Digital Tools and Solutions for Inquiry-Based STEM Learning

Preface

In the 20th century, science and science education enjoyed unprecedented governmental support in many countries. The great success of scientific research followed by its implementation in technology led governments to the assumption that investing in science has a direct and positive impact on the lives of the citizens. Hence, science came to occupy a central position both in society and in human consciousness.

In recent years, this situation has changed. As a result of the intensive integration of information technology in human life, public interest began to shift away from traditional science. The great achievements in the field of Information and Communication Technologies (ICT) and their transformational impact on human life have affected human consciousness. Technology's role in society, as well as its connection to science, is changing. The traditional perception, according to which science was the main factor affecting the quality of human life, and technology was considered merely an "applied science," is already dated and irrelevant. The newer emerging perception, which is gaining more and more popularity, is that technology (and not science) is the predominant factor in human life, and that science plays an ancillary role in the new technological society. To a great extent, these shifts in social consciousness reflect our global transformation into a digital society. Our fundamental perceptions of the world around us are changing. These changes are most noticeable in the shift from scarcity to abundance of information, and from the primacy of entities to the primacy of interactions; as well as in the blurring of distinctions between reality and virtuality and between people, machines, and nature (Floridi, 2014). Moreover, the distinction between science and technology has faded (Levin, 2016). Today, scientific research is unimaginable without the emerging technologies, which in turn are becoming an inseparable part of the scientific endeavor. The interpenetration of scientific and technological research methodologies is another instance in which prior distinctions are becoming less significant. Thus, an increasing number of scientific analytical research methods are being implemented in engineering research, and vice-versa: many technological, design-oriented methods are gaining popularity in scientific research.

These substantial transformations in science, technology and society have significant implications for education, in general, and for STEM education, in particular; these are the focus of our book. Obviously, if the contemporary changes in education could be addressed by merely equipping schools with ICT facilities, the problem would be much more modest in scope and could be managed by promoting technological literacy. In effect, the problem is far more complex. Our awareness of the fact that the changes in STEM education correspond to general transformations in society provides another perspective on the problem. Our underlying assumption is that the new fundamental role of technology in science and society ought to be reflected in each and every component of STEM education: learning, teaching, environment, curriculum, and assessment. Additionally, along with the traditional ways of integrating ICT in education, STEM education can learn from the ways in which scientific research was transformed through digitalization.

Our main intent in this book is to take an in-depth look at the integration of ICT in STEM. Our exploration considers: a) inquiry-based learning to be the key method in STEM learning; b) digitalization to be a means to enhance inquiry-based learning; c) a conscious change in teachers' and students' perceptions to be a crucial factor for transforming STEM education in digital society.

The main motivation for writing this book was our realization that the digital era has transformed STEM education. We asked ourselves: "what are the changes and the corresponding directions that STEM education can pursue in light of the digital turn?" We tried to answer this question by curating a selection of recent and interesting research studies in the corresponding fields.

The chapters included in the book paint a multifaceted picture of these changes, representing a range of different approaches, from theoretical aspects of technology integration to practical implications of the digitalization process. Each approach is uniquely distinct and significant.

The book comprises two sections. The five chapters in Section One, "Inquiry-based Learning of STEM in the Digital Era", examine both new models of learning and existing models that have been significantly revised and upgraded to conform to today's pedagogical standards. The review of these models addresses questions, dilemmas, trends and solutions related to learning STEM in the Digital era. Section Two, "Inquiry-based Teaching of STEM in the Digital Era" complements Section One, by discussing various aspects of the inquiry-based teaching process. The six chapters in this section deal with the efficacy of innovative teaching strategies, methods, and approaches developed to integrate digital technologies in STEM education. The implications of these developments and the challenges they present in terms of teacher training and professional development constitute a focal interest in the second section.

A brief description of each of the chapters follows.

Section 1. Inquiry-based Learning of STEM in the Digital Era

Chapter 1 is devoted to the discussion about the opportunities and challenges of integrating technology into preschool science inquiry-based learning. This study was intended to address the widely-recognized concern regarding young children's protracted screen time, on the one hand, coupled with the apparent necessity and possible advantages of digital literacy acquisition, on the other hand. Should technology be introduced to children at a young age, or are they liable to lose valuable capabilities as we rush to discard habitual analog educational tools in favor of recent new gadgets? How can educators create stimulating yet safe digital environments that enhance scientific curiosity and exploration among young children? These questions motivated the chapter of Ornit Spektor-Levy and her coauthors.

The remarkable role of modeling and computer simulation in the learning of STEM is analyzed in Chapter 2. Modeling and simulation rely on great learning theories, from classical constructivism to epistemological constructionism, and thus can be introduced in education successfully. Moreover, simulation technology represents the so-called computer scientific research paradigm, which considers the inquiry-based study of computer models of scientific phenomena a main method of research. The author of the chapter, Franco Landriscina, discusses inquiry-based learning of computer models and the problems and difficulties of implementing pedagogical simulations. Specifically, the author considers the relationship between student ability to conduct mental simulations, on the one hand, and the computer-based simulation, on the other hand.

