Comprehensive Healthcare Simulation

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

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Comprehensive Healthcare Simulation: Emergency Medicine

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ISSN 2366-4479 ISSN 2366-4487 (electronic)
Comprehensive Healthcare Simulation
ISBN 978-3-030-57365-2 ISBN 978-3-030-57367-6 (eBook)
https://doi.org/10.1007/978-3-030-57367-6

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to the hard working, often underappreciated educators out there without whom none of us would have the success we enjoy today. And to my children, Gannon and Beckett – who teach me as much as I teach them.

Christopher Strother, MD

This book is dedicated to my mother, Teruko Okuda, whose optimistic outlook in life and everlasting radiant energy taught me to believe in people, have faith in humanity, trust in myself, enjoy life, and be present in the moment.

Haru Okuda, MD

Thank you to the Center for Medical Simulation and especially Jenny Rudolph for opening my eyes to the power of feedback.

Steven A. McLaughlin, MD

I would like to thank my amazing family, simulation colleagues, mentors, and the Emergency Medicine community for all their support.

Nelson Wong, MD

A special thank you to Drs. Ryan McKenna and Maram Bishawi for their hard work on the Appendices.

Preface

> Education is not preparation for life, education is life itself. – John Dewey

Dewey was known for his pragmatism. We are hoping this text will be your pragmatic guide to all things emergency medicine simulation.

The complex nature of emergency medicine practice, and its reliance on teams and teamwork, makes simulation a natural and essential part of emergency medicine education. Simulation has grown rapidly in emergency departments and training programs. In 2003, approximately 29% of emergency medicine residencies in the United States used mannequin simulators, about 8% of them owned one. In 2008, those numbers were up to 85% using a mannequin simulator for training their residents, and 43% owning their own (Okuda). Today, this teaching methodology has become practically ubiquitous. Graduating medical students expect simulation to be part of their emergency medicine programs. Most medical schools are widely adapting this teaching method for their students as well (AAMC Survey). The next steps to grow will likely be focused faculty simulation for skills maintenance and in situ and interprofessional training in emergency departments.

There is a growing body of literature in articles and books describing simulation education theory and its effectiveness (McGaghie). For practical details such as: how to start your own simulation program, what if you have one for residents and want to know what's being done for medical students, what if nursing is asking for simulation in your department, we hope the answer is in this text.

Many of the authors in this text contributed to the original *Comprehensive Textbook for Simulation in Healthcare* (Levine et al.). In doing so, it was realized how much could be written specifically in the field of emergency medicine, and that there was a real need for a specific text focused on simulation for emergency medicine education and practice. We recruited emergency medicine simulation experts from around the country: dedicated educators, simulationists, and leaders in the field of emergency medicine and simulation. We asked our authors to keep their chapters practical, focused on best practice and application, with as many real-world examples of the successful application of simulation education as possible.

Our Approach

We've tried to take practical approach in this text with many tips and best practices to help your program grow and develop. We want to help you develop your emergency medicine program in a real way, help you avoid the mistakes that we've already made, and prevent you from having to reinvent the simulated wheel.

Parts of the Book

Part I: Introduction to Simulation for Emergency Medicine

These chapters are designed to give you the background, terminology, and theory needed to be a successful simulation educator. With a practical approach, we'll guide you through the theory, then teach you to build a case, work with your teams, and debrief like an expert to maximize your learners' outcomes. We'll also look at how to approach measuring outcomes for your simulation program, using it as an assessment tool, and how to use simulation as the powerful patient safety tool it can be. Be sure to check out Chap. 7, an excellent review of teamwork training. This chapter not only reviews how to create a team training program, but can be used as an approach to the creation, evaluation, and follow up for any simulation initiative.

Part II: Simulation Modalities and Technologies

With so many simulators and types of simulation out there, how do you decide which one to use? You want to integrate more task trainers, or standardized patients into your program, but what's the best way to do that? In this part we review specific types of simulation and simulators and how you might use them in emergency medicine simulation training. For example, this part might help a residency director decide what type of equipment they need to purchase for their much needed team training program, when they have only a small amount for funding, no upkeep support, and minimal technical expertise.

Each chapter will take the same general approach:

(a) Define and describe what it is
(b) Examples of what's currently out there and the similarities and difference between different types and categories of simulation relevant to EM
(c) Describe how it can best be utilized in emergency medicine education and training
(d) Tips and Tricks
(e) Cost, warranty, and maintenance considerations if available

We'll look at everything from live actors to screen-based simulations to the various basic and advanced simulators to make your experiential learning program work. How much fidelity do I need? What task trainers are out there or can I make my own? I love the idea of moulage, but how do I do it simply and practically? We'll explore all these questions in Part 2.

Part III: The Practice of Emergency Medicine

These chapters will be your guide to simulation programs with specific learners. What curriculums exist for resident simulation? How do I approach medical student education in emergency medicine with simulation? Find out in Part 3. We'll look at teaching residents and students, nursing simulation, and even an approach to pre-hospital providers and what has worked for them! Don't reinvent, review what has worked for others and apply it to your own program.

These chapters take the following format:

(a) Background – history, development, current state, and future uses of simulation in this area
(b) Best practices – describe successful or progressive programs and how they got there
(c) Sample curriculum – published or unpublished simulation curriculum that could be followed
(d) Integrating into existing education – ways to add or expand simulation seamlessly
(e) Challenges and solutions – common barriers and successful solutions

(f) Interface with regulatory bodies – ways simulation can help or harm you with program accreditation and credentialing

Part IV: Subspecialties of Emergency Medicine

Moving from learner types in Part 3 to subject types in Part 4, we give you examples and approaches that have been successful in using simulation to teach pediatric emergency medicine, trauma, ultrasound, and other "subspecialties" of emergency medicine.

Part V: Conclusion

Here Dr. Wong and Dr. Okuda take a look at the bright and expanding future of emergency medicine simulation. In his letter to future simulationists, he will inspire you to see the long-term future and value of simulation as an essential part of emergency medicine and medical education.

Following Dr. Okuda's chapter, you'll find a treasure trove of emergency medicine–based simulation cases (Appendix 1 and Appendix 2). Collected and written by our contributing authors, these will give you a great start to your case bank or inspiration for your own cases. Writing cases is one of the most fun and rewarding part of simulation, and we hope these cases will be useful to your learners for years to come.

