her think-aloud responses to the events as they unfolded.

Gaba used this preliminary work to successfully apply for a \$35,000 grant from the APSF to develop a more sophisticated prototype. Gaba called the more sophisticated prototype CASE (Comprehensive Anesthesia Simulation Environment), which was first described in 1988 [7]. The studies he and his team performed over the following years had some interesting and sometimes unexpected results. For example, he found that experience alone was not a reliable predictor of accident avoidance [30].

Perhaps Gaba's greatest contribution to simulation in anesthesiology was the development of Anesthesia Crisis Resource Management (ACRM) [31, 32]. Gaba had learned that the aviation industry used Cockpit Resource Management (later called Crew Resource Management, CRM) to focus on and develop decision-making and teamwork skills for pilots – not just "stick-and-rudder" technical skill) [3]. He had the insight to bring this practice to anesthesiology. Via a second grant from the APSF, Gaba developed a curriculum, course syllabus, and a set of four simulation scenarios that have since evolved in the now widely taught ACRM paradigm. Pivotal to current ACRM is debriefing after each scenario. Debriefing is generally accepted as the most critical and challenging aspect of simulation-based training. That concept is now widely accepted as a standard throughout the world wherever simulation is implemented. The first ACRM course was ran with a dozen anesthesiology residents in 1990. The book, *Crisis Management in Anesthesiology*, containing descriptions and management processes for eighty anesthesiology-based critical event scenarios, was another landmark, published in 1994 and updated in 2015 [33, 34].

Michael Good and J.S. Gravenstein: Simulation for the Avoidance of Errors

As an anesthesiology resident, Dr. Michael Good was frustrated that he would only care for two or three patients per day. He felt his exposure to critical events and opportunities to develop necessary skills was too small, and that the "surgery" part of the case was not conducive to more efficient mastery learning. In a memoir, he wrote that the "aha" moment that launched him into simulation came to him in 1985, as he practiced in a batting cage, attempting to hit ball after ball in a devoted effort to develop mastery [3].

Good graduated from the University of Michigan with a bachelor's degree in computer and communication science and completed medical school there. Completing his anesthesiology residency and fellowship at the University of Florida in Gainesville, he began his collaboration with Dr. Joachim S. "Nik" Gravenstein, a medical technology guru and patient safety leader, to develop a patient simulator. The two began regular meetings and wrote original code on a personal computer for digital analogs of the cardiovascular system. Gravenstein had connections with the Eindhoven University of Technology in the Netherlands, a group that worked on (among other things) computer modeling of a Bain breathing circuit (known as the "Bain team"). In 1987, Good and Gravenstein recruited Samsun "Sem" Lampotang, who had been a member of the Bain team, and was then a graduate research assistant at the University of Florida Department of Anesthesiology (Fig. 1.5).

Lampotang had expanded on his previous work and developed a mechanical lung that could interact with an actual ventilator and respiratory circuit in a realistic fashion. Based on this advance, the team approached Ohmeda, then one of the two leading manufacturers of anesthesia machines in the US,

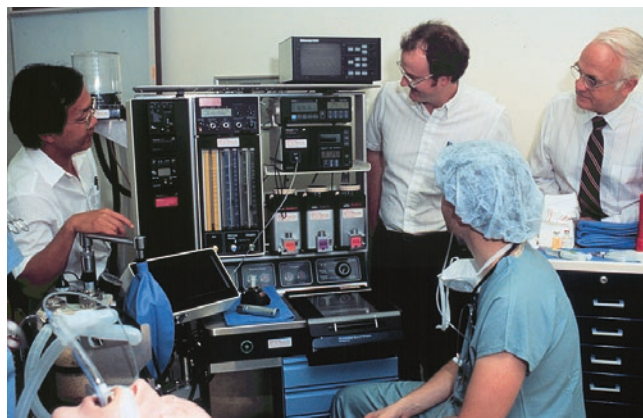


Fig. 1.5 Left to right: Samsun Lampotang, Gordon Gibby, Michael Good (seated), and JS Gravenstein, with GAS, c 1987

for funding to develop an anesthesia simulator that interacted directly with a ventilator. Ohmeda agreed, and Lampotang began developing what became known as the Gainesville Anesthesia Simulator (GAS I) during a summer externship at Ohmeda in 1987. Subsequent enhancements to their design included a computer-controlled vital signs display and the ability to physically consume and excrete anesthetic vapors.

