Chapter 13
Simulation-Based Learning and Education

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> *What is honored in a country is cultivated there.*
> Plato, Republic, Book VIII

Abstract Simulation is vital to many disciplines as has been shown throughout the book. Future specialists in every domain must include modeling and simulation (M&S) as integral part of their learning, education, and teaching the discipline itself. This fact has been accepted by various institutions, universities, and research centers as they incorporate M&S support to various scientific disciplines. This chapter enumerates venues that offer simulation-based education and training across broad disciplinary areas like Engineering, Natural Sciences, Social Sciences and Management, and Information Science. It emphasizes that simulation is an invaluable tool for experiential learning and teaching by performing—in silico (namely, computerized)—experiments and gaining experience.

Keywords Cognitive learning · Deep learning · Future of simulation-based education · Instructional design · Pedagogy · Simulation-based education · Simulation-based engineering education · Simulation-based information science education · Simulation-based learning · Simulation-based natural science education

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13.1 Introduction

One of the three aims of Chap. 1 (titled: "The Evolution of Simulation and its Contribution to Many Disciplines") of this book is stated as: "To point out the fact that the phenomenal developments in many aspects of simulation (Ören 2005, 2011, Ören and Yilmaz 2012), made it an important and even a vital infrastructure for many disciplines. Indeed, time is ripe for enriching many disciplines by the transition from "model-based" paradigm to "simulation-based paradigm" to make them even more powerful. Like many other disciplines in engineering as well as in natural and social sciences, learning, education, and training are already tremendously benefiting from simulation-based approaches (Sowers et al. 1983). This transition may even be quickened and widening in scope by putting more emphasis on simulation education of not only simulationists alone but also for other future specialists in many other disciplines, including "modeling and simulation in all subjects of education, particularly teacher education" (Kazimi et al. 2013).

As outlined in Table 13.1, learning/teaching/education have many connotations. **Learning** is acquisition of new knowledge, skill, or attitude; it can be done through study, including (real life or simulated) experimentation or experience, or being taught. It is an essential ingredient of education and training and can be done in classroom, online, on-the-job, or just-in-time.

Computerized **simulation** (or computational simulation, or computer simulation, or in silico simulation, and mostly referred to, in short, as simulation) is performing goal-directed experimentation or gaining experience under controlled conditions by using dynamic models; where a dynamic model denotes a model for which behavior and/or structure is variable on a time base. So far as non-computerized simulation is concerned, as clarified in Chap. 1 of this book (Ören et al. 2017), "Simulation, in the sense of pretending (to make believe, to claim, represent, or assert falsely), has been used since a long time in relation with both experimentation and experience. Experimentation done by pure thinking is called *thought experiment* (also, conceptual experiment or *Gedankenexperiment*). Thought experiments have been used mostly in ethics, philosophy, and physics. Some examples are prisoner's dilemma and trolley problem (Brown et al. 2014). Physical aids, such as *scale models*, were also used for simulation done for experimentation purposes. Another possibility has been simulation of the real system under controlled experimental conditions, such as wheel and tire simulators." Simulation which is a vital infrastructure for many disciplines can also be very useful in learning and teaching. And has several advantages for experiential learning. In the following sections, many of these concepts are revisited within the realm of simulation-based learning. Since, the issue is learning, pedagogical principles would be beneficial to enhance several types of simulation-based education.

In this chapter, several aspects of simulation-based learning and education are clarified: In Sect. 13.2, basic concepts of learning and simulation as well as simulation-based education, in general, are highlighted. Sections 13.3, 13.4, 13.5, and 13.6 are devoted to simulation-based education for engineering, natural science,

Table 13.1 Outline of connotations of learning/teaching/education

Aspect	Different words/phrases associated with the aspect
What is learned	Information, knowledge, skill, attitude, choices, relationships
Learning	Adaptive learning, autodidacticism, blended learning, cognitive learning, collaborative learning, constructivist learning, digital learning, distance learning, e-learning, experience-based learning, experiential learning, experiment-based learning, formal learning, game-based learning, hybrid learning, in-class learning, informal learning, just-in-time learning, learning by doing, learning from experience, learning from experiments, learning from augmented-reality game, learning from mixed-reality game, learning to learn, lifelong education, lifelong learning, machine learning, online learning, on-the-job learning, open learning, personalized learning, role playing-based learning, scenario-based learning, self-learning, simulation-based just-in-time learning, simulation-based learning, simulation-based machine learning, solitary learning, student-centered learning, teacher-centered learning, technology-based learning To be informed, to be informed by an event, to be informed by an experience
Education	Pedagogy, simulation pedagogy, curriculum, lecture, literacy, illiteracy Adult education, constructivist education, constructivist education philosophy, inter-professional education, mixed-reality education, private education, professional education, self-education, simulation-based education, simulation for developing critical thinking, teacher education, vocational education
Educational goals	Affective educational goals, knowledge-based educational goals, skill-based educational goals
Teaching	Instructor, mentor, tutor; instructing, mentoring, tutoring; tutorial Student-centered teaching; self-teaching Instruction, differentiated instruction, mixed instruction, technology-mediated instruction, web-enhanced instruction
Training	Military training, technology-based training, training for health care, teachers training, virtual training, vocational training, Web-based training
Workforce development	Simulation-based workforce development (for a discipline/trade)

social science and management, and information science, respectively. Section 13.7 is reserved to discuss future of simulation-based education.

