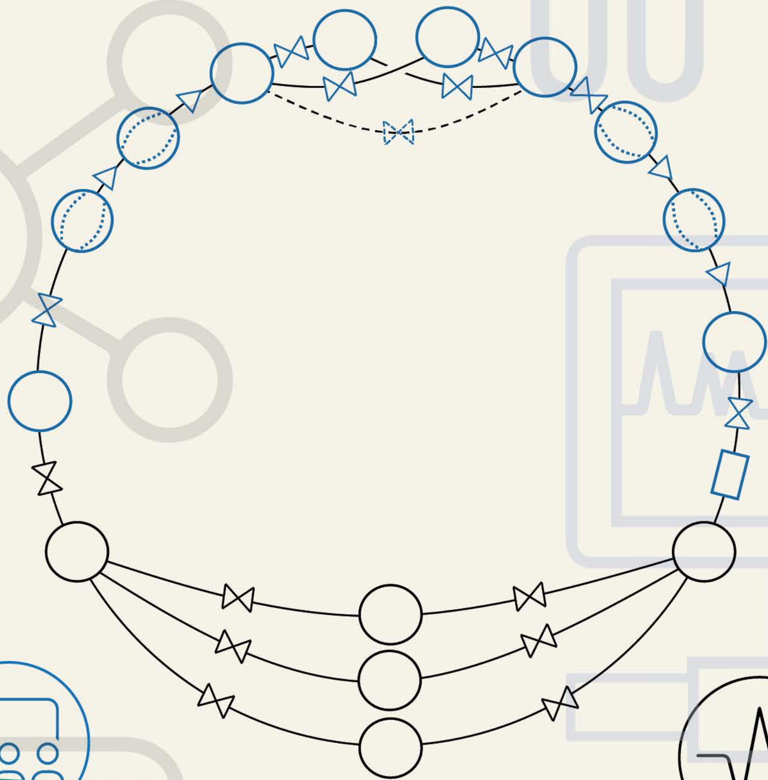
SIMESSENTIALS

R. Helyer E. Lloyd W. van Meurs

Learning Physiology in Context



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This is an extract from the **draft version** of the publication.
The version to be published in **April** may have some minimal differences in form and content.

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Project Managers: Paolo Lippi, Lucia Pampana

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Firenze 50127. Italy

SIMEDITA is committed to publishing works of quality and integrity. In that spirit, we are proud to offer this book to our readers; however, the story, the experiences, and the words are the author's alone.

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Foreword

I joined CAE Healthcare (a part of Madison Industries after March 2024) in February 2022. Immersing myself into the world of simulation and healthcare education and training I found a veritable treasure trove of technologies, physical, digital and virtual; all driven by one physiology model. The more I learned and understood about the physiology model the more intrigued I became! The underlying question I had was: why would people run a simulation without it? My simple parallel (based on being part of a larger CAE organization) was "would you use a flight simulator that did not automatically respond to interventions based on the rules of physics and avionics?" It became a mission of mine to learn more, to gently probe and challenge people I met through the course of my work and let them educate me. Through this process I have moved the model of physiology from the background into the foreground and established the product management discipline with supporting resources around it to manage its evolution and extend its reach and impact in simulation and healthcare education and training.

On two successive days in June 2023, I visited Dr. Helyer in Bristol, UK, and Dr. van Meurs in Lahitte-Toupière, France. Rich and his colleague Dr. Eugene Lloyd at the University of Bristol have made very creative use of the available technologies, and managed to set up physiology teaching programs to a broad range of students. They managed to move from 2 facilitators teaching a handful of students standing around a manikin to 2 facilitators teaching 250 students with virtual patients, while maintaining student satisfaction and test scores! Yet, their highly innovative work was hardly publicized outside of the University of Bristol. The next day in France I talked to Willem, who is one of the original developers of model-driven simulators. He is also an experienced author, so I suggested to Rich and Willem to team up and write the book in front of you. Eugene later on carefully reviewed and corrected the full text. Little did I know how much enthusiasm I would unleash. The publisher SIMEDITA came on board rapidly, and my inbox started filling up with tables of content and sections for the book. The interest of the present work goes beyond the community of CAE Healthcare users. Many of the developed concepts and scenarios can be applied or implemented on other simulators on the market, and the authors and publisher are to be complimented on making the information clear, compact, and shareable. I wish you an enjoyable and informative read, and am very curious about the impact of this timely book on the quality of simulation based medical education and training.