With the funding from APSF, Good's team was able to add substantially to the simulator (now called the "Human Patient Simulator" or HPS). The simulator gained palpable pulses, responsiveness to a twitch monitor, the ability to detect volumes of medications injected, airway resistors, and more. Good's team also hired Ron Caravano, who served as a business administrator for the team. Caravano's business expertise contributed to the market success of the HPS and funding for further developments (e.g., the lung's ability to autoregulate respiratory rate in order to maintain a particular carbon dioxide level). The group's first purchase order came in 1993 from the Icahn School of Medicine at Mount Sinai Department of Anesthesiology, where Drs. Richard Kayne (then the residency program director) and Adam I. Levine installed the first HPS.

Dissemination Since 1990: How Did Simulation in Anesthesiology Propagate?

What were the key factors that enabled the diffusion of simulation since 1990? Clearly, technological advances (with less expensive and more accessible computers) were critical. As we have noted, patient safety seems to have been a main driver of dissemination. The early mannequin simulators (after Sim One) addressed patient safety concerns (e.g., how to discover anesthesia machine faults, how to prepare clinicians to manage critical events). But even in anesthesiology, with the demand to offer a more systematic and controlled process of learning, simulation is seen to have some advantages over the purely apprenticeship form of training. We describe here some important processes that have contributed to the slow growth of simulation in anesthesiology since the initial works of Schwid, Gaba, Good, and Gravenstein.

In 1991, the APSF Executive Committee made site visits to both the Stanford University's and University of Florida, Gainesville's simulation programs to learn about the progress each had made. From these visits, the APSF leadership concluded that simulation was a potentially powerful tool for patient safety. To help promote and disseminate it, the APSF proposed that the three simulation grant awardees collaborate to build a commercial simulator. Such cooperation was ultimately too difficult to achieve, and early dissemination thus took two routes.

CAE-Link, a large Canadian company that worked in flight simulation, worked with Gaba and Schwid to develop the CAE-Link Patient Simulator. They relied heavily on Gaba's CASE simulator and some of Schwid's mathematical modeling for pulmonary mechanics. The simulator was aimed primarily at management of critical incidents, following the CRM concepts that Gaba had adapted from aviation. CAE-Link sold the business to Eagle Corporation, which later sold it to MedSim Corporation. Although it was widely used in the early years of mannequin simulation, ultimately the technology did not survive market competition.

The Gainesville program partnered with the Loral Corporation, a defense contractor, to commercially develop the Human Patient Simulator (HPS). In 1996, the HPS was spun off into its own company, called Medical Education Technologies Inc. (METI), which was acquired 25 years later (in 2011) by CAE Healthcare. This simulator is still in wide use today.

Another aspect of dissemination came in the form of application of the simulators and their intended use by one early adopter. Jeff Cooper was one of the APSF Executive Committee members who had visited both the sites of both awardees of grants for mannequin simulators. Especially impressed by Gaba's ACRM program, he returned to Boston excited and determined to put together a similar offering [18]. Cooper organized the anesthesiology departments at the five major academic hospitals associated with Harvard Medical School to send a contingent of eleven anesthesiologists to Stanford to experience Gaba's ACRM training. The departments funded the travel and tuition, and the participants came away impressed.

Serendipitously, Gaba was preparing for a sabbatical; Cooper invited him to bring his simulator to Boston for 3 months to expose a larger group of anesthesiology providers to the ACRM experience. Seventy-two anesthesiologists, residents, and certified registered nurse anesthetists (CRNAs) participated in the event in the fall of 1992, and feedback was almost uniformly positive. This led to a collaboration of the five hospitals to build the Boston Anesthesia Simulation Center in downtown Boston. It was equipped with the first CAE-Link production mannequin. The Boston Anesthesia Simulation Center (BASC) was renamed the Center for Medical Simulation (CMS) in 1996. This first educational program outside of the centers that developed the first mannequins likely gave further credibility that the idea of simulation had value.