Two subjects are not covered in this chapter: simulation-based training for military as well as simulation-based training for health sciences, since two chapters (Chaps. 10 and 14) are dedicated, for these two subjects.

13.2 Simulation-Based Learning and Education

Due to richness of the field of learning and associated concepts (see Table 13.1), in this section of the chapter we point out some of the possibilities for simulation-based learning and simulation-based education. Table 13.2 lists associations/

Table 13.2 Associations/networking related with simulation-based learning, education and training

Acronym	Expanded form
ABSEL	Association for Business Simulation and Experiential Learning
CoLoS	Conceptual Learning of Science
EBEA	The Economics and Business Education Association
ETSA	European Training and Simulation Association CIC (ETSA)
IMSF	International Marine Simulator Forum
ITSA	International Training and Simulation Alliance
KTSA	Korea Training Systems Association
NICE	National Initiative for Cybersecurity Education
NASAGA	North American Simulation and Gaming Association
NM&SC	National Modeling and Simulation Coalition
NTSA	National Training Systems Association (USA)
SAGSET	The Society for the Advancement of Games and Simulations in Education and Training
SEE	The Simulation Exploration Experience
Simulation Australasia	Simulation Australasia

networking related with simulation-based learning, education, and training. A website maintained on simulation in learning, education, and training may also provide relevant information (Ören 2017a).

Even in pre-computer era, some forms of simulation have been successfully used for education and training. For example, role playing (as a type of simulation) is used for training. Similarly thought experiments provide bases for decision-making. “Tell me and I’ll forget; show me and I may remember; involve me and I’ll understand” says a Chinese proverb. Both real life experiments and experiences provide occasions for this type of learning by involving learners. Even though real life experiments and experiences are valuable, sometimes they may be risky, costly (including opportunity costs), not feasible, and may take a long time, in addition being haphazard. Computerized experiments and experiences provide possibilities for realistic experiments and experiences under controlled conditions.

To cover anatomy of simulation-based learning, we concentrate on five W and one H aspects of learning—namely on Who, Why, What, When, Where, and How—as outlined in Table 13.3.

13.3 Simulation-Based Engineering Education

Simulation in engineering begins with mathematical models that use physics-based methods, empirical collections, or a combination of two for balanced fidelity and complexity (Çakmakcı et al. 2017). These mathematical models can be defined at

Table 13.3 Elaborations on 5W1H aspects of (simulation-based) learning/teaching

5W1H Aspects	Elaborations
Who learns	• Beginner, advanced beginner, competent, proficient, expert, master (Denning and Flores 2016) • Student, apprentice, professional, one who needs knowledge (information) • Computer (software agent, robot)
Why learn (Goals and objectives) (Bixler and Wilson)	Types of objectives or domains of learning (Wilson): • Cognitive objectives (to increase an individual's knowledge) (Bloom et al. 1956; Anderson 2013) (being informed) (education) • Affective objectives (to change an individual's attitude, choices, and relationships) (Krathwohl and Bloom 1999) (education) • Psychomotor objectives (to build physical skill) (Harrow 1972) (training) (fine motor skills, gross motor skills; operational skills)
What to learn/teach	• Informing: Learning/teaching knowledge/information – Existing knowledge – Discovered (previously unknown yet existing) knowledge – Generated knowledge • Education: Learning/teaching attitude, choices, and relationships • Training: Learning/teaching skills – Motor skills, decision-making skills, operational skills
When to learn	• Just-in-time learning, lifelong learning • Moods that support learning: ambition, confidence, perplexity/bafflement, resolution, serenity/acceptance, trust, wonder (Denning and Flores 2016) • Moods that block learning: apathy, arrogance, boredom, confusion, distrust/skepticism, fear/anxiety, frustration, impatience, insecurity, overwhelm, resignation (Denning and Flores 2016)
Where to learn	• Classroom learning • Distance learning • Online learning • In situ learning
How to learn	• Learner learns herself from available sources (books, Web) • Machine learning system learns itself (non-supervised learning) • Teacher (instructor, tutor, mentor) teaches (informs) • Experiential learning by experiments [in vivo, in vitro, in silico (computerized)] by experience (role playing)

multiple abstraction levels to aid the learning of a relevant scientific concept. A model at a high level of abstraction is termed as lumped model. In engineering education, for specialized streams like electrical engineering, where we have

Maxwell equations, the theory is well established. Consequently, abstraction levels can be designed in an incremental manner and learning can be supported by both real and virtual systems.