Simon Walls
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Jan. 2024

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1.2 Our journey into teaching physiology

A key logistical consideration, and perceived obstacle, in teaching physiology using simulation is learner throughput. In other words, how can a large learner cohort all have the same learning experience, within constraints of timetable, faculty, and location?

In health sciences education, the normal setting for simulation-based learning is a simulation room or "suite" equipped with a manikin, medical equipment, possibly a display for a clinical monitor emulator, and a one-way mirror to a control room. These locations are ideally suited to sessions with a relatively small number of learners and facilitators. The focus of the session would normally be diagnosis and treatment, patient safety, or interpersonal skills. Sessions are "hands-on", with learners interacting with the physical manikin and real or emulated equipment. In a typical UK undergraduate medicine course the learner cohort is circa 250 per taught course unit or module per year. To put a cohort of this size through just one learning session in a typical simulation environment under time constraints (taught topics are often covered in a single week) requires multiple repeat sessions, in multiple suites, with multiple instructors, and multiple specialist technical support staff. The above description is based on current numbers of healthcare students. This number is likely to increase significantly to meet global demand for providers.

Given the appetite for training using simulation with current numbers of trainee doctors and nurses alone, how then can simulation be used in the teaching of physiology at a greater depth to both learner groups? An how about other groups? This broader group comprises any learners for whom some depth of knowledge of physiology is appropriate and includes: biomedical sciences, physiology, pharmacology, neuroscience, biomedical engineering, veterinary and dental medicine, among others. Suggestions to expand teaching using simulation to these groups are met with concerns about resources, both in terms of locations and the numbers of facilitators that are required to deliver it. These concerns, together with a lack of understanding of how to benefit from physiologic model-driven simulators, are among the reasons that to date simulation has not been widely adopted for teaching physiology to a wider learner cohort.

A simple solution to deal with logistical problems is to abandon the classic "simulation-suite" environment and to use simulation in environments with a larger learner capacity. Sessions can then be plenary, and depending on the size on the facility, may allow an entire learner cohort to enjoy the learning experience in a single session. This model is a very efficient way of achieving high learner throughput, at the same time ensuring individuals all receive a consistent experience with the same qualified facilitator. The University of Bristol has developed and embraced this model in its undergraduate curricula, but implementation has been a journey over a number of years using a range of media. Any of the steps outlined in this introductory section could be appropriate for expanding physiology teaching using simulation, depending on available facilities.

The first step to high-throughput simulation teaching at the University of Bristol (UB) was to increase learner numbers in each simulation session to circa. 30 learners, but still in the same location (simulation suite) as the manikin. Learners observed vital signs and physiological data provided by the clinical monitor emulator on large screens, taking notes on worksheets and engaging in discussion as the scenario progressed. Volunteers would take vital signs or interact with the manikin as required for the simulation and report back to the wider group. These tasks were typically limited to palpating pulses, changing inhaled gas mixtures, or using a bag-mask-valve apparatus on the CAE Human Patient Simulator (HPS). The move to this model was driven by our educational needs analysis for physiology: is it necessary for ALL learners to be able to take signs such as pulses? Practical, tactile, clinical-skills are not a prerequisite for understanding physiological mechanisms. Feedback from learners collected in end of unit surveys suggested no change in satisfaction working in a larger group. Moreover, some learners commented they were relieved to not to have to interact with the manikin in front of the group. See Chapters 2 and 5 for a more detailed educational needs analysis, and evaluation results, respectively.

Figure 1.1. A medium size student group studying physiology in a simulation suite. Note the display of physiological data using the CAE Muse facilitator interface on the large screen.

