Preface

What we consider the technology of today has revolutionized the way societies function in nearly every respect: commerce, communication, information access and distribution, entertainment, marketing, and social interaction. Nearly everywhere you turn, and at any moment, you can observe someone doing something with technology -- from talking on a cell phone to listening to music on an iPod, checking email to playing a game on a hand-held device, updating Facebook status to reading the newspaper online, and much, much more. Given its propensity for making our lives easier, it only makes sense that we would strive to integrate technology into all aspects of our lives: work, home, and entertainment. To be considered fully participative and productive members of the global society today, all of its citizens have a responsibility to intentionally seek and attain a certain level of technological literacy, embracing all technology has to offer in terms of productive enterprise.

Today’s K-12 schools are not exempt from this expectation; teachers, administrators, and students alike should all be literate in the use and application of technology. Progressive preschools, elementary schools, middle schools, and high schools (along with post-secondary institutions and other formal, and informal, educational entities) all infuse multiple facets of technology into their curricula and day-to-day operations. These schools apply technology in a variety of ways: some have initiated a 1:1 student-to-technology program, where each child in every classroom is assigned an iPad, tablet, laptop computer, or other device, providing almost endless opportunities for purposeful interaction with technology; some implement a “bring your own device” (BYOD) strategy, allowing students to select whatever electronic tool they already have and use it for class; some require every teacher to enter grades and attendance in a database via computer; others encourage teachers to reach out to the parents of struggling students by email, in addition to phone; still others provide the means for parents to access their child’s grades, school calendars, and homework details by visiting an online portal. Many schools utilize several or all of the preceding and more. The capacity for schools to advance their charge, namely to produce an informed, responsible, critical-thinking, problem-solving, decision-making, and employable future citizenry, can be greatly aided and enhanced through the intentional exposure to, and explicit instruction of, skills specifically related to technology. Clearly, the integration of technology for a variety of purposes should be an inherent and overt goal of all schools.

**SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM)**

In addition to the general societal revolution heralded by the explosion of technology, another specific revolution has led to a reformation in curriculum and methods of instruction for teaching and learning in
science-related classrooms. Science, technology, engineering and mathematics (STEM) as a term, initially emerged from initiatives at the National Science Foundation (NSF), but has evolved to describe curriculum and employment areas that emphasize engineering, physical sciences, math and computer sciences, life sciences, and technology integration. Much research has been conducted about using technology to enhance the effectiveness of STEM education. This body of knowledge has been crucial in supporting the appropriate use of integrated technology for effective and efficient STEM teaching and learning. Even so, much more research is needed to further enhance our ability to address the need for improved skills and understandings of STEM for our future workforce. In addition to these workforce issues, the general public will benefit from a collective of citizens who will have these skills and understandings and may use them to make quality life and personal decisions.

Although this book is designed to reach out internationally, and includes chapters from authors in several different regions of the globe, some of the specific discussion will relate to STEM education as it looks in the United States of America. And, even though one would hope that at least some overall integration of science, technology, engineering, and mathematics occurs in classrooms around the globe, portions of the discussion will need to focus on the individual disciplines separately.

Advances in science, technology, engineering, and math (STEM) are critical to determining a nation’s prosperity and success in procuring and utilizing natural resources, establishing and maintaining national security, and stretching the boundaries of innovation – all of which have been in place in the United States since the days following Sputnik and the “space race” (circa 1960). We are all understandably concerned about global environmental sustainability, national security, and how we will fare in this age of technological revolution, especially when we consider how our current students are performing in the STEM disciplines within a market of International competition. We ask ourselves, who will be responsible for envisioning the next technological innovations? The answer could have important ramifications for the world.

According to international tests, students in the United States are falling behind a number of global competitors when it comes to STEM. Our own Nation’s Report Card identifies similar weaknesses in science and mathematics. Individual state tests show clear and present problems in the way science is being taught in our elementary, middle, and high school classrooms today. Nevertheless, the STEM workforce is expanding and educators in America must address this growing need for STEM workers by motivating students to consider and enter STEM fields, and adequately preparing them to work in these disciplines. Scientists use technology to aid in the collection and analysis of data, representation and modeling, and the communication of information, so it is critical that technology be infused into the STEM curriculum where practical and appropriate.