Experimentation with a real system (albeit of reduced complexity in a lab setting) warrants a physical laboratory while a virtual system warrants a simulation laboratory (e.g., simulation software in a desktop setting). In this age of higher costs of university education and more accessible online education, having a simulation-based engineering education curriculum is a preferred option. Bringing both the real and virtual together for a simulation experiment is a nontrivial engineering challenge and requires expertise in hardware–software codesign and distributed simulation platform engineering (Mittal and Zeigler 2017). The primary motivation of bringing these elements together is to deliver an experience to the trainee and tutor him through scenario-based learning (Errington 2009, 2011). In the defense domain, a Live, Virtual, and Constructive (LVC) environment is used, where live assets are integrated with virtual assets with varying levels of abstraction. The virtual assets can be of identical fidelity as the real-world assets, where they are called emulators, or of reduced fidelity, where they are called simulators. An emulator adheres to the rules of the asset/system it is emulating and it behaves exactly like the real-world asset, but in a different environment. A simulator, on the other hand, behaves in a *similar* way as of a real-world asset and is implemented in a completely different way. These simulators may vary in degree of complexity and abstraction, and require model engineering. A reduced complexity simulator at a much higher level of abstraction is often called a constructive entity. Conducting an LVC event is a nontrivial exercise as there is human element present in a reasonably complex experiment. LVC environments are usually used in defense domain to bring realism to combat training in an operational context in distribute mission operations (DMO) setting (Mittal et al. 2015).

In the engineering domain, hardware-in-the-loop (HIL) environment is mostly used that corresponds to LVC in the defense domain. HIL environment usually incorporates live and virtual systems (e.g., simulators, software, and hardware) and may not consider human-in-the-loop or man-in-the-loop in the same amount of usage as in LVC training. All the established fields of engineering, (as described in Sect. 13.2 of this book) can use HIL to develop Test and Evaluation (T&E) strategies. Consequently, the path to training, education, test, and evaluation is available and customizable. However, in cross-disciplinary engineering, the path is not straightforward.

There are many emerging streams, such as cyber-physical system (CPS) engineering, netcentric complex adaptive systems (CAS) engineering, system of system (SoS) engineering for which there is not enough theory present to deliver a closed-loop solution. These disciplines are currently replete with emergent behavior as the final form of the theory is still developing. Many times, the emergent behavior is the very behavior that is desired out of such a complex system. Efficient methodologies are needed to understand the emergent behavior, harness it and thereby, make them predictable so that the training and engineering processes can be developed (Mittal 2013; Mittal and Rainey 2015). Until the theory is developed and validated, simulation-based experimentation becomes the preferred means to bring in the existing theories in relevant contexts for engineering a solution (Mittal and Martin 2017). These solutions require continuous training and feedback from existing solutions that improve the solution itself in an iterative manner.

In the era of complex system engineering, simulation-based methodologies provide a virtual environment to experiment and experience the complex phenomena and a means to investigate the usefulness of a particular solution and the solution's impact to the overall environment. The Internet of Things (IoT) phenomenon, indeed, has no existing theoretical model as the phenomenon is fairly new. How can learning and tutoring be ever attempted in engineering the new world of these super-connected ecosystems that involve human, physical systems/devices, cyber environment, and shared infrastructures such as electricity, transportation, and many others? The design of a virtual workbench is the first step to develop training, experimentation and experience in helping build the next generation of complex systems engineers.

13.4 Simulation-Based Natural Science Education

The use of modeling and simulation in education, particularly in the various disciplines under the heading of the physical sciences, comes within the slightly broader category of computational science. The US Department of Energy's Graduate Fellowship on Computational Science (in a survey of computational science and engineering education programs published by the Krell Institute) defines the term, as applied to education, as "an interdisciplinary field that applies the techniques of computer science and mathematics to solving physical, biological, and engineering problems" (Krell Institute 2016). In many cases, the phrase "computational science" is used intermittently with the phrase "modeling and simulation," especially in the context of education and research (Denning 2000). As computers become more ubiquitous in our society, it is natural that they will be given a greater use within our education systems, and within education for the physical sciences this means the use of computers to represent and solve problems. Within the scientific method this means constructing models (for different purposes), and using simulators to reinforce learning about the natural phenomena that such models represent.

It is significant to note the importance of advanced computing in scientific discovery and the place of simulation in the scientific discovery process. Advanced Scientific Computing Research (ASCR) is a program of the US Department of Energy (DOE).

> The mission of the Advanced Scientific Computing Research (ASCR) program is to discover, develop, and deploy computational and networking capabilities to analyze, model, *simulate (emphasis added)*, and predict complex phenomena important to the Department of Energy (DOE). A particular challenge of this program is fulfilling the science potential of emerging computing systems and other novel computing architectures, which will require

> numerous significant modifications to today's tools and techniques to deliver on the promise of exascale science (DOE ASCR).