Shortly after the Harvard-affiliated hospitals' simulation program was established, simulation was adopted in New York in the Anesthesia Department at Mt. Sinai Hospital. After hearing about the human patient simulator from Dr. Richard Kayne, and after visiting the University of

Florida, Gainesville to see the GAS simulator, the department's chair, Dr. Joel Kaplan, quickly developed interest in using simulation [3]. Mt. Sinai was the first beta test site for the METI HPS. In 1994, under the directorship of Dr. Adam I. Levine, they formed their first simulation center. This initiative morphed and expanded to become the HELPS (Human Emulation, Education, and Evaluation

Lab for Patient Safety) Center Program in 2002, where they currently perform educational simulations, MOCA simulations, and simulation for reentry to anesthesia practice after extended time away from clinical duties [35].

Many other applications of simulation to the practice of anesthesiology have been developed. We describe many of these in Table 1.1.

Table 1.1 Varied uses of simulation in anesthesiology and when they first were introduced

Activity	Description
Resident training in crisis management	One of the very first uses of simulation was for residents managing acute events, based on the principles of Anesthesia Crisis Resource Management [33]. Virtually all anesthesiology programs now have such programs of various types
Trainee training in procedures	Partial task training (e.g., intubation mannequins) predated the modern era of mannequin-based simulation. More recently, task trainers for regional anesthesia and central line insertion (with or without ultrasound guidance) have become popular [38, 39]
Use of simulation in training of nurse anesthetists	Not too long after simulation mannequins became available commercially, training for procedures and managing critical events were adopted in schools of nurse anesthesia. Joanne Fletcher, EdD, CRNA and John O'Donnell, DrPH, CRNA, at the University of Pittsburgh and Alfred Lupien, CRNA, Ph.D., then at the Medical College of Georgia, were early pioneers [40]
Research in human performance	One of the first uses of mannequin-based simulation was in the study of human performance in anesthesiology to develop better prevention of initiating events and improved responses to events [41–43]. The work by this group has been followed over the years by the use of simulation for many different aspects of human performance, teamwork, educational methods, etc.
Introducing new clinical techniques	In 1998, Murray and colleagues demonstrated how simulation can be used for training in the use of a new drug or technology, in this case the introduction of remifentanyl [44]
Resident performance assessment	Devitt and colleagues and Gaba and colleagues both reported on the use of simulation for performance assessment in 1998 [45–47]. Later, deeper work in developing assessment processes for technical skills and rating rubrics was reported by anesthesiologist David Murray and his psychometrician colleague, John Boulet [48, 49]. They demonstrated that reliable scoring can be produced through careful development of the scoring instruments and effective rater training. More recently, Blum and colleagues demonstrated that reliable rating instruments can be created for identifying behavioral performance weaknesses early in residency [50]. That assessment via simulation has come of age is evidenced by the American Board of Anesthesiology's (ABA) use of a low-fidelity OSCE in its licensing exam, beginning in 2017 [51]
Perioperative teamwork (TOMS)	Almost all early uses of simulation in anesthesiology involved only anesthesiologists or only CRNAs as learners. One notable exception is the Team-Oriented Medical Simulation (TOMS) program started in Switzerland in 1995 by Drs. Hans Schaefer, Robert Helmreich, and Daniel Scheidegger. Using a pig liver-based simulation scenario, they trained teams of surgeons, anesthesiologists, and nurses in teamwork skills [52]
Training practicing anesthesiology providers	The first decade of the modern era of anesthesiology simulation focused mostly on trainee education. In 2001, a program for attending anesthesiologists was created among the hospitals affiliated with Harvard Medical School, catalyzed by an incentive from their insurance company, CRICO (Controlled Risk Insurance Company) [53, 54]. CRICO offered a \$500 rebate from the approximately \$10,000 annual premium for those who participated in this training at least once every 3 years. Virtually all attending anesthesiologists did so between 2001 and 2003, and the program became permanently established. Over a few years, this training became a requirement for hospital credentialing
Maintenance of Certification in Anesthesiology (MOCA®)	In 2008, the ABA adopted a requirement of a 1-day, CRM program every 10 years for maintenance of certification of anesthesiologists [55] licensed starting in that year. A process was created to endorse anesthesia simulation programs to conduct the courses; the American Society of Anesthesiologists' Simulation Education Network currently includes 49 centers. However, vocal anesthesiologists pushed back against the requirement, and it was made optional starting in 2015
Reentry into practice	Simulation has been used to evaluate providers whose clinical skills are in question or who are returning to practice after an extended hiatus. Such a program was developed at Mt. Sinai Hospital around 2002 [56, 57]