Without the requirement for all learners to interact with the manikin in learning physiology, a natural progression was to upscale to an even larger group. Practical-class teaching laboratories are typically equipped to accommodate over 100 learners. At UB the limit in medicine and biosciences is 140. Initially, the learner group was divided into one small group (preferably self-selected) in the simulation room, and the remainder in the larger class laboratory, with rooms linked by two-way audio and video. This was facilitated by the proximity of the teaching laboratory and simulation suite. Live images were relayed to the larger room, along with projection of a clinical monitor emulator on large screens. The facilitator was present in the large room, with an assistant in the simulation suite. Some liveliness was introduced into the sessions by communication via large, speech-bubble signs that could be held up to the camera as the voice of the subject or patient. In order to assist students in navigating the worksheet, a roving demonstrator/teaching assistant was employed to assist the lead facilitator in the large room. Again, there was no change in overall student satisfaction on moving to this model. Presumably learners either understood there was no need for physical interaction or were satisfied with their peers reporting signs, led by enthusiastic facilitators. There was even some reluctance among students to be placed in the smaller group in the simulation suite with the manikin. They reported they feared missing out on the larger group experience with the lead facilitator.

The third iteration of this model was the adoption of tetherless manikins (CAE iStan and Athena). This eliminated the need for complex room to room audio and video communication, allowing students to observe the interactions of volunteers with the manikin directly in the same location. A camera was used to relay images of the students and manikin, usually located at the front of the class, to screens situated throughout the laboratory. The instructor, technician, and manikin all in one room allowed for greater fluidity in delivery of the session. Model-driven physiology meant that the technician was not tied to the simulator control computer, attempting to run the simulation "on-the-fly". It was notable that most students preferred to be reflexive learners, observing and discussing, rather than volunteering to interact with the manikin and report to the wider class.

Figure 1.2. Large student group learning in a large capacity location. Note the projection of physiological data on the large screens, using the CAE Muse facilitator interface. The instructor and technician are front-centre and students are noting data on worksheets.

The fourth and final iteration came in 2022 with the advent of "virtual patients" (CAE Evolve with Embody). Again based on educational needs analysis and the observation that learners tend to be reflexive rather than active volunteers interacting with the manikin, the step was taken to dispense with manikins altogether and move to a virtual patient. This

presented significant advantages. On-screen presentation of the patient improved visibility of vital signs and perceptibility of sounds (e.g. heart sounds) throughout the teaching laboratory. Virtual patients can show more signs such as changes in skin pallor, and there is a wider variety of patient including various ethnicities. A key advantage of virtual patient based simulators is that they are much more affordable than physical manikins, with a license for a model-driven virtual patient at circa EUR 4,000 at the time of writing. By the end of the 2022-2023 teaching session, over 1200 students had experienced up to 6 simulation sessions using virtual patients.

Figure 1.3. CAE Maestro Evolve learner interface: clinical monitor emulator and virtual patient.

Finally, it is worth noting the effects of the global pandemic. In the spring of 2020, all face-to-face teaching at UB ceased, and like most institutions there was a scramble to find solutions to continue delivering learning. Desperate times lead to innovation, and using the model-driven simulation interface without the manikin we were able to deliver our simulation sessions across the globe. Using an online learning environment: Blackboard with Collaborate, real-time physiological data were provided to learners via the waveform display in the same way as in a face-to-face session in the teaching laboratory. The technician ran the simulation from the Centre, with the instructor working from home, and learners logged into the sessions from their respective lockdown locations. Microsoft PowerPoint slides, also see Chapter 4, were used to structure the session and video showed what might be seen on the patient or subject. Students were able to interact during the session by making suggestions and asking questions using a chat function, with the simulation paused when there were opportunities for discussion. End of unit feedback was very positive, with some students noting the sessions were the highlight of their learning. The experience of delivering simulation-based teaching to cohorts of circa. 250 students per online session demonstrated the potential for application to distance learning, and provided additional support for the use of virtual patients rather than physical manikins for teaching physiology.

Assessment of educational needs, program design, implementation, and assessment of simulation-based learning of physiology took place over more than two decades and included many iterations. Several were described in this introductory chapter. For the benefit of the reader, the subsequent chapters provide a linearized sequence of considerations and decisions leading to the present efficient and successful delivery formats. Chapter 2. Educational needs, predominantly addresses the "why" question. Chapter 3. Program design, the "what" question, and Chapter 4. Implementation the "how" question. Chapter 5. Evaluation, addresses the "how well" question, and Chapter 6. Future the "whereto" question.