Technology used to be explicitly linked to science, as in “science and technology,” relegated to a subsidiary status and potentially dependent association; however, technology is no longer considered subordinate to science, and instead may well be elevated in standing relative to it. Clearly, technology as a general description, is a far-reaching and diverse term, encompassing much more than science today. It permeates essentially every component of a school’s formal curriculum and has wide applications. As a tool, and set of related skills, technology forms a natural and applicable union with each of the other disciplines in STEM. Connections to science and engineering are perhaps more obvious than to mathematics, but computers, calculators, and software -- to name just a few -- are clearly important resources for both theoretical and applied mathematics. Both the National Council of Teachers of Mathematics and the Next Generation Science Standards advocate active use of technology in the teaching of mathematics and science. And, the International Society for Technology in Education has created sets of technology
standards for teachers and students. Integrating and infusing technology into the science, engineering, and mathematics curricula may almost happen automatically, even without consciously addressing state or national standards. But this is only true for those curriculum developers and teachers who are knowledgeable about and comfortable with “technology.” And, alas, that is not everyone.

Engineering, while certainly a free-standing discipline of its own accord, has typically been covered under the auspices of “science,” at least within K-12 state and national standards. Although, in the past few years, the National Academy of Engineering has explored the possibility of generating content standards for K-12, there are none as of yet. Engineering relies on the fundamental principles of scientific and technological knowledge, facilitating and furthering our capacity to design, build, and evolve societal infrastructure. And, as anyone who has formally studied the mechanics of engineering knows well, complex mathematics underlies much of the technical and practical nuances of both statics and dynamics.

Science and mathematics, as disciplines themselves, embody separate but related collections of specific content knowledge and skills. Each can be applied in certain instances, with specific intent, yet each is equally difficult to remove fully from a greater context, or Gestalt, in which the other factors to a varying degree on a spectrum of interconnectedness. For example, science can serve as a venue for the application of mathematics, whereas the progression of mathematical theory can foster the advancement of science into new areas previously limited by an incomplete mathematical expression. The Principles and Standards for School Mathematics (2000) and the Next Generation Science Standards (2013) identify several specific standards that should be covered by schools in relevant math and science classes respectively.

There is precious little room to debate the ubiquity and applicability of technology, or the interdisciplinarity of the STEM fields: K-12 teachers should be actively using and teaching technology, and actively using it for, and within, the teaching of STEM. Teachers should not only consider the application of technology to each STEM discipline separately, but must consider technology within an interdisciplinary and holistic framework of STEM. To illustrate this point, compare and contrast Figure 1a to Figure 1b. The realization of a truly interdisciplinary approach to STEM learning will require, for some, a conscious and deliberate change in thinking.

TECHNOLOGY AS A DOORWAY TO THE FUTURE

Today’s technologies have opened doors many of us had only dreamed possible just a few years ago, and because of the recency and originality of technological diversity today, many of us have been left behind with regard to technological prowess—especially in comparison to the youngest generations. Individually, none of us should despair at any perceived personal deficiencies or discomfort using technology, because for most of us, there simply are not enough hours in a day, week, or year, to learn every new high-tech gadget or interactive program out there now. However, we should concede that with a little motivation, practice, and perhaps assistance, essentially all of us can achieve some level of technological proficiency. Those who consider themselves tech-savvy or technologically elite may find that they are not in need of suggestions or encouragement to dive into new technologies, but that is not the case for everyone. Enough teachers, and laypeople, face challenges that it warrants mentioning. And, while it is essential to incorporate technology in the curriculum, it is critical to understand the potential for its abuse. Along with the numerous advantages, a few potential disadvantages must be recognized and actively addressed related to the use of technology in schools, including: curricularly unrelated, off-task,
and non-instructional instances of texting, instant messaging, Facebooking, and other “multitasking” activities during instructional time.