We hope that you will find this book both complete and practical. We see it as an on-your-desk reference for teaching simulation, improving your own program, or adding a new aspect to your medical education in emergency medicine using simulation theory and practice. Thank you to all of our authors for their hard work, patience, and dedication to their craft!

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Part I

Introduction to Simulation for Emergency Medicine

1 A Historical Perspective of Simulation in Emergency Medicine

Paul E. Phrampus

Introduction

Since its inception, emergency medicine has needed to employ diverse educational strategies to ensure the development of competent emergency physicians with a knowledge that spans the entire practice of medicine. Additionally, the emergency physician needs to be able to expertly perform a significant number of procedures that range from simple and common to complex, time sensitive and rare.

The educational challenges within emergency medicine lie in the combination of the depth, breadth and diversity of medical knowledge that is necessary. Further, there are the complexities of initial skill acquisition and maintenance of competence over time. When looking at the historical perspective of simulation it is easy to recognize that since the beginning of emergency medicine some form of simulation has been inextricably involved. When one considers this diverse need for education it is clear that simulation will play an integral part into the future.

Looking retrospectively at this journey is complicated by the fact that the definition of healthcare simulation has changed over time. Currently, the term simulation encompasses a more inclusive position that recognizes multiple modalities, technologies, methods of teaching and assessment, that substitute aspects of interaction with the healthcare environment, and/or patients, with the actual practice of medicine.

Today's definition of healthcare simulation includes many modalities including part task trainers, anatomical models, computerized high-fidelity simulators, interactive computer software, human beings such as standardized patients, and/or standardize persons, as well as environmental replicas just to name a few. This is in contradistinction to the early to mid-2000's when the working vision of simulation in healthcare was essentially a newly created simulation center filled with high-fidelity simulators that had recently become prevalent, popular and more ubiquitously available.

A review of the medical literature provides part of the story of simulation in emergency medicine. However, as with many educational endeavors in the medical field, the historical documentation insofar as publications in peer-reviewed, scientific journals, are somewhat limited compared to the amount of training that has been accomplished. It is also complicated by the fact that many of the educational principles and foundational studies supporting simulation appear in the psychology and/or education literature primarily. This landscape is changing over the last decade as several new peer review publications, trade journals and scientific meetings have emerged that are disseminating information and best practices, as well as distributing results of traditional hypothesis driven research initiatives that are involving healthcare simulation.

Early Uses of Simulation in Emergency Medicine

One of the first published studies of the use of simulation in emergency medicine was ironically that of an administrative decision making exercise ostensibly aimed at developing competence of administrative leaders of emergency medicine in the 1970s [1]. Other emergency medicine early adopters/publishers reported simulation training associated with disaster training for students in emergency medicine programs [2].

It was in the late 1960s when the first Resuci-Annie and Andy manniquins (Fig. 1.1) were created that allowed wide scale disseminated training to ensure competency with mouth-to-mouth resuscitation as well as cardiopulmonary resuscitation (CPR).

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C. Strother et al. (eds.), *Comprehensive Healthcare Simulation: Emergency Medicine*, Comprehensive Healthcare Simulation,
https://doi.org/10.1007/978-3-030-57367-6_1

Fig. 1.1 A product information sheet from 1960's for Resusci-Andy

Fig. 1.2 A replica of an early mouth to mouth resuscitation simulator

Not surprisingly many of the earliest uses of simulation in emergency medicine training centered on acute resuscitation and airway management. This likely occurred secondary to the fact that there were some rudimentary airway models available as well as airway management being recognized as a key-skill in the curriculum of emergency medicine training.

In the mid-1970s this author had a first introduction to simulation while in elementary school. While taking a first aid course at the local YMCA a task trainer had been designed to demonstrate the procedure of mouth-to-mouth resuscitation of near drowning victims. Interestingly, a careful look will realize that the design afforded feedback to the participant along with the opportunity of deliberate practice for mouth-to-mouth resuscitation (Fig. 1.2).

Commercially available airway task trainers were also becoming a prevalent part of the training in emergency medicine focusing on bag valve mask ventilation as well as more complicated procedural skills such as endotracheal intubation.

Parallel to this emergence of early commercially available task trainers were other homemade models to reach needs that emanated from the ideas of innovative faculty members. One example was a porcine model of corneal metallic foreign body removal. Figure 1.3 as well as other bovine models for emergency airway procedural training (Fig. 1.4). Similarly, many emergency airway workshops focused on the training of emergency cricothyroidotomy by employing the airways of various large animals obtained from slaughterhouses as well as human cadaver labs. Some of these early innovative approaches are still used today in the training of emergency medicine residents.

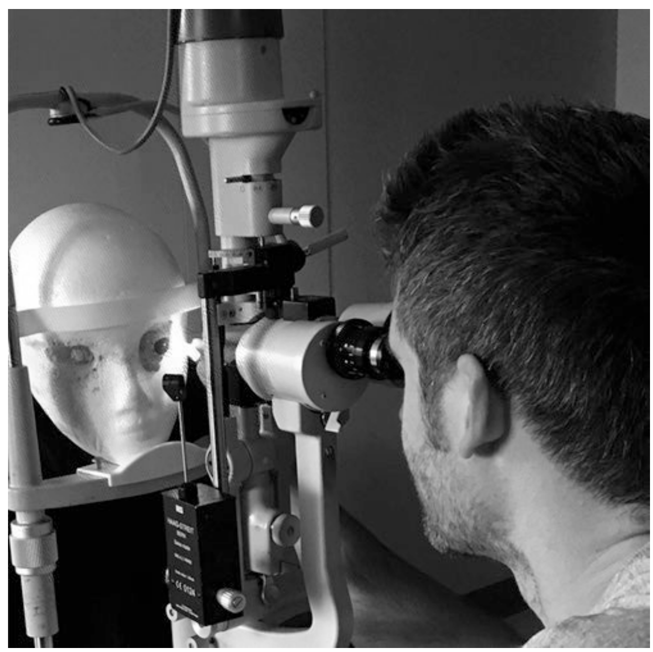

Fig. 1.3 Ocular foreign body removal using a porcine task trainer

In the early 1970's the use of electrocardiogram rhythm generators connected to monitoring equipment allowed for the student to demonstrate competency with the dynamic interpretation of EKG rhythms during mock resuscitation events affectionately known as mega-codes (Fig. 1.5). Shortly thereafter several CPR mannequins were fitted with the electronics that could safely disseminate the energy from a defibrillator, thus affording live practice and the demonstration of competence using the equipment properly and

Fig. 1.4 Airway procedure training using bovine model of task training

Fig. 1.5 An early task trainer, EKG rhythm generator. (Image courtesy of Laerdal)

safely. These important early electronics were also able to give feedback to the EKG generating equipment to allow the automation of a preprogrammed event such as a recovery to normal sinus rhythm if the treatment was rendered correctly. While the term simulation was not used for this type of learning at the time, it is evident today that it easily fit within a more modern interpretation of the term scenario.