After the initial introduction of simulation in what we might call the “modern” era that started in the late 1980s, simulation in anesthesiology, typical of most technology innovations, had slow growth through the 1990s. We summarize here many of the new applications of simulation that appeared either first in anesthesiology or were introduced into anesthesiology from elsewhere. Most of these topics are given deeper discussion in other chapters of this book

Society for Simulation in Healthcare

An important milestone in the growth of simulation in anesthesiology, and later for all of healthcare, was the formation of the Society for Simulation in Healthcare [36]. This organization grew out of anesthesiology over several years. It started in 1995 with the *First Conference on Simulators in Anesthesiology Education* at the University of Rochester in New York, with fewer than 100 attendants. Daniel Raemer, Ph.D., attended the second conference. He was a biomedical engineer who had developed various clinical technologies while working in the Department of Anesthesia at BWH, and was introduced to simulation by Jeff Cooper, who brought him onto the BASC team in 1995. Raemer, as President of the Society for Technology in Anesthesia (STA), steered the topic of the 1998 annual meeting to “Simulation in Anesthesiology.” The meeting drew an unusually large turnout. In 2000, the leadership of STA convened the first International Meeting on Medical Simulation (IMMS) in Scottsdale. Based on growing attendance, an independent society, the Society for Medical Simulation (SMS), was formed in 2003. Raemer became the first President of the Board of Overseers at its first meeting in January 2004, in Albuquerque, New Mexico. Raemer was elected as its first Chairman. In 2005, Ms. Beverlee Anderson (widely acknowledged as having been critical to the success of the society) was hired as the first Executive Director.

It is a testimony to the wisdom of anesthesiology as a field and its simulation leaders that the society it spearheaded was deliberately designed to be ecumenical and interprofessional. This is unusual since so many healthcare specialties have traditionally leaned toward independence. The society’s organizing documents required a diversity of healthcare professions to be members of the Board. But, it was not until 2006 that SMS changed its name to the Society for Simulation in Healthcare (SSH) [36]; SSH renamed its meeting to the International Meeting for Simulation in Healthcare (IMSH), recognizing the truly interprofessional spirit and collaboration that is vital to patient care effectiveness and patient safety. The society membership is currently broadly distributed among physicians, nurses, allied health professionals, educators, and scientists.

Dan Raemer advocated for SSH to start its own journal. And thus, another milestone for simulation internationally was SSH’s creation of its first journal, *Simulation in Healthcare* in 2005. Its first Editor-in-Chief was anesthesiologist and healthcare simulation pioneer, David Gaba. Gaba retired from the position in 2016. He is widely credited with leadership that enabled growth in research and practice of healthcare simulation [37].

Analysis and Conclusions

Technologies and pedagogical frameworks for the modern era of simulation were catalyzed and enabled by innovative applications in anesthesiology. Yet, the core of this story is not about technology- it is about pioneers, their passions, and the dissemination of a new idea that arose at a time when unmet needs were ready for it. One common theme from these stories is that all the pioneers had some education in engineering or computer science. And, in most of the stories, there were close collaborations of interprofessional teams, including engineers. Perhaps there is a familiar message here about the critical contribution of engineering to many medical advances and the power of interprofessional teams.