Most concerning of all, there is the unfortunate, and significant, fact that too many teachers—at all levels—are technology phobic, poorly adept, or simply out-of-touch with the pervasiveness and essentiality of technology to the classroom environment. At the end of the day, technology is here to stay, albeit maybe not in all of its present incarnations, but certainly as a means to foster efficiency and further the daily capabilities of the 21st century workplace. If schools are truly designed to create a literate and skilled citizenry, then they must embrace the changing face of instruction in light of technological advances. Consequently, teachers themselves must embrace the use of technology; not just paying lip service to the importance of it, but really working to grasp the power and potential technology provides for teaching and learning. Much easier said than done, to be sure. And, to be fair, teachers are already oftentimes overloaded with larger class sizes, standards-based assessments, additional non-teaching duties, and reading- and math-related professional development initiatives; so how can more time be found to learn the plethora of new technologies seemingly popping up endlessly day after day? For some of those tech-savvy “digital natives” who seem to delight in all things technological, there is simply not enough class time to explore each and every gizmo, gadget, and app that just has to be shared with their students. For other digital natives and many “digital immigrants,” either the time or appeal, or both, of technology may be elusive or end up free-falling to the bottom of the mounting stack of responsibilities in an average school day. A solution to the problem of insufficient time is not necessarily easy to
discover, but there are options and incremental steps that each and every teacher can utilize to learn new classroom technologies and become increasingly more comfortable and confident with technology.

WHAT IS TECHNOLOGY?

The term technology encompasses a variety of resources and takes on a number of different meanings depending on the situation or setting. Consequently, it is important to establish what is meant by technology as a component of STEM, and how this differs from technology integration, if indeed it does. For purposes of this book, we will define technology very loosely as a collection of electronic tools and skills that can be used to accomplish a specific task, reserving technology integration specifically for the action of applying the tools and skills of technology to the teaching and learning of STEM, especially to the solving of authentic problems. The technology of today comes in a variety of forms: hardware, software, animations, simulations, games, probes, social media (e.g., Facebook), and more.

Most would agree that new technologies have been transforming our lives and world. As is the case in our educational institutions at all levels, students and teachers are using more technologies more often than perhaps they were even just a few years ago. There is no doubt about the potential of integrated technology for effective and efficient teaching and learning, but continued research related to integrated educational technologies will continue to help us better understand how technologies are best used, and sometimes misused, in our classrooms. In addition, systematic formative and summative assessments provide practitioners data to ascertain if indeed the technologies and curriculum are providing desired learning outcomes. In some instances non-technological strategies may be effective and should be maintained if they help students learn. This book highlights many examples where integrated education technologies have improved STEM learning.

Almost one hundred years ago sound recordings and radio broadcasts were finding their way into teaching and learning environments. It is generally accepted that the term technology represents tools, systems, or mechanisms developed based upon applied science, and in most cases equipment often used by skilled laborers to solve complex tasks. Technology is often viewed as the delivery mechanism, and the success of implementation depends upon the overall instructional design and the quality of the curriculum. A combination of good teaching and integrated technology is commonly understood as a road-map for success. In addition to the notion of technology as instructional delivery, technology serves as a tool for classroom discovery. Consider students, in a multi-disciplinary lesson, using data sets, and software such as Google Earth to explore and better understand the complex issues related to carbon dioxide emissions in terms of how they impact weather, public health, and people in various geographical and social situations. Such a problems-based inquiry learning activity exemplifies students using a variety of tools including online (and real) data sets, software applications, and documentary about real and current issues. Again, the success of this scenario in terms of learning is contingent upon quality instructional design combined with good teaching.

CHALLENGES

A growing number of challenges plague both teachers and schools as they strive to incorporate technology and train students in its use. A few of them include:
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1. Technology is unavailable at the school for enough, or all, students to use.
2. The available technology is well behind what is considered “cutting-edge” or relevant for today.
3. Schools may have technology, but the staff is ill-equipped to train faculty in its use and application in instruction.
4. Teachers are afraid of using technology (tech-phobic) or do not have the skills to use it.
5. Teachers do not know what technology resources and applications are available to them or how to evaluate and use them for instruction.