In the 1980s higher technology task-based simulation equipment began to emerge and was being rapidly employed into various training programs. This corresponded with the development of the American Heart Association's first advanced cardiac life support (ACLS) program which was first released in 1979 [3]. The development of such task training equipment was important and timely, as it corresponded with the recognized need to rapidly disseminate ACLS knowledge across the spectrum of physicians providing such care, but also to other members of the healthcare team such as critical care and emergency nurses, as well as paramedics to name a few. Looking back, it could also be argued easily that it was anecdotally demonstrating the power, effectiveness and scalability of immersive learning, when combined with traditional knowledge base learning that could help change the paradigm for emergency care learning methodologies and designs of the future.

In the late 1980s the American Heart Association released several courses related to Pediatrics including formal guidelines on pediatric CPR and the rollout of the Pediatric Advanced Life Support (PALS) initial formal curriculum [3]. This in turn, was accompanied by the development of many commercially available task trainers associated with pediatric resuscitation emergencies.

Additionally, in the late 1980s there was a proliferation of the personal computer which found its way into many academic institutions and businesses. During this timeframe, there were several interactive computer programs that were developed that allowed one to practice and receive feedback on their decision-making with regard to adherence to and treatment based the ACLS algorithm. Early programs were often text based cases combined with rudimentary graphics. It was nonetheless experiential learning that provided feedback as well as deliberate practice opportunities. This type of software can easily be argued to have been a precursor of more sophisticated virtual reality and virtual patient medical training systems of today.

In the early 1990s there was significant work from the discipline of anesthesiology related to simulation training aimed at patient safety in the operating room [4]. These efforts sparked significant interest into the development of human patient simulators. Several of these were full-body mannequins, with high-fidelity capabilities that allowed replication and control of numerous aspects of human anatomy and physiology. Features such as gas recognition and the inclusion of physiologic based hemodynamic trending that responded to therapy were becoming available.

The fact that many of the features in these early high-fidelity simulators developed for anesthesiology focused on airway management, acute resuscitation and critical procedures, as well as the management of hemodynamic emergencies made them very desirable for emergency medicine training. However, many of the early models were prototypes, exceptionally expensive, technologically complex to

Fig. 1.6 Early model of a lower-cost, portable, high-fidelity patient simulator set up in a hotel room for training emergency medicine personnel

operate, and harbored reliability issues which limited their ultimate scalability and widespread use early in their development.

Early in 2000 the SimMan® simulator was released and it incorporated patented technology developed at the University of Pittsburgh into the airway features of the simulator (Fig. 1.6). This created a simulator platform that incorporated low cost elements that brought together many of the features needed for education, training and assessment of emergency medicine. In comparison to the earlier high technology models, SimMan® was not physiologically modeled and was less complex but offered complete control of a limited number of physiologic parameters of the simulator to the educator.

The ability to replicate a significant number of airway pathophysiologic situations, perform several emergency procedures, detect ventilations, as well as cardiac compressions and display the hemodynamic parameters commonly available in the intensive care unit on the monitor made the platform ideal for emergency medicine training. Another critical feature that allowed for significant scalability and deployment was the price point was reduced from over $200,000 for the earlier simulators to approximately $45,000 per unit. Thus, a trade-off occurred between features and overall costs that allowed wider scalability.

The release of the human patient simulator platform created a competitive business development environment that resulted in several high-fidelity simulators mimicking many parts or actions of a human being. However, the development pathway shared by several companies continued to focus on acute resuscitation, procedural competency and emergency procedures which was ultimately a benefit to emergency medicine education programs.

The combination of the lower cost of the simulator units, the lessening of the complexity to operate them as well as the improvements in the underlying technological stability led to the development of many early pioneering simulation centers. Additionally, these factors allowed for implementation of innovative education curriculums into the training of emergency medicine for medical students and residents, as well as the training of prehospital care personnel.

The University of Pittsburgh had developed an anesthesia simulation center that grew rapidly and became multidisciplinary by 1997. Faculty members worked to creatively to integrate the technology into teaching methods that maximized the efficiency and effectiveness of utilization. Since 1997, simulation has been an integral part of the University of Pittsburgh medical student curriculum for emergency medicine. It was formally incorporated into the residency training program in 2001 with the introduction of mandatory simulation training program in emergency department airway management. The University of Michigan and the Massachusetts General Hospital were also early adopters of formal inclusion of simulation based training into programs for emergency medicine that began in the late 1990's and early 2000's [5].

Lastly, in the mid to late 1990's there was a growing interest in the medical education community in developing medical education training programs that allow practice in the development of competence with communication skills [6]. This resulted in another now common form of simulation technique known as standardized patients, or standardized participants (SP). This modality uses trained actors to play the role of patients, family members, and/or other roles within a simulation scenario. This helped to overcome some of the fidelity and realism limitations associated attempting a nuanced conversation with a mannequin based patient or family members.

Over the period discussed above, many of the foci of simulation efforts were on the educational accomplishments of individuals, often performing procedural skills, and/or demonstrating competency in adherence to algorithms and emerging best practices.

Rapid Recent Growth

From the mid-2000 timeframe to present there has been a rapid proliferation of simulation programs with a focus in emergency medicine training that has arisen from a variety of influencing factors. The first, has already been discussed in the earlier section regarding the availability of simulation equipment that became much more affordable, technologically reliable, as well as features that were often ideally aligned with emergency medicine.

In November 2000, the Institute of medicine released its sentinel report, To Err is Human, which outlined significant safety problems in the United States healthcare system healthcare system that lead to the death, and/or disability caused by medical error [7]. Specific findings included breakdowns in competence, inefficient use of technology as well as significant problems involving communications between healthcare providers as well as the ability to function, and work in teams. In this report simulation is cited 19 times as a potential methodology to help with a solution to many of the problems.

