Optimizing STEM Education with Advanced ICTs and Simulations

Preface

The change in our society has experienced as we entered the digital age, and especially the corresponding transformation of science education, gave rise to research activities at the intersection of inquiry-based STEM learning, emerging technologies, and digital society. This type of research corresponds to the field of study known as Science, Technology and Society (STS). However, given the digital character of the contemporary STS transformations, we call this extended field of studies Science, Technology and Digital Society (STDS). The research presented in our book, "Optimizing STEM Education with Advanced ICTs and Simulations," belongs to this new field.

Thematically, the book presents a continuation of our previous book, titled "Digital Tools and Solutions for Inquiry-Based STEM Learning." In comparison with the first book, which mainly includes theoretical chapters that discuss emerging research directions and approaches for integrating ICT in science education, the present book reports the results of educational research that examined the implementation and optimization of STEM educational practices in which digital technologies are a prominent component.

A brief description of each of the chapters follows.

One of the most promising emerging technologies in education, wearable technology, is the subject of Chapter 1, written by Joel Drake and his coauthors. The chapter presents real examples of using wearable devices in school settings. These examples are cases in which students study themselves as objects of inquiry, tracking their own activities, and then gathering and analyzing the data. The chapter demonstrates that using wearable devices as tools of inquiry constitutes a highly valuable method for gaining a comprehensive understanding of a variety of STEM topics.

Chapter 2 reports on a study about learning and teaching climate change in school science lessons. The authors of the chapter, Allan Feldman and his colleagues, describe the Climate Change Narrative Game Education (CHANGE) project, which integrates ICT in the classroom in numerous ways. The project incorporates students' lived experiences into the curriculum, and takes advantage of the great opportunities that ICT offers, to facilitate students' inquiry into climate science. It combines specific educational games with hands-on activities, to engage students in inquiry-based learning of climate-change science. The authors mention ways to connect school science with academic science, in order to attract students to study the topic even further.

The focus of the study presented in Chapter 3 by the authors Hovardas et al. is inquiry-based learning conducted in virtual labs. These are science labs based on emerging digital technologies. In the study, the virtual labs are used by primary school students to carry out successive learning tasks involving experimentation. The virtual lab tools assist students in two ways: in formulating scientific hypotheses and in designing the experiments. Both of these are metacognitive, inquiry-based students' activities that did not exist in the traditional, pre-digital classroom. This is a brilliant example of integrating emerging technologies in STEM learning in a way that enriches the science lesson significantly.

Chapter 4 deals with Collaborative Learning Science and its assessment, focusing specifically on measuring students' performance in collaborative problem solving (CPS) tasks. One way to standardize the assessment of collaborative skills is to use computer-based agents to

serve as the collaborators in the interactions with students. The author of the Chapter, Yigal Rosen, posed a dual goal: to empirically examine students' multi-faceted performance and the distribution of collaborative skills across collaboration methods and settings, and to propose a computer-based approach for CPS assessment. The author describes a pilot study that was conducted to address these goals.

Chapter 5, written by Amal Ibourk and her coauthors, deals with integrating technology in middle school. The authors analyze an inquiry-based, technology-enhanced online unit for learning genetics. The focus on highly complex topics in genetics such as heredity and variations of traits provides a great example of the advantages of integrating technology in the discipline; indeed, integrating ICT simply makes the learning of genetics feasible. Dynamic visualizations offer the students opportunities to interact with the scientific phenomena, performing various experiments. In genetics education in the digital age, The STEMGenetics software plays a role of the legendary drosophila fly.

One of the important directions in the development of future education is educational gaming. The well-known dilemma of "*Homo faber* vs. *Homo ludens*" is representative of the type of deliberations that preoccupy our changing society. The notion of Homo faber, "Human as maker," stresses our ability to create. This is perhaps one of the most important and transformational elements of the networked world, which provides a unique set of affordances for understanding the relationship between new media and learning. *Homo ludens*, "human as player," is perhaps the most important --albeit overlooked-- element for understanding our relationship to new media. Chapter 6 deals with a specific and promising kind of educational game, which utilizes the emerging mobile technologies. A specific kind of gaming, mobile gaming, is in the focus of the chapter. The author of the chapter, Dennis M. Bressler, argues that this type of game presents a unique opportunity for students to be immersed in collaborative STEM inquiry. Students playing the game INPLACE demonstrated higher levels of engagement and scientific inquiry than did students in a conventional controlled activity.

Inquiry-based chemistry education is the subject of Chapter 7. The author of the chapter, Sharona T. Levy, discusses an approach that combines complex system simulation and collaborative role-playing, to produce a specific inquiry-based teaching method. The main question addressed in this chapter is how do we design a learning process that supports students' deep learning of emergent systems? The results of a research study described in this chapter demonstrate that a design that engages students in collaborative role-playing, in the context of a social experiment that requires the use of complex systems, provides an effective and promising way of studying complex systems in contemporary, technologically enhanced schools. This kind of learning activity is a remarkable example of the innovative role of ICT in inquiry-based STEM education. More than just an educational operational tool, this use of ICT brings to light a new and unprecedented approach to STEM learning.

Chapter 8 deals with inquiry-based learning of chemistry through the use simulations. Tanya Gupta and her colleagues, the authors of the chapter, present the design and implementation of interactive simulations of topics in organic chemistry that are typically difficult for chemistry learners. Moreover, the proposed simulation provides an option for assessing student understanding based on problem solving abilities. Results of the study show that simulation-based learning is highly effective, both for advancing students' understanding of the topics and for the purpose of student assessment.

Professional development of science educators in light of the new demands of the digital age is the topic of Chapter 9. As the digital age is changing the ways scientists and citizens view and

understand the world, both students and educators have to be prepared for the new reality. Anna Lewis, the author of the chapter, deals with the remarkable phenomenon of the digital age, namely, the shift from scarcity to abundance of information, which, in turn, gave birth to the emerging science research paradigm - Data Intensive Science. Along with traditional inquiry-based STEM learning, educational activities oriented to big data, represent a new, intensively developing and highly-facilitating inquiry-based educational activity, which should be an integral part of STEM teachers' professional development.

Chapter 10 is a case study of pedagogical practices in the realm of teacher education. The author, Katarin Alinta MacLeod, describes a pedagogical approach and the corresponding BEd course titled “Teaching and Learning in the Physical Sciences”. The author is currently a professor in the Faculty of Education and a former graduate of the Physics Department of the same institute. Her personal experience and awareness afford an insider's view of the problems that teacher educators must contend with in our changing world. Methodologically, the course she describes combines three main components of STEM education: content, pedagogy and technology, with an emphasis on inquiry-based orientation and intensive ICT integration.

Teaching special categories of students, as well as teaching in non-standard conditions, are traditionally topics of particular interest, as such teaching requires both dedicated methods and special means. Addressing the problems and challenges of teaching incarcerated students is the focus of Chapter 11, written by Michael Krezmien and his coauthors. Developing scientific ways of thinking is considered highly desirable for such students, as it increases their chances of successfully reintegrating into society and becoming active and productive citizens.

We hope that this book will serve educational researchers, educators, and teacher educators as a comprehensive reference for a new field of studies - Science, Technology and Digital Society (STDS), and various areas of STEM education where the role of digital technologies addressed and researched.