Another organization related with advanced computing is SciDAC (Scientific Discovery through Advanced Computing). "There are currently four SciDAC Institutes with 24 participating institutions …. The mission of these SciDAC Institutes is to provide intellectual resources in applied mathematics and computer science, expertise in algorithms and methods, and scientific software tools to advance scientific discovery through *modeling and simulation emphasis added*)." (DOE SciDAC).

However, it is also important to distinguish the following point: Classifying concepts, including disciplines, having a common aspect (in this case "computation (al),") under this common aspect may be misleading and may lead to misinterpretations and confusions. An example follows: "Computational immunology (or systems immunology) involves the development and application of bioinformatics methods, mathematical models, and statistical techniques for the study of immune system biology." (Yale immunobiology). Hence, considering "computational immunology" under the concept of "computation" would be wrong. "Computational" is an aspect of "immunology." Like mathematics which is an essential—albeit distinct—element of computation, simulation is an essential, yet distinct, element of computation.

Sixty years ago, when the first "satellite" was launched in 1957, it was called an "artificial satellite." With the advancements of the field, now the term "artificial" is not used. With the maturity of many fields, similarly, the term "computation(al)" may be dropped and the contribution of simulation may be explicit by the attribute "simulation-based."

In the process of education with the natural sciences it is typical that a student will undergo a variety of different learning activities. This is in accord with many different approaches to education, and can be represented by a variety of different interpretations of Bloom's Taxonomy of Learning Domains (Anderson 2013). It is important for students to learn about the physical phenomena of the science they are studying (chemistry, biology, geology, etc.) by studying their characteristics, constituent parameters, and the general and specific terms and definitions associated with each. But it is also important for the student to gain understanding and appreciation for how these phenomena work. This is particularly true within the context of the higher levels of Bloom's Taxonomy, where students must know enough about a phenomenon so that they can evaluate when it is occurring (and how); to be able to analyze a representation or claim about such a process; or to be able to create reports or explanations of such a process. To accomplish this, students must not only learn about the physical science, but must be able to apply the scientific method to studying it.

In both learning about a physical science, and in applying the scientific method to studying it (observations, the formation of hypotheses, and testing through experimentation), it is crucial that students can both understand, and create scientific models. This has widely become recognized as the third leg to scientific exploration, alongside empiricism (or observation of phenomena), and rationalism (the construction of theories from basic principles). A model can take two forms, that of a model of the phenomena, or a model of data about a phenomenon (Frigg and Hartmann 2017). In both cases, this can lead to a simulation, the first of which will help students to visualize what happens when the phenomena takes place, and the second will help the student understand the data that affect the process, and can lead to simulated data when results from observation are not available.

The value to education of such simulation is on several levels. First, it allows students to observe and understand a natural phenomenon when observation of the actual event is difficult or inaccessible. Some examples include biological processes that occur rarely, or at a difficult to observe scale—things happening at the molecular level, or at the neural level, for instance might be difficult to "observe" but a suitable computer simulation can assist the student in understanding what is being represented by a theory or model, and this leads to greater understanding of the phenomena itself. An example of such a simulator is the molecular workbench, the name for a collection of highly interactive molecular simulators designed to assist students with understanding difficult, but important principles about molecular dynamics, especially in biological systems (Tinker and Xie 2008). Secondly, it allows students to observe a phenomenon that is predicted by a model, but may not have occurred yet. Such an event could include a stellar process (such as the progression of stars through various sequences, leading to a possible nova or supernova), effects of perturbing an existing system that might be in equilibrium, or possible effects of activity on the environment.

An example of an education model that fits some of the above criteria is the Mitigation Simulator, available online from the Koshland Science Museum (National Academy of Sciences 2017). This is a simulator, where the student may choose several different criteria for adopting a Mitigation Strategy to avoiding bad effects of greenhouse gas emissions. The student can then explore different solutions to problems, and see how they fit within their selected strategy. In so doing, the simulator teaches the student about not only the reality of conflicting constraints on possible solutions, but also the proposed efficacy of different possible approaches to limiting or mitigating the greenhouse gases. In this way, the student gains not only insight into the effects of the gases on the environment, but also gains an appreciation for how it affects the natural world, the economic world, and the political world. Similar information could be taught using only textbook definitions and explanations (declarative cognition), but the impact of having to balance the different strategies with the selected constraint introduces the student to having to balance their choices within the model (procedural cognition).