Commensurate with this heightened recognition of medical errors was an appreciation for the cost of medical mishaps and procedural failures that was receiving widespread attention. The cost of errors with care was being evaluated by payors such as medical insurance companies, risk management and malpractice insurance companies, as well as hospital systems that were becoming significantly more financially liable.

The attention of such groups with a direct financial interest in healthcare errors combined with the public appreciation for harm associated with medical care began to create another interesting opportunity for the spread of simulation. Situations requiring the practice on actual patients in the historical model of "see one, do one, and teach one" were beginning to undergo significant scrutiny by policymakers and payers as well as patients and their families. This is particularly true in areas where simulation has developed sufficiently to allow safe practice and competency demonstration that does not need to occur on actual patients. Some have deemed this need to incorporate simulation methods as an ethical imperative [8].

Additionally, the widespread proliferation of the American Heart Association programs found its way into recommendations of various clinical entities, and risk management programs requiring the training of thousands of healthcare providers to obtain advanced program certificates.

In 1999, the American Council for Graduate Medical Education (ACGME) and the American Board of Medical Specialties (ABMS) developed core competencies associated with the accreditation of graduate medical training programs. The requirements for residency programs in emergency medicine to develop the ability to document the education of and prove the attainment of competency in several of these core competencies required the development of additional, and innovative educational modalities. For this, simulation fit a niche need in several areas including teamwork training, procedural competence of skills, as well as communications. Some have evaluated the use of simulation in the assessment of individuals based on the ACGME guidelines [9].

In 2004 the emergency medicine journal *Academic Emergency Medicine* published an article entitled "See One, Do One, Teach One: Advanced Technology in Medical Education" which was a report of a consensus meeting of members of the Educational Technology Section of the 2004 AEM Consensus Conference for Informatics and Technology in Emergency Department Health Care [10]. One of the statements issued regarding mannequin based simulation concluded *"Emergency medicine residency programs should consider the use of high-fidelity patient simulators to enhance the teaching and evaluation of core competencies among trainees."*

In 2009 the ACGME and ABMS as well as many additional stakeholders further defined the need to develop a next generation training accreditation program that focused on specific areas of development and a more specific way of evaluating residents over the course of a residency training program. The program became known as the Next Accreditation System (NAS) and required that each medical specialty develop "Milestones" in core content areas aligned with the expected evaluation criteria would indicate a competence level that a resident should achieve for a given time in an accredited program. When considering the practice of modern emergency medicine that includes demonstration of critical thought process, the application of knowledge as well as the performance of procedures. It should come as no surprise that the original milestones drafted for emergency medicine list simulation as a suggested potential evaluation method in 19 of the 23 practice area milestones associated with emergency medicine training [11].

During this period the utilization of simulation in emergency medicine expanded significantly beyond the competencies of an individual, but began to include teamwork, team leadership training, communication skills as well as the use of simulation in systems assessment and systems design [12–14].

Technology has continued to advance and has led to the development of increasingly advanced simulators and task trainers are now become commonplace in the teaching of students and residents. There has been tremendous growth in systems focusing on training associated with the use of ultrasound as a point of care diagnostic and treatment tool for the Emergency Department (Fig. 1.7).

Thus, as this section indicates there is a multifactorial reason for the development of simulation programs associated with emergency medicine. However, there are still significant challenges that lie ahead when one considers factors such as overall costs, developing standards of assessment, as well as the complexities associated with true curricular integration that results in simulation efforts being incorporated into the mainstream of emergency medicine curriculums.

Fig. 1.7 High-fidelity ultrasound simulator for training Emergency Medicine Residents

Academic Development and History of Key Organizations

The continued growth and widespread acceptance of simulation in emergency medicine over the last three decades led to several collaborations between organizations that either contributed to or have benefited from involvement of the emergency medicine community in simulation.

The Society for Simulation in Healthcare

The Society for Simulation Healthcare (SSH) was founded in 2004 as a multidisciplinary organization with a goal of enhancing the value of simulation in healthcare. According to the SSH website they were founded *"by professionals using simulation for education, testing, and research in health care, SSH membership includes physicians, nurses, allied health and paramedical personnel, researchers, educators and developers from around the globe."* [15]

The SSH has developed the largest annual multidisciplinary meeting in the world for healthcare simulation. The meeting attracts thousands of people from around the world to engage in scholarly discussions, research presentations, networking and learning focused on simulation healthcare. The SSH also successfully launched the first peer reviewed, indexed journal devoted solely to simulation in healthcare. The SSH also launched the first multidisciplinary simulation accreditation program.

The emergency medicine community has played a crucial role in both the development of the SSH, as well as having been recipient of some of the fruits of the organization as a key community of practice stakeholder in healthcare simulation. Since the inception of the SSH emergency physicians have played a significant role in leadership, including a near continuous presence on the Board of Directors, as well as a past presidents of the organization.

There are many emergency physicians on the editorial board of the Journal, Simulation in Healthcare. Further, there has been a significant scientific contribution from the emergency physician community in terms of scholarly publications and presentations at both the international meeting, as well as the peer-reviewed journal. Two articles from emergency medicine authors were featured in the inaugural issue of the Society's journal [16, 17].

Emergency physicians have been actively participating in the SSH having formed an affinity group in 2006, a special interest group in 2008, and were one of the first groups approved by the SSH Board of Directors as a *section* in 2014. The significance of these milestones as an important part of the contributions of the community of emergency medicine by the fact that it takes continued active participation, demonstrating progress as well core number of dedicated members to continue the activities.

The Society for Academic Emergency Medicine

In May of 2008 the Society for Academic Emergency Medicine dedicated the annual meeting consensus conference to simulation for emergency medicine through a competitive process. The meeting was titled "The Science of Simulation in Healthcare: Defining and Developing Clinical Expertise." This grant funded consensus conference allowed a high level of networking between thought leaders in the emergency medicine simulation community to participate in a large audience consensus process with over 300 participants resulting in several key publications [18–21].