Also interesting is that, from what we can tell, the pioneers who simultaneously developed their applications of simulation did so independently. We might expect that the early work of Abrahamson and Denson, while before its time, would have informed the ideas of Philip, Schwid, Gaba, Good, and Gravenstein, but that does not appear to be the case. Rather, each instantiation of simulation emerged from different driving goals and without knowledge of Sim One – a form of “convergent evolution”. Philip was driven by an educational interest in one topic that was especially challenging to teach without the aid of simulation of mathematical models; Schwid was similarly interested in education as it related to physiology, pharmacology, and resuscitation; Gaba started out of interest in understanding human performance in managing critical events generically and improving it; Good’s and Gravenstein’s objectives were to improve mastery performance. These different drivers led to several successful implementations of simulation and, together, spread of the technology through different means.

Competition and market pressure between several companies also helped spread simulation technologies. We discussed the two companies that arose specifically to address anesthesiology-related needs. One succeeded; the other failed (those stories are not well enough documented yet to be understood). The other current market leader, Laerdal, had a different origin (i.e., in resuscitation). While that has some relationship to anesthesiology, anesthesiology was not the source of the company’s entry into the market.

There is no one truth about how any idea propagates to become mainstream [58]. For simulation, there were several drivers, including development of enabling technologies, unmet needs in education, and the factor that we believe catalyzed simulation’s explosive growth – a growing focus on patient safety. In many (but not all) cases, grant funding enabled dissemination.

The pattern of simulation's trajectory of dissemination is not unusual. With any innovation, there are early adopters who are willing to take a risk on something new, and the speed of dissemination varies after that. Passionate pioneers who use these technologies to address the needs they identify most with likely accelerate the spread; this has been the case with simulation. There is much credit to be given to those who developed the many pioneering applications of simulation in anesthesiology and contributed to its spread throughout healthcare around the world. Those who benefit from simulation, most of all the patients, should be thankful to those who took the challenges and risk and had the passion and perseverance to see their ideas succeed.

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Introduction

“See one; Do one; Teach one...” While this approach worked well for generations, we now live in a world in which evidence-based medicine is the expectation. Similarly, calls for educational reform across the health professions compel us to practice evidence-based education. In this chapter, we will review the evolution of educational theories and practices, from the Flexner era through current educational best practices (see Table 2.1).

Evolution of Perspectives on Teaching and Learning

Education across the health professions shifted significantly in the past 50 years, away from the simple application of teaching and learning principles that apply to children as honed in primary and secondary schools (pedagogy) to teaching and learning principles uniquely effective for the adult learners (*andragogy*). Most learners in the health professions are considered adult learners for the purpose of designing educational experiences not only because of their age but also because of their cognitive and social level of maturation.

Adult learners have fairly well described learning needs. Malcolm Knowles [1], who built on earlier European models of adult learning, described six major assumptions related to motivation in adult learners:

Table 2.1 Teaching in a New Era

	Flexner-era focus	The twenty-first century best practices
Focus of field	Teacher centric	Learner centric
Mode of learning	Content delivery	Content discovery
Learner engagement	Passive (lecture, readings)	Active (multimodal)
Social context	In isolation	In groups and teams
Learning	Time on task based	Competency based
Epistemological view	Cognition as objective and rational	Cognition as context dependent and bounded
Clinical decision-making	Decisions as logical	Subject to unconscious bias
Teacher role	Expert that gives knowledge	Facilitator that guides learning

For additional readings, see L D Fink, (2013) [11] Creating Significant Learning Experiences

1. Need to know: Adults need to know the reason why and how they are learning.
2. Self-concept: Adults learn value through autonomous self-directed learning.
3. Prior experience: Adults prefer learning that is connected to available resources and mental models.
4. Readiness: Adults prefer learning that is immediately connected to their own work or personal lives.
5. Orientation: Adults learn better when problem-based rather than content-based.
6. Motivation: Adults respond better to internal rather than external motivations.

Understanding and capitalizing on these motivators can help the educator design effective learning experiences.

When mapping the topics for learning, there are three domains of Bloom’s taxonomy [2] of learning: *cognitive, psychomotor, and affective*. These are often referred to as knowledge, skills, and attitudes/behaviors, or “KSA,” across the health professions’ education literature [3, 4]. Each of the domains is described as having levels of increasing complexity (see Table 2.2).