In general, in education, but in particular in the physical sciences, the use of computational science techniques (in particular modeling and simulation) will facilitate students gaining insight into the subject matter being addressed (in this case, scientific principles and processes); students will benefit from a deeper understanding of the subject through seeing visual representations and dynamic representations of the subject matter; and students will likely become more engaged in the course (Lean et al. 2006). Such approaches have become so apparently valuable, and a part of the pedagogy, that the term for their employ is now coming to be accepted as model-based learning. Such learning includes both learning by modeling, but also requires learning to model. This, however, can be embedded into the education process by the educator, much as learning laboratory methods are germane to physical science education, learning about virtual modeling and virtual tools will gain a similar footing in model-based learning (Blumschein et al. 2009). The benefits of studying science, in silica, using virtual tools, present an enormous benefit to educational environments where resources are scarce, but in all venues, have all the benefits listed earlier.

13.5 Simulation-Based Social Science and Management Education

According to the bureau of labor statistics in the United States, Research and Development in the Social Sciences and Humanities represents 59,930 employees of which 8% are in the computer and mathematical occupations (Bureau of Labor Statistics 2017). Of these current employees, it is unclear how many have formal or informal training in the field of modeling and simulation. In the meantime, the National Center for Education Sciences reports that 531,200 bachelor's degrees were conferred in the fields of business, Social sciences, and history in 2013–2014 which together represents nearly 30% of all bachelor's degrees in institutions participating in Title IV federal financial aid program. There is a tremendous opportunity to educate the future workforce in Modeling and Simulation

In contrast, the same institution reports that the Computer, Modeling, Virtual Environment, and Simulation which is the broad category that encompasses Modeling and Simulation only graduated 291 students at all levels (certificate, two year, four year, and graduate) for the same time span. Table 13.4 shows a list of US academic institutions that award degrees in the simulation field either as a first or second major or certification. This is encouraging news because it shows an acceptance of the role of modeling and simulation in the generation and enhancement of student's abilities and marketability in the workplace.

Table 13.5 displays US research centers where students can interact and learn from the state of the art in basic and applied simulation methods within several university research centers. These centers are multidisciplinary and embody the ideal of simulation education.

However, the numbers clearly show that an approach that consists of training simulation engineers to think and investigate like social scientists and humanists is not a viable option by itself. Instead, an alternative would be to train social scientists to incorporate principles of modeling and simulation in their curriculum. Table 13.6 shows a sampling of social sciences, humanities, and multidisciplinary programs where principles of modeling are incorporated and taught.

In addition to the comprehensive inclusion of modeling and simulation in these programs, it is worth noting that other disciplines such as experimental archeology or

Table 13.4 A sampling of US institutions offering a computer modeling, virtual environment, and simulation program

State	City	Institution name
Alabama	Huntsville	University of Alabama in Huntsville
California	Los Angeles	University of Southern California
Colorado	Colorado Springs	University of Colorado, Colorado Springs
Idaho	Moscow	University of Idaho
Indiana	Hammond	Purdue University-Calumet Campus
Iowa	Davenport	Eastern Iowa Community College District
Kansas	El Dorado	Butler Community College
Michigan	Southfield	Lawrence Technological University
Minnesota	Saint cloud	Saint Cloud State University
New Hampshire	Nashua	Daniel Webster College
New York	Rochester	Rochester Institute of Technology
Pennsylvania	Moon	Robert Morris University
	Philadelphia	University of Pennsylvania
Virginia	Virginia Beach	ECPI University
Washington	Redmond	DigiPen Institute of Technology
	Seattle	Academy of Interactive Entertainment
Wisconsin	Madison	Herzing University-Madison
	Rhinelander	Nicolet Area Technical College

Table 13.5 US research centers offering opportunities in M&S education

Domain	University	R&D centers
Economics	Yale University	Cowles Foundation for Research in Economics
Engineering	Carnegie Mellon University	Center for Sensed Critical Infrastructure Research
Engineering	Massachusetts Institute of Technology	Massachusetts Institute of Technology, Engineering Systems Division
Modeling and Simulation	Old Dominion University	Virginia Modeling, Analysis and Simulation Center
Modeling and Simulation	University of Alabama in Huntsville	Center for Modeling, Simulation, and Analysis
Modeling and Simulation	University of Central Florida	Institute for Simulation and Training
Transportation	Georgia Institute of Technology	University Transportation Center
Transportation	Massachusetts Institute of Technology	Intelligent Transportation Systems
Transportation	Northwestern University	Northwestern University Transportation Center
Waste Management	Cornell University	Cornell Waste Management Institute

Table 13.6 A sample of programs teaching modeling and simulation (National Center for Education Statistics 2017)