In 2009, members of the simulation community within SAEM were granted permission by the Board of Directors to form an Academy of Simulation. According to the SAEM website the purpose and function of the Academy provides a venue for SAEM members with a special interest or expertise to join to perform a number of functions. Among the purposes listed includes the ability to "Provide a forum for members to speak as a unified voice to the SAEM BOD as well as to other national organizations within their scope of special interest or expertise." [22]

In May of 2017 SAEM held a second consensus conference focusing on simulation entitled "*Catalyzing System Change Through Healthcare Simulation: Systems,* *Competency, and Outcomes"* to address critical barriers in simulation-based research [23]. A series of publications resulted from this meeting to continue to encourage scholarship and advancement of the use of simulation in a number of important areas of Emergency Medicine ranging from training, competency assessment as well as operations and care delivery.

Other Organizational Involvement in the Proliferation of Simulation

The American Association of Medical Colleges (AAMC) had previously founded a peer-reviewed computerized database that served as a repository for medical education materials. In the mid 2000's the AAMC undertook the development of a template and standardize review pathway specific to publishing simulation scenarios to help with high quality simulation scenario materials for sharing in and amongst its members.

More recently the American College of Emergency physicians (ACEP) has acknowledged the usefulness of simulation through including simulation-based workshops at the annual meeting as well as offering continuing education programs focusing solely on a simulation-based methodology.

The roles of the ACGME and the ABMS were covered previously in this chapter but should be thought of as to organizations who will likely contribute significantly to the need for simulation in the future as it relates to assisting with the assessment and demonstration of competency of individuals in accredited training programs.

The Simulation Literature and Emergency Medicine

An evaluation of the literature associated with simulation and emergency medicine demonstrates that the emergency medicine community has been forward thinking insofar as embracing innovative education into the training for emergency medicine. A search strategy combining the terms emergency medicine and simulation currently yields over 600 results. As one may imagine, the results are broad-based ranging from postulating the value of simulation to articulating specific possibilities for curriculum integration and modification of existing training efforts through the exploration of very specific modalities for very specific initiatives.

Some of the key publications authored by emergency physicians have also been used to appropriately enlighten others involved in the design of future undergraduate medical education programs as well as graduate medical education programs [24–26].

There are many efforts at postulating or trying to quantify the potential value of various modalities of simulation for utilization in the training of emergency medicine. Studies range from exploration of individual skills training efforts to those involving teamwork and communications.

Other studies have contributed to pushing forward the agenda to use simulation as a competency assessment tool as well as an educational method [9, 27–31]. Others had evaluated the concept and importance of accreditation form simulation programs relative to emergency medicine [32].

The emergency medicine community has also published literature suggesting strategies for implementation of simulation for competencies that have been identified as important in training programs, but have a history of being difficult to assess. Some of these include communication skills, delivery of bad news and other topics involving teamwork [30].

There have been recommendations published on how simulation may be useful as a rehabilitation or remediation tool for students and/or residents in emergency medicine training programs [33]. Emergency medicine authors have reported unique uses of simulation and the training of others for work in austere environments and special situations such as disaster management leadership training. [19]

Others from the community of emergency medicine look at simulation as a tool, one of many, to be embedded in areas that are critical to the future that likely involve changing of some traditional thought processes as well as multiple learning strategies. Examples such as this are demonstrated in efforts that describe the potential for incorporating simulation into an effective strategy to build an education agenda aimed specifically at error prevention in emergency medicine [34, 35].

There have been reports from the emergency medicine community that describe uses of simulation quite creatively. Okuda et al. describe a novel use of simulation that "allows the educator to watch the decision-making process of the learners as they manage simulated complex scenarios in a cooperative, competitive environment." [36] The net result of such efforts increases the visibility of simulation, can become attractive and somewhat fun for the participants, as well as provide those in educational leadership positions different vantage points for which to conduct assessments and/or evaluations of their programs and/or the individual participants of their programs.

Some reports from the emergency medicine community document simulation as a useful in-situ evaluation tool to further identify systems as well as individual latent threats and potential identification of issues that can help direct the resources and investment in further training/education programs for quality and patient safety initiatives [37].

Somewhat more recently, there has been an increase in demonstrating the usefulness of simulation as a part of a systems design and/or human factors tool. Such implementations have demonstrated effectiveness with studying the flow of emergency department patients in a simulated environment to attempt to identify inefficiencies that can be identified and remedied [38, 39]. Other systems design implementation for simulation describe using simulation to identify latent threats and hazards in new clinical spaces prior to their opening as well as in functional clinical patient care units.

Conclusions

The future for simulation in emergency medicine is bright. When one considers the multiple factors that have led to the significant increase in the number of simulation programs over the last few years it becomes apparent that these pressures will likely increase. The increased need to provide objective assessments of people in training programs as well as an appreciation for the advantages of experiential learning will continue to demonstrate value. A timeline of key events in the history of simulation is shown in (Box 1.1).

Patient satisfaction, throughput and expense reduction and other aspects of emergency department efficiency and quality will continue to areas that will benefit from simulation in planning new models of care for the future. Once planned and implemented, simulation holds great promise for ongoing evaluations of such improvement processes.

The reduction of unintended harm from medical care will continue to take center stage in improvement efforts moving forward and be more directly linked to educational and assessment programs involving individuals as well as healthcare teams, and environments. The financial pressures of penalizing systems for unintended harm and inefficiencies will continue to drive this forward and have a considerable effect on seeking out potentials that can mitigate such instances. It is quite natural that simulation will play a role.

Lastly, the tolerance for practicing on real patients will continue to decrease, and rightfully so as we identify appropriate simulation modalities and instruments that can minimize such practice until a plateau of competency is demonstrated by the healthcare provider.

Simulation in emergency medicine will continue to play an important role in various aspects of education, planning, discovery and defining the future of our practice. The greatest challenge lie ahead in defining the value and the most efficient and effective utilization of the many simulation based tools that are now available.