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Table 2.2 Bloom's taxonomy and levels of competency

	Cognitive	Psychomotor	Affective
More complex	Creating	Naturalizing	Characterizing
	Evaluating	Articulation	Organizing
	Analyzing	Precision	Valuing
	Applying	Manipulation	Responding
	Understanding		
Less complex	Remembering	Imitation	Receiving

Adopted from Anderson and Krathwohl (2001) [5]

First, *cognitive learning* of knowledge can take many forms. Knowledge is often defined as content, information, or protocols, and usually takes the form of materials that are given to the learner. Examples of learning within this domain might include the memorization of anatomical nomenclature and structures, function and use of equipment, or a series of criteria and decision points within a resuscitation protocol. The updated version of Bloom's taxonomy and its application to learning was described by Anderson and Krathwohl (2001) [5], in which they further defined four subcategories of knowledge as factual, conceptual, procedural, and metacognitive. While discussion of these is beyond the scope of this introductory chapter, the domains are useful for defining the levels of outcomes expected from the learning.

The most common model used to identify the developmental levels of learning in medical education is *Miller's model* (1990) [6], in which a learner gains progressing competencies toward independent practice.

1. Knows: Can report definitions, identify landmarks, or discuss the underlying physics
2. Knows how: Can describe the detailed steps in a procedure either written or orally
3. Shows how: Can accurately complete a skill according to a checklist
4. Does: Can complete a skill within the complexities of clinical environment

The cognitive domain of Bloom's taxonomy is considered the standard framework for writing learning objectives for a given learning activity. We should note that charts of sample objectives, or "verbs," are often based on only the cognitive domain and omit the psychomotor and affective domains. If simulation session goals include learning in domains beyond the cognitive, appropriate objectives should be defined in these areas as well (see also Chap. 3).

Assessment of cognitive learning has been oversimplified in the past. Multiple choice questions and "fill in the blank"-type text questions have been used to assess the learner's ability to recall definitions, identify structures, and recognize patterns [7]. In the clinical context, there are many more contextual factors affecting procedural decision-making and

metacognition that require more sophisticated approaches to assessment, such as case studies, direct observation, or portfolios (see Assessment section below).

Second, *psychomotor learning* of skills may occur in various forms and progresses through an anticipatable sequence of developmental stages. While not limited to psychomotor learning, deliberate practice as described by K Anders Ericsson [8] has been the standard theory for skills acquisition in the health professions. The basic premise rests with the notion that expert performance is primarily the result of expert practice, not innate talent or natural abilities, meaning how one practices matters most.

The four critical characteristics of effective *deliberate practice* are:

1. Motivation: Learners must attend to the task and exert effort to improve.
2. Link to the known: Learners must understand the mechanism and purpose of the task easily in the context of pre-existing knowledge.
3. Immediate feedback: Learners must receive immediate formative feedback.
4. Repetition: Learners must repeatedly perform the same task accurately.

Many simulation centers invest in partial task trainers, which are models in which the learner may perform a focused portion of a skill repeatedly, for deliberate practice. Examples of such equipment include intravenous arms, central line torsos, or phantom models for ultrasonography. Skills acquisition in the context of simulation-based learning is most effectively accomplished through separate deliberate practice on task trainers, prior to integration into a scenario.

Assessment of psychomotor learning is often accomplished by accuracy measures, such as percentage of errors in repeated performances or time to completion [9].