The editors of this book have worked with college students, practicing teachers, university colleagues, and K-12 students who all display a variety of interest, skill, and proficiency in the use of technology. One thing we hear and parrot often is the phrase “just start using it.” The first step is to be proactive, rather than reactive, and start slowly, engaging or interacting with some new forms of technology. In only this way can people actively begin to construct a knowledge base, and establish a toolbox of applicable skills, for the utilization of the various forms of technology. With even more new and creative technologies popping up every day, we must consciously select which individual representatives we wish to devote our time and explore. These days time is more precious than gold, and wasted time translates into lost money, inefficiency, and discouragement. Just as with individuals, there is the potential for schools to experience myriad challenges as they seek to acquire and implement technology. Some of these problems have specific formulas for solving, others do not.

POTENTIAL SOLUTIONS

While there are a number of possible solutions to the aforementioned challenges, they can probably be grouped into a couple of basic categories: 1) those that require funding (e.g., professional development, trainers, purchase of materials) and 2) those that do not require funding (e.g., interest, motivation, time). This book is designed to focus on providing data and recommendations in relation to the last two challenges mentioned earlier:

1. Teachers are afraid of using technology (tech-phobic) or do not have the skills to use it.
2. Teachers do not know what technology resources and applications are available to them or how to evaluate and use them for instruction.

It is much easier to provide advice and relay experiences, than it is to give money, and that is what this book is written to do. To obtain funding, schools and teachers may consider writing grants to obtain technology in the form of hardware and software, access expert professional development opportunities, hire trainers, and overhaul systems (e.g., web pages, interactive databases, etc.). Districts, administrators, professional learning communities, and teachers all work at their respective levels to facilitate change and usher in new eras of technology use as they are able, but sometimes additional resources are necessary.
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**IMPETUS FOR THE BOOK**

The driving force behind this book is the desire to provide a resource with examples of technology and technological applications that have been used, or are being used, in schools and classrooms around the globe. Because best practice is defined through rigorous empirical research, many of the chapters in this book are based upon research findings that support effective integration. Unfortunately, the book cannot serve as a “how-to” manual for incorporating technology in classroom settings; however, it can and does serve as a model for what could be done with technology in the classroom by sharing descriptions of research studies conducted in relevant and applicable settings (mostly K-12), discussed in terms of implementation strategies, recommendations, and lessons learned. The primary aim of the book is to provide practicing in-service teachers, and teachers-in-training (i.e., pre-service teachers), a compendium of evidence-based technological applications they can consider using in their classes. The readers and users of the book are encouraged not only to look into the various animations, simulations, software applications, integration models, and the variety of tools and resources discussed in the book, but to try them out in their own classrooms. Since it can be challenging to know which of the myriad technologies one should try in the classroom, descriptions of what has been done, with what, who, and where, can be very useful. Therefore, a secondary aim of the book is to illustrate learning gains, achievement, and perceptions of learners using the herein described resources, and in so doing, suggest how, when, or if using them can be beneficial to the learning process. Of the many technological devices and applications out there today, only a select few have actual data supporting their use or value in instructional environments. The research-based recommendations provided in this book lend further credence to a few of the established applications, and new evidence for a few others.

**ORGANIZATION OF THE BOOK**

Data and findings from a variety of studies involving K-12 students, college students, and pre-service teachers are reported with emphasis on applicability to the K-12 environment. The book has been divided into three distinct sections with 18 total chapters. The first section, comprised of eight chapters, covers a variety of research-based studies that address important STEM teaching and learning issues. This first section provides important findings and recommendations to enhance the use of integrated instructional technologies for higher-order thinking and active learning of STEM content. The second section of the book consists of five chapters all pertaining to real-world environmental and social issues in STEM. This section contains various studies that explored inquiry and problem-based teaching methods to help educators better understand the advantages of and skills for science awareness instruction related to critical trends and issues that impact humans and the natural world. The final five chapters in the third section provide excellent examples of educational technologies for efficient and effective teaching and learning in STEM classrooms. The intention for this final section is to give practitioners some detailed illustrations of technological STEM classrooms, perhaps to serve as models for what might serve the needs and desires of those wanting to enhance their teaching through integrated technologies for STEM learning. Certainly, the individual chapter topics transcend any imposed boundaries, but the compartmentalization was an attempt to group chapters into a coherent scheme for purposes of device or discipline similarity, curricular application in a science or STEM methods-type college course, and to provide the reader with some content continuity.
Section 1: Teaching and Learning in STEM