Discipline	Description
Cognitive science	A program that focuses on the study of the mind and the nature of intelligence from the interdisciplinary perspectives of computer science, philosophy, mathematics, psychology, neuroscience, and other disciplines. Includes instruction in mathematics and logic, cognitive process modeling, dynamic systems, learning theories, brain and cognition, neural networking, programming, and applications to topics such as language acquisition, computer systems, and perception and behavior
Consumer economics	A program that focuses on the application of micro- and macroeconomic theory to consumer behavior and individual and family consumption of goods and services. Includes instruction in modeling, economic forecasting, indexing, price theory, and analysis of individual commodities and services and/or groups of related commodities and services
Demography and population studies	A program that focuses on the systematic study of population models and population phenomena, and related problems of social structure and behavior. Includes instruction in population growth, spatial distribution, mortality and fertility factors, migration, dynamic population modeling, population estimation and projection, mathematical and statistical analysis of population data, population policy studies, and applications to problems in economics and government planning
Econometrics and quantitative economics	A program that focuses on the systematic study of mathematical and statistical analysis of economic phenomena and problems. Includes instruction in economic statistics, optimization theory, cost/benefit analysis, price theory, economic modeling, and economic forecasting and evaluation. Examples: (Cost Analysis), (Economic Forecasting)
Engineering/Industrial management	A program that focuses on the application of engineering principles to the planning and operational management of industrial and manufacturing operations, and prepares individuals to plan and manage such operations. Includes instruction in accounting, engineering economy, financial management, industrial and human resources management, industrial psychology, management information systems, mathematical modeling and optimization, quality control, operations research, safety and health issues, and environmental program management
Management science	A general program that focuses on the application of statistical modeling, data warehousing, data mining, programming, forecasting, and operations research techniques to the analysis of problems of business organization and performance. Includes instruction in optimization theory and mathematical techniques, data mining, data warehousing, stochastic and dynamic modeling, operations analysis, and the design and testing of prototype systems and evaluation models. Examples: Business Intelligence, Competitive Intelligence

(continued)

Table 13.6 (continued)

Discipline	Description
Public policy analysis, general	A program that focuses on the systematic analysis of public policy issues and decision processes. Includes instruction in the role of economic and political factors in public decision-making and policy formulation, microeconomic analysis of policy issues, resource allocation and decision modeling, cost/benefit analysis, statistical methods, and applications to specific public policy topics. An example: Public Policy Analysis
Sculpture	A program that prepares individuals creatively and technically to express emotions, ideas, or inner visions by creating three-dimensional art works. Includes instruction in the analysis of form in space; round and relief concepts; sculptural composition; modern and experimental methods; different media such as clay, plaster, wood, stone, and metal; techniques such as carving, molding, welding, casting, and modeling; and personal style development

simulated dig (Brown and Fehige 2014) and simulation-based cosmology employ simulation techniques to enhance, promote, or create new skills and experiences. The future of simulation lies in its ability to connect with the large number of students in the humanities and social sciences. Already, there is a formal process taking place and informally we can say that it is accelerating. The future is bright indeed.

13.6 Simulation-Based Information Science Education

The academic topic of information science includes several closely associated disciplines including computer science, information systems, software engineering, computer engineering, and others. It also includes several topics related to information system management and the library sciences. For the education discussion, here, we will stick to the first group of topics—those related to information systems and computer science.

In studying information systems, students can be expected to learn (very broadly) (1) the skills of building (and using/maintaining) systems, (2) the use of such systems in a larger environment, and (3) the formal science and theory that are the bases for such systems. Different programs, of course, concentrate on different aspects. A computer science program might feature much more formal science and theory than an information systems program. In all three of these cases, however, the education process can profit greatly from the use of modeling and simulation.

Instructing students in the skills of understanding how systems work divides easily, in this discipline, into hardware-based systems and software-based systems. Students can be taught (establishing and reinforcing declarative knowledge) how the various components work, and can then be expected to build and use such systems (establishing procedural knowledge). In the case of hardware systems, using such tools as logic simulators, and even modeling and simulation software such as Simulink can help understand how things like circuitry and memory systems work, as well as the basics for digital system design (Yousuf et al. 2014). In the case of software systems, it is more typical to build the software itself, but even here modeling and simulation can assist the education process by providing tools such as simulated data streams, to serve as input for testing software. In learning about how systems such as database management systems work, it is typical to work with a simulated data base, usually on a smaller, more abstract scale, than a large actual database. In addition, there are simulators available for learning about languages such as SQL—a very valuable example are those language simulators available from the W3 Schools (an online resource for augmenting the education about software and markup tools valuable for making distributed systems) (W3 Schools). An overview of simulators and articles on the same can be found in (Alnoukari et al. 2013), which covers programming, architectures, digital design, and some of the subjects of the next category of instruction—especially computer networks.