1.3 About this book

This short book is intended as both a theoretical reference and a practical guide to a broad range of simulationists: program directors, instructors, and technicians who accompany undergraduate students in learning the core subject of physiology. Physiology is presented "in context" by reference to whole-body systems, and by presenting phenomena in a simulated clinical environment. The text is based on our long experience with this modality in the bachelors degrees: anatomical science, biochemistry, biomedical engineering, biomedical science, dental science, medicine, neuroscience, pharmacology, physiological science, psychology, veterinary nursing, and veterinary science. We demonstrate how adapted simulation solves the challenges with high numbers of learners, while maintaining satisfaction scores and learning outcomes. For the benefit of the reader, the subsequent chapters provide a linearized sequence of considerations and decisions leading to the present efficient and successful delivery formats. Chapter 2. Educational needs, predominantly addresses the "why" question. Learner profiles, specific program requirements, and curriculum integration are considered. Chapter 3. Program design, addresses the "what" question. Learner activities, simulation scenario design, facilitation and assessment, notably how simulation data can be used in learner assessment, receive attention. Chapter 4. Implementation, addresses the "how" question. Models of human physiology and simulator interfaces are described, as are sequencing of content and activities during simulation runs. Post simulation session data analysis and learner engagement also receive attention. Chapter 5. Evaluation, addresses the "how well" question based on experiences and learner outcomes for several of the courses at the University of Bristol. In Chapter 6. Future, the "whereto" question is addressed, and recent technological development and recommendations for additional educational impact studies are provided.

Authors

Richard J. Helyer, PhD, is Senior Lecturer in Physiology and Human Simulation at the University of Bristol. He teaches nearly 2000 undergraduate students per year in principles of whole-body physiology. He pioneered high-throughput learning after the early adoption of simulation in the learning of physiology in Bristol. Always enthused by the application of technologies, his research interests spanned pyrolysis mass-spectrometry, relatively early application of PCR and finally electrophysiology before moving to a teaching-track position. He held numerous roles including School Education Director in Physiology, Pharmacology & Neuroscience. Dr Helyer has made many contributions to scientific meetings describing the application of simulation to learning whole-body physiology with an emphasis on using the physiological model.

Eugene Lloyd, BSc, MBCHB. is Program Co-Director at Bristol Medical School, Senior Lecturer at the University of Bristol, and an emergency medicine clinician. His passion is medical education and he was instrumental in the delivery of a new integrated curriculum that saw its first graduate doctors in 2021. He was pivotal in the drive to use simulation in teaching physiology in the earliest years of medical curricula, with the aim that a better understanding of physiology improves patient safety. Dr Lloyd has contributed to numerous meetings in both physiology and medical teaching on the subjects of physiology teaching, novel assessment and patient safety.

Willem van Meurs, PhD, Affiliate Professor of Perinatology, University of Porto Faculty of Medicine, was instrumental in the development of a range of acute care training simulators at the Universities of Florida and Porto. Life-like responses of these simulators are created via mechanical and mathematical models of cardiorespiratory physiology and pharmacology. Commercialized by CAE Healthcare, these simulators have generated over 1 billion dollars in sales and significantly reduced the need for training on live animals and real patients. Dr. van Meurs is a regular contributor to SIMZINE and his other books include Modeling and Simulation in Biomedical Engineering, McGraw-Hill (2011), and The Dolls' Engineer, SIMEDITA (2023). He also served as the president of Society for Simulation in Europe (SESAM).

This book offers a comprehensive guide to simulation-based physiology education of a broad range of undergraduate learners. It centers around sessions following the hypothetico-deductive method with, for medical and veterinary students, special attention to diagnosis, clinical decision making, and treatment outcome. It covers educational strategies, program design, and implementation. The text describes the innovative learning methods developed by the authors, relying on virtual patients and model-driven simulators. Educational throughput is improved 20 fold, while maintaining learner satisfaction and outcome.

Cover illustration by Pietro Cordini
Central figure on the cover: Willem van Meurs

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