CONTENTS

INTRODUCTION

As I approached the room an enthusiastic cheer broke through the air. This was not a rock concert or in a stadium. This sound, bursting through the door of the STEM Lab, was the full voice of third-grade students appreciating a lesson in Biochemistry. Their excitement confirmed for me the power of hands-on learning in STEM.

—MARTHA OSEI-YAW,
PRINCIPAL, A.D. SULLIVAN SCHOOL

YOU ARE HERE

All helpful road maps have a starting point. This book began in the STEM Lab at the A.D. Sullivan School. Often STEM Labs can be found in affluent communities or in schools that focus only on high-performing or advanced learners. A.D. Sullivan is neither of those. It is an urban, bilingual primary school serving a primarily economically disadvantaged population. Eighty-two percent of its students are Hispanic and African-American. More than a quarter of the students have limited English proficiency and 12 percent of the students have special needs. A.D. Sullivan classes meet in a nearly century-old building, the school operates on a below-average budget, and it has **a highly successful STEM program including a STEM Lab**. If they can do it, so can you (Figure I.1).

FIGURE I.1 Students at work in the A.D. Sullivan STEM Lab.

Neither of us began our careers as STEM experts. Martha comes from a public education background and Deborah from a private school and nonprofit administration background. For each of us the STEM turning point was a moment of understanding about how important STEM is to education and the future of our students. This led to enrollment in a doctoral program for Educational Technology Leadership, where we met and began our collaboration. We share our story because there may be those among you who fear that you don't know enough about STEM to build a STEM Lab. The answer is quite simple: Go and learn.

In addition to our academic studies, we took every opportunity to explore STEM education in the field. We attended and presented at conferences, visited numerous STEM Labs, volunteered to help with community-wide programs, and participated in a variety of STEM committees and online communities. One thing we learned is that no one can know everything there is to know about STEM or STEAM; and you do not need to be a STEM expert to begin the work of building a STEM Lab. The best things to do are to continue learning and to gather the best possible expertise around you. Building a successful STEM Lab requires teamwork.

ISTE EDUCATION LEADER STANDARDS

This book is designed to complement the 2018 ISTE Standards for Education Leaders (Appendix A), which serve as a theoretical framework "supporting digital age learning, creating technology-rich learning environments and leading the transformation of the educational landscape" (International Society for Technology in Education [ISTE], 2018). In each chapter, selected standards will be highlighted in a text box alongside the corresponding material. Here is an example:

ISTE STANDARD
VISIONARY PLANNER

Leaders engage others in establishing a vision, strategic plan, and ongoing evaluation cycle for transforming learning with technology. Education leaders:

2e. Share lessons learned, best practices, challenges and the impact of learning with technology with other education leaders who want to learn from this work.

This standard exactly reflects our goal for this book: to share what we, and others, have learned while building and researching STEM Labs. The full text of the Education Leader Standards is available in Appendix A.

WHY STEM?

School labs are not a new phenomenon. Many of you reading this book could describe experiences in the chemistry or biology lab, in shop and in home economics. What differentiates the STEM Lab from previous generations of labs? The answer, in a word, is STEM. STEM is the widely known acronym for Science, Technology, Engineering, and Mathematics. Dr. Judith Ramaley, Assistant Director of the Education and Human Resources Directorate at the National Science Foundation (NSF), first coined the term STEM in the context of discussions of workforce needs in a highly unpredictable and quickly evolving technological environment (Chute, 2009). In 2005, the U.S. National Academies of Science, Engineering, and Medicine (NASEM) issued a report titled "Rising Above the Gathering Storm." Highlighting the connection between economic success and STEM professions, this report stated: "Our primary and secondary schools do not seem able to produce enough students with the interest, motivation, knowledge, and skills they will need to compete and prosper in an emerging world" (Committee on Prospering in the Global Economy, 2007, p. 94). Another existing challenge identified in the report is the need to prepare math and science teachers to better support K–12 students.

The popular conclusion was that a universally strong STEM education would be the best way to achieve the goal of a well-prepared workforce. A Congressional STEM Education Caucus, formed in 2003, then challenged the educational establishment to improve STEM learning. They described the challenge as follows: "Our knowledge-based economy is driven by constant innovation. The foundation of innovation lies in a dynamic, motivated and well-educated workforce equipped with STEM skills" (Our knowledge-based economy, n.a., para. 1).

In the years following the NASEM report, numerous studies analyzed the level and effectiveness of STEM education in schools around the globe. Students in the United States ranked below their counterparts in many other nations (Barshay, 2018; DeSilver, 2017). In response, national and state leaders set out to understand and define effective STEM education, in order to develop pathways for improving STEM education and increasing the number of STEM-trained professionals for the marketplace. One outcome of these efforts was a frequently used definition of STEM education as:

> *An interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (Tsupros, Kohler, & Hallinen, 2009)*

The goal of STEM Education was to bring together the study of these four disciplines in a learning construct that takes advantage of the best tools that education in the digital age has to offer.

DEFINING AND UNDERSTANDING STEM EDUCATION

Constructionism, an educational theory developed by Dr. Seymour Papert, provides the foundation for STEM Education as defined above. Constructionism suggests that students learn "by actively constructing knowledge through the act of making something shareable" (Martinez & Stager, 2013, p. 21). Papert asserted that Constructionist theory was confluent with John Dewey's vision of educational environments where "learning is achieved through experimentation, practice, and exposure to the real world" (Papert, 1993, para. 11). Technology, in Papert's view, offers the exact tools necessary to convert Dewey's epistemology into an accessible, practical reality. Most importantly, he saw the role of technology as part of a movement for educational change that will be led by "an army of agents," the students themselves (Papert, 1993, para. 11).

Where the definition of STEM Education speaks about teaching "rigorous academic concepts," Papert spoke about the powerful ideas that are an inherent part of learning science and mathematics (Tsupros, Kohler, & Hallinen, 2009). His concern was that teachers might use technology to continue to teach the same rote applications in the same way they had before technology was available. Papert encouraged teachers to continue to develop their own STEM literacy so that through their teaching an understanding of "powerful advanced ideas" could be facilitated at every level (Papert, 1993).

STEM education applies project-based learning as a means of producing concrete solutions for real-world problems. This is what Jerome Bruner (1966) described as authentic learning involving "deep immersion in consequential activity" (Dougherty, 2016, p. 184). This methodology is the primary delivery system for STEM Education. Among the components of project-based learning are: the composition of driving