The art of instructing students about how information systems work in a larger environment can focus on several different aspects. How do such systems work with each other (such as networks and distributed systems), how do such systems work with human users (such as cyber security and human systems interaction), and finally how do such systems affect their environment (such as courses of study on the impact of computers on society)? These are all questions (as a sampling) that might be answered by a course of study that can use (successfully) modeling and simulation to improve the education. In education about networks, there are many network simulators that simulate many different aspects about a network, for the student to again gain some procedural knowledge, along with the theoretical and declarative knowledge they gain from classroom study. One example in this area is the successful program Network Simulation 3 (or NS3) (ns-3). Several scholarly studies about the usefulness of using network simulation in classroom education exists, including a very good introduction to the topic found in Riley (2012), which introduces NS3 along with a competing simulator that has different features. There are simulators that involve serious gaming for a more interactive and immersive experience. These are used to teach principles of cyber security and cyber defense skills. One such example is the simulation game CyberCIEGE (Irvine et al. 2005). Some of the topics and skills that can be taught with such a simulator are briefly enumerated (Cone et al. 2006):

- Introduction to Information Assurance
- Information value
- Access control mechanisms
- Social engineering
- Password management
- Malicious software and basic safe computing
- Safeguarding data
- Physical security mechanisms.

Finally, the third grouping of education that we are looking at in this section includes the use of modeling and simulation in the instruction of formal science, and theory, especially in computer science. For this purpose, we have tools such as R and Matlab to investigate a number of subjects related to the computability of numbers, computation theory, and symbolic logic. Many of the same principles found in the section on teaching the physical sciences may apply here. An interesting addition, especially in the area of formal sciences (based on theory proposal, and refutation), is the case of the Scientific Community Game (SCG). The SCG uses the structure of a game (in the sense from game theory) to allow participants/players to serve in a game of proposing and opposing a scientific discovery, with the game rules being based on Popper's method of refutation (Abdelmeged and Lieberherr 2013). The game is developed by a group of researchers from Northeastern University. This "game" involves a model of scientific communities and how they approach problem-solving in the formal sciences. The approach could be a useful teaching tool for instruction (Abdelmeged et al. 2016).

13.7 Simulation-Based Educational/Training Activities in Other Fields and Countries Other Than USA

In Sect. 13.2, on Simulation-based Learning and Education, Table 13.2 lists associations and networking related with simulation-based learning, education, and training independent of geography. In Sects. 13.3 through 13.6, simulation-based engineering education, natural science education, social science and management education, and information science education are covered. Two related and important topics are not covered in this chapter, since they are covered in depth in two other chapters in this book. These topics are: the contribution of simulation to health care as well as health education and training, in Chap. 10 by Hannes Prescher, Allan H. Hamilton, and Jerzy Rozenblit and the role of simulation in military training, in Chap. 14 by Agostino Bruzzone and Marina Massei. In these chapters, most of the examples given are USA educational institutions. However, simulation as well as simulation-based education is practiced in many other regions and countries. In Chap. 5—Simulation-Based Cyber-Physical Systems and Internet of Things—Bo Hu Li, Lin Zhang, Tan Li, Ting Yu Lin, and Jin Cui also cover simulation education in China.

Table 13.7 displays a list of national simulation associations other than USA and China. Table 13.8 displays simulation associations by region/language.

In addition to the simulation associations listed in Tables 13.7 and 13.8, there are many research centers and military groups active in simulation (Ören 2017b).

Table 13.7 A list of national simulation associations in countries other than China and USA

Country	Society/Association
Australia	OzSAGA—Australian Simulation and Games Association
	SIAA—Simulation Industry Association of Australia
Bulgaria	Bulsim—Bulgarian Modeling and Simulation Association
Croatia	CROSSIM—Croatian Society for Simulation Modelling
France	CNRS-GdR MACS—Groupe de Recherche “Modelisation, Analyse et Conduite des Systemes dynamiques” de CNRS
	VerSim—Vers une théorie de la Simulation
Hungary	HSS—Hungarian Simulation Society
India	C-MMACS—Indian Society for Mathematical Modeling and Computer Simulation
	INDSAGA—Indian Simulation and Gaming Association
Italy	ISCS—Italian Society for Computer Simulation
	Liophant Simulation
	MIMOS (Italian Movement for Modeling and Simulation)
Japan	JASAG—Japan Association of Simulation and Gaming
	JSST—Japan Society for Simulation Technology
Korea	KSS—The Korea Society for Simulation
Latvia	LSS—Latvian Simulation Society
Netherlands	SAGANET—Simulation and Gaming Association Derneği (Medical Simulation Association)
Norway	NFA—Norsk Forening for Automatisering
Poland	PSCS—Polish Society for Computer Simulation
Romania	ROMSIM—Romanian Society for Modelling and Simulation
Singapore	SSAGSg—Society of Simulation and Gaming of Singapore
Slovenia	SLOSIM—Slovenian Society for Modelling and Simulation
Spain	AES—Spanish Simulation Society (Asociación Española de Simulación)
	CEA SMSG Spanish Modelling and Simulation Group
Sweden	MoSis—The Society for Modelling and Simulation in Sweden
Taiwan	TaiwanSG Taiwan Simulation and Gaming Association
Thailand	ThaiSim—The Thai Simulation and Gaming Association
Turkey	BinSimDer—Bina Performansı Modelleme ve Simülasyon Derneği
	MSD—Medikal Simülasyon Derneği
UK	NAMS—National Association of Medical Simulators
	UKSIM—United Kingdom Simulation Society