As mentioned, the emergence of new learning methods, in general, and innovative design-oriented methods, in particular, is the main tendency in STEM education nowadays. Chapter 3 deals with design-based learning (DBL) developed and used to facilitate collaborative learning of STEM. The author of the chapter, Joycelyn Streator, shows that integrating ICT made it possible to utilize the potential of the DBL in inquiry-based STEM learning. Today, a number of efficient Web-based tools are available to support this type of learning. The author demonstrates that design has to be considered an inquiry-based activity in STEM learning.

One of the important phenomena that emerged in the digital era is social media, which is already considered a significant part of the native habitat of today’s students. Chapter 4 of the book deals with social media intended to support STEM inquiry-based practices, particularly scientific argumentation. The authors, Jana Craig-Hare and her colleagues, consider social media to provide an educational environment that supports the type of collaborative scientific inquiry in which students are involved. Scientific activity has a social nature and as such it requires viewing students as “digital citizens” living in a digital habitat. A study of the behavior of digital citizens as scientists in a digital society is the focus of the chapter.

The fact that both social media and networking are deeply rooted in pedagogy is demonstrated in Chapter 5. Its author, Evgeny D. Patarakin, proposes a new form of educational activity, which has arisen at the intersection of social media, network analytics and computer modeling. According to the proposed approach to learning, students’ reflection regarding their place and functioning within the network is utilized as a valuable learning activity. Actually, social media is combined with an agent-based educational environment where students can carry out innovative scientific inquiry.

Section 2. Inquiry-based STEM Teaching in the Digital Era

Chapter 6 deals with experimental, inquiry-based learning in the digital era. Authors of the Chapter, Dina Tsybulsky and Ilya Levin, traced the sequential changes that occurred in the experimental triad (subject-instrument-object) during the history of science education. The authors discuss the evolutionary process, beginning with the classic experimental triad and following it through to the digital era triad. They show that each of the triad's components has changed in the digital era. The digital triad represents a new scientific entity, which, in turn, has begun to appear in STEM educational practices.

Dealing with ICT in STEM education calls for an examination of the pedagogical potential of available online educational resources. After all, the accessibility of the resources on the Net determines to a great extent the success of ICT in STEM learning. Chapter 7 explores the potential of Web-based tools for engaging learners and promoting inquiry-based STEM learning. The authors, Isha DeCoito and Tasha Richardson, analyze the most promising ICT tools: simulations and remote laboratories in physics education.

Chapter 8, written by Jean-François Hérold and Jacques Ginestié, deals with the problem of learning efficiency when using digital tools in STEM education. The authors study how ICT could be considered a cognitive aid for the student. Both the learner-centered and the teacher-centered views are applied. The authors demonstrate the necessity for teachers to understand the ability (or inability) of certain students to learn in an ICT-enhanced class. They demonstrate the importance of emotion and motivation and their effects on learning and on the teacher-learner dynamics in the classroom.

Technology-enhanced inquiry is the focus of Chapter 9. The authors, Michael L. Connell and Sergei Abramovich, emphasize the value of the constructivist approach to ICT integration in STEM education, when "learners enter into an intellectual partnership with the computer" (Jonassen, 2000). This remarkable approach, rooted in the seminal works of Seymour Papert and his followers, views human-computer interaction through the lenses of the so-called "glass boxes", rather than relying on the "black boxes" with their traditional "right or wrong" answer. As an illustration, the approach is mapped onto a collaborative STEM-related activity.

In the transition to the digital era, teacher training obviously attracts special attention. Chapter 10 discusses the implementation of collaborative educational technologies in the education of STEM teachers. The main aim of teacher education is defined as providing teachers with inquiry-based teaching skills and positive attitudes regarding inquiry-based learning. This can be achieved by studying a wide spectrum of technological means used in the contemporary classroom. The author, Marina-Milner Bolotin, provides a comprehensive study of some collaborative educational technologies and demonstrates how these technologies can be implemented in STEM teacher education.

The classical educational *constructionism–instructionism* dilemma (Papert, 1980) corresponds to two alternative approaches to ICT-enhanced education. Traditionally, MOOC is considered an instance of ICT-based instrumentalism, which is a far cry from inquiry-based education. The authors of Chapter 11, Miri Barak and Abeer Watted, discuss using the MOOC platform for conducting project-based learning activities. They present a project-based MOOC course in nanotechnology. Such a combination provides an alternative view, showing the potential of MOOCs in STEM learning.

We believe that this book provides a much-needed reference source in the field of Inquiry-based STEM education. We hope that educators, researchers and students will find it useful for gaining insight into the regularities and features of STEM education in the Digital Age, as well for envisioning new ways to transform and enhance STEM education.

References

Floridi, L. (2014). *The fourth revolution: How the infosphere is reshaping human reality*. OUP Oxford.

Jonassen, D. (2000). *Mindtools for schools: Engaging critical thinking with technology*. Columbus, OH: Merrill.

Levin, I. (2016). Cyber-physical Systems as a Cultural Phenomenon. *International Journal of Design Sciences & Technology*, *22*(1).

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.

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