Box 1.1 A Brief Timeline of Historic Factor in the Development of Simulation from and Emergency Medicine Perspective

1960's	CPR task trainers Resusci Anne and Andy
1979	Administrative simulation for EM published
1980	First EM Board examination
1980's	Widespread adoption of ACLS task trainers and technology
1994	High technology, physiology based human simulators appear focusing on Anesthesia training
2000	Lower cost human simulators with features for EM focus come to market
2004	Society for Simulation in Healthcare founded
2008	First SAEM consensus conference on simulation
2009	ACGME milestones for EM recomends simulation
2010	High technology and virtual reality simulation equipment becomes more readily available
2017	2nd SAEM consensus conference on simulation

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Education and Learning Theory

2

James Kimo Takayesu, Nelson Wong,
and James A. Gordon

Active Learning (AL)

The hallmark of simulation is learner engagement using a clinical scenario accompanied by debriefing that allows for reflection and re-engagement. These two elements – active engagement and critical reflection – align seamlessly with the operating principles of active learning. Active learning encourages learners to clarify, question, apply, and consolidate new knowledge. This process stimulates self-assessment in real-time as new knowledge is acquired and applied, encouraging learners to bridge the gap between their current competence and that just outside the leading edge of their performance. By engaging critical thinking skills, active learning allows for increased retention and encourages transfer of new information [1]. While not all active learning involves simulation, simulation is based on the foundation of active learning, requiring the application of knowledge in situations that mimic real life performance with opportunities to expand knowledge, skills, and attitudes through guided reflection. Simulation can contextualize new knowledge in scenarios that replicate actual clinical practice while also challenging or reinforcing heuristics that are central to emergency medicine practice. Emergency medicine is a specialty heavily weighted toward rapid clinical assessment in the midst of diagnostic uncertainty, which makes dynamic clinical simulation an effective teaching tool. Medical simulation has the dual ability to not only recreate clinical situations, including rare and critical cases, but also allows learning to occur in a protected time and space difficult to achieve in the typical Emergency Department bedside environment.

Beyond knowledge retention, active learning facilitates the formation of cognitive and emotional pathways for accessing and applying knowledge in clinical contexts. This application process expands and elaborates knowledge in ways that traditional passive teaching methods do not, leading to durable learning and retention (see Fig. 2.1). Because simulation learning is centered upon knowledge expansion through application, there is a need for some degree of basic knowledge prior to application to make the most of a simulation exercise. In this sense, simulation can be a particularly useful in targeting the higher levels of Bloom's taxonomy (see Fig. 2.2), after the acquisition of basic medical knowledge and principles that permit clinical reasoning and competent performance. Simulation does not replace traditional forms of pedagogy, but rather acts as an instrument for reinforcing, correcting, and

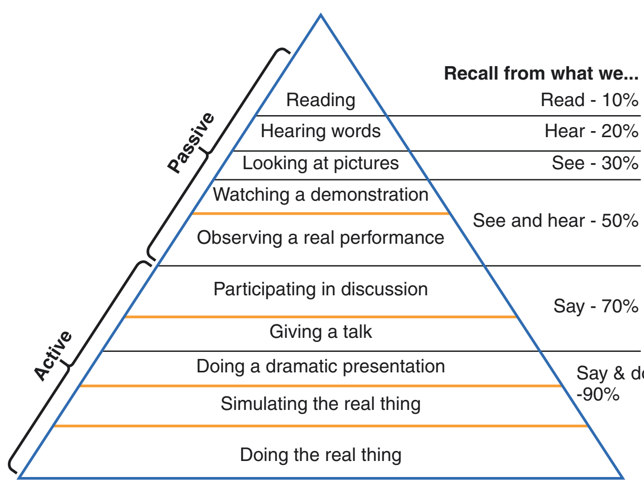

Fig. 2.1 Retention by teaching method pyramid. (Adapted from Dale [40].)

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C. Strother et al. (eds.), *Comprehensive Healthcare Simulation: Emergency Medicine*, Comprehensive Healthcare Simulation,
https://doi.org/10.1007/978-3-030-57367-6_2

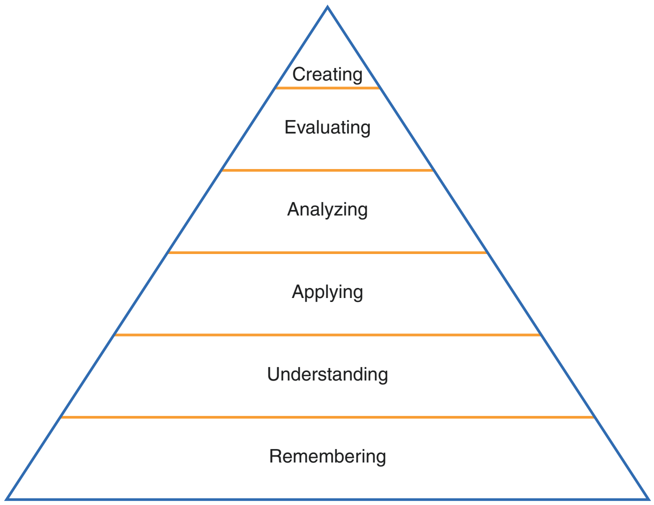

Fig. 2.2 Bloom's Taxonomy classifies levels of cognition reflective of effective learning. As knowledge is acquired, learners should be able to use it with increasing task complexity as they gain mastery. (Adapted from [38])

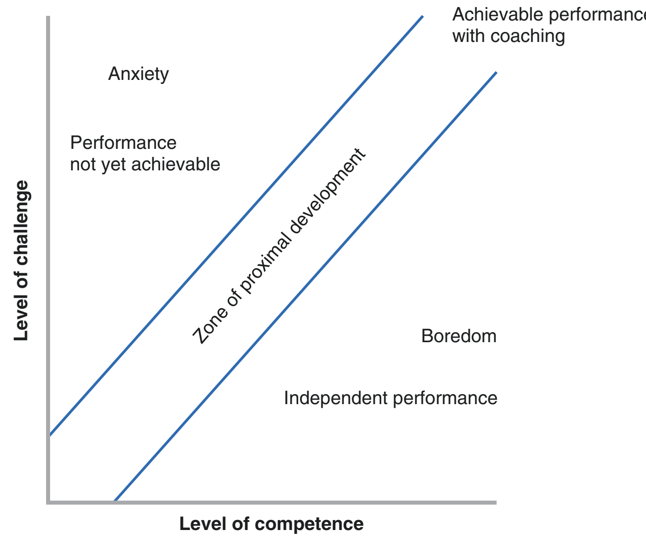

Fig. 2.3 The relationship between the Zone of Proximal Development (ZPD) and the Circumplex Model of Affect is commonly represented as a graph plotting competence against challenge. As the learner gains knowledge, new experiences create additional challenges that require application and extension. The level of the challenge should be difficult enough to emotionally active and cognitively engage the learner within their ZPD

expanding the types of knowledge that drive clinical performance. The simulationist's objective is less to disseminate knowledge, but rather to create an environment for active learning and ongoing clinical development.