13.8 Future of Simulation-Based Education

Some of our views expressed in this chapter are necessarily based on trends, since they are so evident. However, based on the dictum “The best way to invent future is to invent it,” we prefer to express our normative views on how disciplines can

Table 13.8 Simulation Associations by Region/Language

Region	Society/Association
Americas	CSSSA—Computational Social Science Society of the Americas
Asia	AFSG—Asian Federation for Serious Games
	ASIASIM—Federation of Asian Simulation Societies
Asia-Pacific	APSSA—Asia-Pacific Social Simulation Association
Australia /New Zeeland	MSSANZ—Modelling and Simulation Society of Australia and New Zealand Inc.
Czech and Slovak Republics	CSSS—Czech and Slovak Simulation Society
Dutch Benelux	DBSS—Dutch Benelux Simulation Society
Europe	ARGESIM (Arbeitsgemeinschaft Simulation News) Working Group Simulation News
	ESSA—The European Social Simulation Association
	EUROSIM—Federation of European Simulation Societies
	EUROSIS—The European Multidisciplineray Society for Modelling and Simulation Technology
	SESAM—Society in Europe Simulation Applied to Medicine
French	FRANCOSIM—Societe de Simulation Francophone
German	ASIM—German Simulation Society
Mediterranean and Latin America	IMCS—International Mediterranean and Latin American Council of Simulation
Pacific Asia	PAAA—Pacific Asian Association for Agent-based Approach in Social Systems Research
Scandinavia	SIMS—Scandinavian Simulation Society: DKSIM (Denmark), FinSim (Finland), NFA Norway), MoSis (Sweden)
Swiss, Austrian, and German	SAGSAGA—Swiss Austrian German Simulation And Gaming Association

benefit by being simulation-based and to realize this as soon as possible, to have simulation-based learning, teaching, training, and education to be widely adopted by them. Adoption of model-based approach by many disciplines is the right choice, since simulation itself is model-based (Ören and Zeigler 1979; Ören 1984).

As the opening quotation from Plato states "What is honored in a country is cultivated there," simulation-based activities can flourish especially in cultures (countries, institutions) that value rational decisions. In a rational World, simulation is an invaluable tool for experiential learning and teaching by performing—in silico (namely, computerized)—experiments and gaining experience. Especially in many cases, when in vivo (on real systems) or in vitro (in laboratory) experiential knowledge generation is not feasible, economical, or otherwise desirable, computerized experiments and experience (i.e., simulation) becomes very convenient and sometimes even superior to in vivo and in vitro experiential knowledge generation. Education for simulation-based disciplines may prepare future professionals to get full benefits of using simulation and can have an opportunity to enrich their disciplines.

In personal development, a good recommendation is to "Work smarter, not harder!" The proverbial sharpening the axe, as also stated by Abraham Lincoln is: "If I had six hours to chop down a tree, I'd spend the first four hours sharpening the axe." We argue that, for many disciplines, adopting the simulation-based paradigm and in preparing future professionals in these disciplines, promoting simulation-based learning, education, and training would be very beneficial. Simulation is already included in the curriculum of many disciplines. It is hoped that all conferences on education will also include some presentations/panels on the benefits of simulation in education.

To solve problems, one needs knowledge, knowledge processing knowledge, and intelligence; however, some solutions might be detrimental (to the society, even to humanity) if implemented without ethical considerations. For sustainable civilizations, an indispensable ingredient is ethics which necessitates respect to the rights of others. There are codes of ethical behavior for several professions including for simulationists (SimEthics; Ören 2000, 2002a, b). The ideal is, in professional courses (of engineering, natural and social sciences, as well as in information science), to teach relevant aspects of ethical behavior. However, in simulation-based education of several disciplines, the inclusion of SimEthics would also be highly desirable.

Review Questions

1. If you are involved in the education/training/learning of any topic, are you familiar with the benefits of simulation in this field? For example, are you familiar with several sources (such as associations, conferences, publications, software) of information about the use of simulation in education (as given, for examples at http://www.site.uottawa.ca/~oren/sim4Ed.pdf)?
2. How simulation is essential in the development of decision-making skills? Give several examples.
3. How simulation is essential in the development of motor skills? Give several examples.
4. How simulation is essential in the development of operational skills? Give several examples.
5. What are the benefits of teaching simulation concepts/techniques/software in education of future engineers?
6. What are the benefits of teaching simulation concepts/techniques/software in education of future scientists?
7. What are the benefits of teaching simulation concepts/techniques/software in education of future social scientists?
8. Why simulation is used in several aspects of health care? What would happen if simulation is not used in health-care education?

9. Why simulation is used in several aspects of military training? What would happen if simulation is not used in military training?
10. Why simulation is used in several aspects of management? What would happen if simulation is not used in management education?
11. How simulation can be beneficial in distance education?

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