Finally, *affective learning* of attitudes, beliefs, and behaviors is often more complex requiring thoughtful staging by the educator and more effort by the learners. Krathwohl (1964) [2] described levels of learning with increasing sophistication, from basic to complex:

1. Receiving: Awareness of (and willing to tolerate) the existence of ideas, materials, or phenomena
2. Responding: Commitment (in some manner) to the ideas, materials, or phenomena by taking action to respond to them
3. Valuing: Willingness to be perceived by others as valuing the ideas, materials, or phenomena
4. Organization: Integration of the value with those already held into an internally consistent philosophy
5. Characterization: Takes action consistently according to the internalized values

For example, a department may decide to integrate principles of team communication from Team STEPPS including the two challenge rule, in which team members are empowered to “stop the line” if they sense or discover an essential safety breach. This may be a difficult change of organizational culture, especially in places where challenges to traditional authority may not be welcome. Learners at the Receiving level will tolerate the notion that those with authority may need to be challenged, but may not want to speak up. The Responding level learners might be able to speak up during a simulation, while those at the Valuing level are willing to encourage others to speak up in the clinical environment. Those at the Organization stage will become comfortable with a changing culture of respectful cross-monitoring and open discussion of safety issues, and those at the Characterization stage will be able to consistently role model the new behaviors as part of their professional practice.

While assessment of effective or attitudinal learning has been often neglected completely, this domain has recently received fresh attention and scrutiny [10]. Observable behaviors were used as proxies for non-observable values and intentions. These may only indicate a Responding level of isolated action, and not an integration of new values into a cohesive approach to professional practice. Reflective writing or authentic (in situ) assessment by peers can be informative in this context.

In the following sections, the additional theories that help define the individual learners’ needs are summarized.

Learner Centric Approaches

Recognition that the quality of teaching and learning is best assessed in the learners, not in the actions of the person at the lectern, drawings on the board, or in the slides on the screen, has shifted the approaches in the field of health professions education from focus on improving teaching skills to focus on creating meaningful learning environments and individual learner activities and outcomes. This shift from teaching-centric to learner-centric approaches is the keystone that defines current best practices in adult education, with broad implications from higher education to professional and clinical education [11]. Additionally, the learner is now seen as having learner characteristics associated with specific developmental stages.

Developmental models within the clinical settings are readily visible, especially in the discipline of pediatrics. Erik Erikson’s stages of psychosocial development guide clinical assessment and care, and education’s developmental models serve similar purposes of better understanding the learners. The *novice to expert model* (Dreyfus and Benner) [12, 13] describes stages of professional development and skills acquisition.

1. Novice: Rigid adherence to rules with no discretionary judgment
2. Advanced beginner: Limited situational awareness, without ability to prioritize
3. Competent: Deliberate planning with some awareness of actions and effect on goals
4. Proficient: Holistic view and prioritizes, applies heuristics meaningfully
5. Expert: Intuitively transcends guidelines in treating whole and can be analytical when needed

Understanding the learner through these stages helps in designing effective learner centric experiences. A novice is not ready to think about complex prioritizations and can only follow rules. The *zone of proximal development* (ZPD) (Vygotsky in Chaiklin 2003) [14] describes the area of growth that is immediately beyond the current abilities of the learner, but within reach with support of scaffolding, which is a teaching method designed to increasingly promote the learner’s independence in understanding over time. For example, optimal learning for the novice might be to start focusing on the situation as a whole, with the recognition that some rules can uniformly apply across contexts. Similarly, the competent learner may still need to be learning about how actions affect the overall goal of patient care.

Similarly, by understanding the individual learner’s developmental stage, learning environments or simulation sessions can be tailored to include just enough, but not too much, realistic environmental factors. *Cognitive load theory* (Sweller, 1988 [15]) refers to the brain’s ability to sort through and focus on certain stimuli, while becoming overwhelmed when overburdened with stimuli. Initially described in the context of multimedia-based instructional design, cognitive burden was primarily derived from sorting out portions of the media that were important to attend to for successful learning. With regard to education, cognitive load has a number of varieties that warrant consideration, given their influences on a learner’s ability to learn effectively:

1. Intrinsic cognitive load: The inherent difficulty of a topic or task. Calculus has more intrinsic cognitive load than simple addition.
2. Extraneous cognitive load: This depends on the manner in which information is presented to the learner, and is the portion controlled by the instructor.
3. Germane cognitive load: The cognitive activity devoted to processing, construction, and automation of information and activities. This is where learning occurs.

Simulation environments may contain multiple extrinsic cognitive load factors as distractions, such as crying family members. The mental effort required to suppress the non-educative factors may adversely affect the learning outcome.