Chapter 1 introduces gaming as a learning strategy in STEM. Authors DeCoito and Richardson consider the potential for acquiring 21st century skills and the effects on student engagement of a specific biology game used to explore integrated STEM content. Consequently, their work with pre-service teaching candidates sets a solid stage for examining other strategies for teaching and learning STEM. Chapter 2, by Smith, Rooney-Varga, Gold, Oonk, and Morrison, examines media literacy challenges within a context of climate change science. Their findings have implications for using digital resources with secondary students in STEM. In Chapter 3, Gomes and Mensah discuss using assistive technologies to improve scientific literacy for students with learning disabilities. Reichen, Oliveira, Oliver, and Florencio-Wain, explore through a case study analysis in Chapter 4, the use of technology in mathematics for helping English Language Learners improve their language skills and content knowledge. Chapter 5 investigates STEM learning with historically underrepresented groups. Specifically, Buck, Beeman-Cadwallader, and Trauth-Nare analyze African American girls’ reasoning through technology-enhanced inquiry. In Chapter 6, Niwat describes findings related to the combined use of physical and virtual experimentation on student perception and motivation in high school chemistry. Mahnaz, Morge, Narayan, and Tagliani describe technology use in Problem-Based Learning for understanding middle and high school science and mathematics concepts within Chapter 7. The section concludes with Chapter 8, in which Akaygun analyzes visualization technologies for modeling concepts in macroscopic and microscopic chemistry as a way to increase comprehension in high school.

Section 2: Real-World Contexts for STEM

Chapter 9, authored by Dass and Spagnolo, describes how teachers can develop skills for using inquiry learning with middle school students through technology combined with the integration of mathematics and science. The study documents findings from a two-year period of classroom implementation with in-service teachers. In Chapter 10, Chang, Kelly, and Metzger, discuss qualitative findings from semi-structured interviews, and other instruments, with in-service teachers participating in a three-day sustainability workshop. Videos related to real-world sustainability were used to elicit teachers’ perceptions about the components of sustainability in one aspect of the study. Authors DeBay, Patchen, Vera Cruz, Madden, Xu, Vaughn, and Barnett explore urban ecology with high school students who collected tree data and analyzed it using Geographic Information System technologies in Chapter 11. Pre- and post-assessments and interviews were used to examine how the students perceived and understood the value of city greenspace. In Chapter 12, Poling, Naresh, and Goodson-Espy describe the importance of statistical problem solving and analysis skills for drawing conclusions about data. The investigations included may be equally suitable for middle or high school students and pre-service teachers. With Chapter 13, the section concludes with Marrero, Gunning, and Woodruff’s examination of freely available authentic datasets online and their classroom use by in-service teachers. A variety of qualitative data is analyzed to illustrate the value of these online resources for helping student to make real-world science connections.
Section 3: Educational Technologies for Use in STEM

Chapter 14, by Snead and Simms, discusses the combined use of several technologies for understanding the physics of kinematics and achieving higher-order thinking in middle and high school science. In Chapter 15, Boyd Harlow, Dwyer, Hansen, Hill, Iveland, Leak, and Franklin describe the incorporation of computer programming into the curriculum of elementary and middle school classes, stressing the importance of acquiring computer science knowledge and skill prior to entering high school. Gatling illustrates, in Chapter 16, a model for a field-based science methods course in which pre-service teachers practice using and applying technology to lessons in an elementary afterschool STEM-enrichment program. The model emphasizes technology integration, science standards, pedagogical practices, and content knowledge. Technology-assisted formative assessment through the use of videography, online quizzes, and more, is the focus of Irving’s Chapter 17. The final chapter in the section and book is Chapter 18, by Ault, Craig-Hare, Ellis, Bulgren, Kretschmer, and Frey, and in it the authors describe the use of gaming to foster high school students’ interest in STEM.

It is our hope that the research, descriptions, and strategies provided in the eighteen chapters of this book suggest both reasons and ways for practicing and pre-service K-12 teachers to enhance their classroom integration of technology in STEM.

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