Learning Theory

While an in-depth discussion of learning theory is outside of the scope of this chapter, it is important to review the most salient models of the learner and learning theories related to simulation. These theories and concepts are the underpinnings of sound simulation design and help to understand the limitations and, more importantly, the potential of simulation education in adult learning.

The psychological theory of **behaviorism** relies on a core assumption that stimuli create a reflexive response that is reinforced through reward or discouraged through punishment [2]. In its most basic form, simulation is a teaching tool meant to provoke a response and to promote specific behaviors through immediate feedback. **Constructivist theory**, developed by Piaget, challenges behaviorism, stating that learning is an active thoughtful process by which knowledge is constructed based on personal experience rather than reactions to reward or punishment [3]. This model of the learner underscores the importance of experience in driving learning. Looking outwards from the individual learner, **social constructivist theory** developed by Vygotsky emphasized the important role of social interactions in effective learning through instruction. This instruction provides the learner with a 'scaffolding' that helps the learner to grow by allowing them to elaborate upon their knowledge just outside of their current understanding, called the zone of proximal development [4] (see Fig. 2.3). This emphasis on the importance of instruction, gauged to the level of the learner in conjunction with new experiences, is a foundational theme to simulation educational practice.

Drawing from both Piaget and Vygotsky, Bruner further elaborated on constructivist theory by placing an even greater emphasis on the role of good **instructional design**, not just the engagement of instruction, as the scaffolding that helps the learner develop their knowledge structure in both content and complexity [5]. Thus, in addition to learner motivation and quality feedback, the design of the simulation exercise is critical to the learning process. As knowledge structures become more complex, new structures are adopted, replacing and subsuming the previous less-integrated structure. For example, the approach to acute chest pain and hypoxia in the emergency department may involve a relatively simple differential diagnosis for the novice, including pulmonary embolism, acute coronary syndrome with congestive heart failure, and pneumonia. With increasing case complexity, the content and differential diagnosis may be broadened to include rare entities such as atrial myxoma, post-infarction VSD, and papillary muscle rupture.

While these learning theories were primarily directed at explaining a theory of **pedagogy** for primary and secondary education, Malcolm Knowles characterized the essential characteristics of adult learners in his theory of **andragogy** [6]. Rooted in the psychological principles described by Maslow, andragogy has five assumptions which inform instructional design for an adult learner: (1) *self-direction* – adults set learning goals based on that which is immediately relevant to their lives and future direction; (2) *experience* – learning is influenced by the previous experiences a learner brings to the teaching encounter and is driven by new experiences which contextualize new knowledge; (3) *roles* – adult learning needs are set and prioritized by one's professional role and the demands this role places on them; (4) *immediacy* – adult learning is driven by the need to solve current problems encountered in daily life; and, (5) *motivation* – learning is internally motivated by a desire to succeed. For example, when teaching the principles of teamwork one could start by asking the learner about whether they have ever seen or run a code (establish self-direction); having them describe the experience including what could have been done better (anchor on personal experience); and prompting them to reflect on what they would need to do to improve the delivery of care for the next time (establish their own role, emphasize immediate application, and cater to intrinsic motivation). Simulation has a natural relevance to adult learning because of its experiential context. The importance of this context is classically described in John Dewey's theory of "learning by doing" [7]. These assumptions highlight the importance of setting appropriate learning goals, defining roles, and providing structured feedback that builds upon the learner's internal motivation to achieve.

David Kolb developed a model for adult experiential learning that directly informs instructional design. The **learning cycle** defines four sequential phases of learning based on four foundational learning styles, following the central tenet that "learning is the process by which knowledge is created through the transformation of experience" (see Fig. 2.4) [8]. A concrete experience first challenges the learner, forcing reflection on the learning needs required to meet the challenge. Abstract conceptualization denotes the next phase during which the learner elaborates on their knowledge and attempts to understand how the new knowledge will improve their performance. With a new knowledge structure comes active experimentation: applying the new knowledge in more complex and challenging contexts until a new challenge is identified. For example, a learner with a challenging case of a patient in cardiogenic shock may be compelled to understand more about the disease's management. Learning may take many forms (reading, learning from peers or superiors) but simulation is critically important as a means of providing opportunities for active experimentation that will permit the development of the procedural and conditional knowledge (see section "Metacognition") essential for improved performance. Kolb's learning cycle not only supports the utility of simulation experiences in the learning cycle, but also emphasizes the importance of good instruction in the form of debriefing and reflection as complementary and synergistic to the simulation itself.

Context and Transfer

Simulation learning experiences can range from paper-based exercises to full-scale mannequin-based simulations in realistic environments with standardized participants replicating a real-world clinical context. As such, simulation is not restricted to a specific setting or context other than requiring some form of experiential learning that aspires to replicate or approximate reality. **Fidelity** refers to the degree to which the exercise matches the appearance and behavior of the actual experience. The equipment and staffing requirements of a simulation exercise vary based on the experience level of the learner and the learning objectives of the session [9].

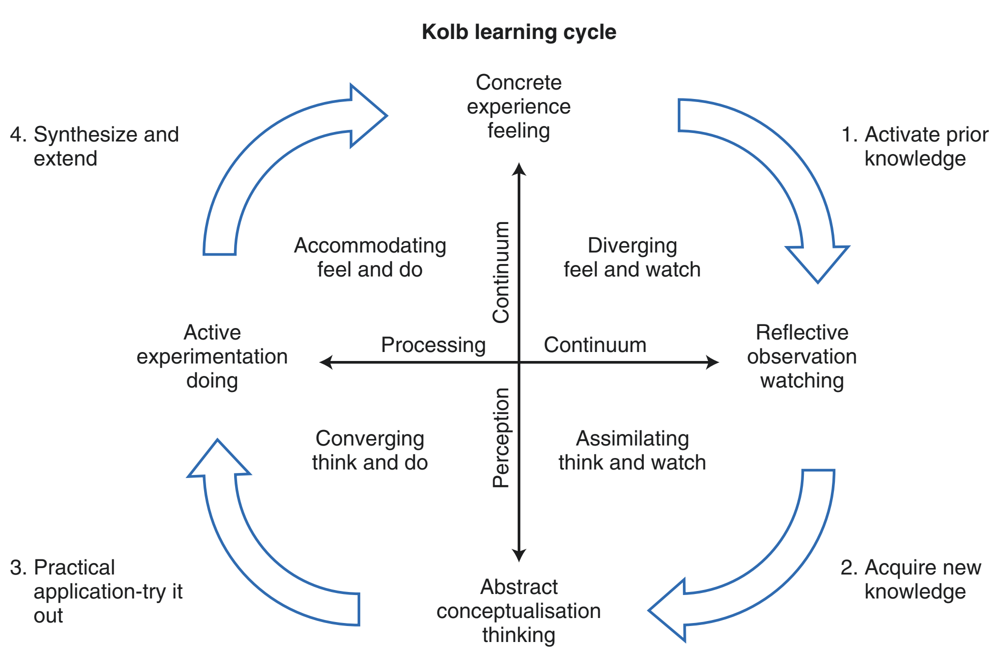

Fig. 2.4 The Kolb learning cycle [39] depicting the four phases of learning and the four learning styles of diverging, assimilating, converging, and accommodating. Learning activities should lead the learner through the entire cycle to ensure knowledge synthesis and extension through active experimentation

Teaching cricothyroidotomy to a first year resident requires much less design and resources than teaching a third year resident how to manage a complex trauma resuscitation.

The fidelity of a simulation can be understood in the context of the environment and the learner's experience of that environment. **Engineering and environmental fidelity** refers to the appearance and feel of the simulation environment, and its effectiveness in providing the learner with realistic sensory input during the exercise. **Psychological fidelity** is defined by the emotional and behavioral authenticity experienced by the learner during the simulated exercise. Higher fidelity simulations are useful in teaching and assessing more expansive non-technical teamwork and communication skills, such as those targeted by Crisis Resource Management (CRM) [10, 11], in addition to core technical and cognitive skills. Some work has suggested that psychological fidelity may even be more important than the engineering fidelity of a simulation in supporting performance gains [12, 13].

An additional aspect of psychological fidelity is the personal emotional response that the learning experience evokes in the learner. The **Circumplex Model of Affect** describes a relationship between emotional activation and deactivation in comparison to whether an experience is perceived as pleasant or unpleasant [14–17]. Based on the circumplex model (see Fig. 2.5), human emotion can be divided down into 4 major quadrants: pleasantly activated (happy, excited); pleasantly deactivated (calm, relaxed); unpleasantly deactivated (bored, sad); and unpleasantly activated (frustrated, anxious). Historically, much of traditional higher education has been experienced while learners are in a relatively deactivated emotional state (i.e., during routine lectures or readings); however, many of the most memorable events in an individual's life occur during a relatively activated state (i.e., a dynamic emotional experience). Immersive simulation seems unique in its ability to recreate a level of emotional activation that can support intense learning and retention in ways that parallel real-world experience [17].

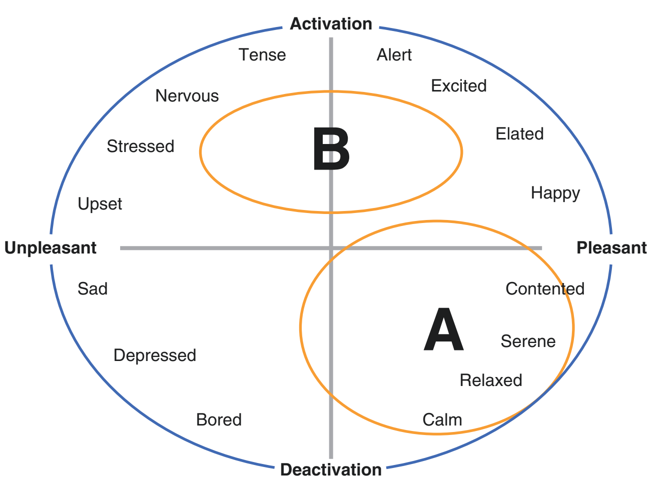

Fig. 2.5 Circumplex model of affect [14–17] as hypothetically applied to the medical learning environment. Area A represents the emotional state commonly experienced by learners during traditional pedagogic exercises (e.g., lectures, conferences, readings); area B represents the typical emotional state of learners during immersive simulation exercises. This dichotomy is thought to represent a unique and fundamental difference between simulation and alternative teaching and learning environments. Areas A and B of overlay on the core circumplex model represent a theory described by investigators at the Institute for Medical Simulation at the Center for Medical Simulation in Boston, Massachusetts. (Figure and descriptive legend text reproduced and updated with permission from the American College of Chest Physicians [17]. Core circumplex model, without areas A and B, reproduced with permission from Cambridge University Press [16].)

Because the reaction of the learner to a simulation experience can be titrated by the instructor, the educational experience can be customized and replicated in a safe, controlled environment. In this sense, fidelity is a characteristic of the simulation that creates realism for the individual to "buy into" the fiction of the case to a sufficient degree that they are engaged in the exercise. Increasing the affective complexity of a simulation in a way similar to the real world experience has proven valuable for developing certain procedural skills [18]; however, overwhelming the learner with excessively stressful environments (seen in the activated extremes of the circumplex model) has been shown to impede learning and retention [19, 20]. When designing a trauma simulation, for example, introducing a disagreement among consultants or inserting an inexperienced RN in the scenario may increase emotional complexity as part of an instructive encounter; however, having the patient subsequently become unstable and code in this setting might overshadow any learning of resuscitative principles. This underscores the importance of titrating fidelity to the level of the learner's cognitive and clinical abilities, balancing the affective learning with the psychomotor (technical) and cognitive learning objectives.

Cognitive load theory dictates that learners can only process a limited number of data points at a time based on their experience level [21]. There are three types of workload, intrinsic, extraneous, and germane. The intrinsic load relates to the task complexity and the expertise of the learner. A novice learning IV placement requires a much simpler task complexity, perhaps with lower fidelity needs, than a more advanced learner with real-world experience [12]. The extraneous load comes from processes that are not directly related to the learning at hand. When learning sepsis resuscitation, calming a panicked family member is not directly related to learning the principles of resuscitation. While such a distraction may be too challenging to the novice, it enhances the psychological fidelity of for the more experienced learner and can be an important secondary learning outcome for the simulation. The germane load refers to learning processes that are directly related to the intrinsic load such as task complexity (e.g. placing a chest tube in a patient with pleural adhesions) and context variability (e.g. placing a chest tube in a patient with hemothorax and hemorrhagic shock requiring an auto-transfusion setup). Combining the circumplex