Introduction

The NGSS (NGSS Lead States, 2013) have opened the door for engineering to join science as an equal partner in the classroom. What this will look like is still unfolding, but happily, we are not starting from scratch. Many talented educators have been developing instructional materials in engineering for a long time. That's what this book is all about.

The idea of integrating technology and engineering into science teaching is not new. More than 100 years ago, educators such as John Dewey advocated technology education for all students (Lewis, 2004). The call for integrating technology and engineering into science standards began with publication of *Science for All Americans* (AAAS, 1989) and has been featured prominently in standards documents ever since. A case in point is the NSES (NRC, 1996), which advocated that all students should learn about the relationship between technology and science, as well as develop the abilities of technological design.

Despite the many efforts to infuse science teaching with ideas and activities in technology and engineering, the call has been largely ignored. One of the reasons was simply momentum. Science education has traditionally included only the core disciplines of life science, physical science (including chemistry) and Earth and space sciences, so there has been little room for technology and engineering. A second reason is that, although state standards were commonly derived from the NSES and *Benchmarks for Science Literacy* (AAAS, 1993/2008), which also called for engineering and technology, each state crafted their own standards, and most ignored engineering and technology. As of 2012, only 12 states included engineering in their science standards (Carr, Bennett, & Strobel, 2012).

A third reason is confusion about the term *technology*, which most people only apply to computers, cell phones, or other modern gadgets (Meade & Dugger, 2004). There is even less understanding of the term *engineering*. If you've ever had difficulty with plumbing in a hotel room and reported the problem to the front desk it is likely that they called "engineering" to fix the problem. It's not surprising that most people think of engineers as people who fix things (Lachapelle, Phadnis, Hertel, & Cunningham, 2012).

Today the situation is entirely different. A blue ribbon panel of the NRC, which included Nobel Prize-winning scientists, engineers, university professors, and educational researchers have created a new blueprint for science—*A Framework for K–12 Science Education: Practices, Core Ideas and Crosscutting Concepts* (NRC, 2012). The *Framework* calls for engineering to be included at the same level as Newton's laws and the theory of evolution. Furthermore, the *Framework* served as the blueprint for the

NGSS, which are aimed at replacing the current patchwork of state science standards with a common core, as has already been done in mathematics and English language arts. To emphasize that these standards are not federal but rather an initiative of the National Governor's Association, the full title of the new standards is *Next Generation Science Standards: For States, by States.*[*]

In the new world of science education that is being brought into being by these two documents, engineering is a true partner to science. There are several good reasons why this change may pay off at the classroom level in a big way.

The Value of Engineering to Reduce Declining Interest in Science

Most children love science, but it doesn't last. The majority of research studies have found that interest in science remains strong for most boys and girls throughout the elementary grades but begins to drop off in middle school (Osborne, Simon, Collins, 2003; Sneider, 2011). A few studies, however, have shown some decline as early as elementary school, and a consistent finding is that at all ages most girls exhibit less interest than boys and students of most minority ethnic groups tend to be less interested in science than Caucasian and Asian American students.

The introduction of engineering as a continuous thread in the science curriculum has the potential to change that trend and maintain students' interests in science as they transition to high school. There are several reasons why (from Cunnngham & Lachapelle, 2011):

- While many students who are competent in science view the subject as irrelevant for future careers or everyday life, some of these same students—especially girls and underrepresented minorities—respond positively to subjects such as environmental and medical engineering since these topics have obvious relevance to people's lives.
- Engineering involves students working together in teams, so design challenges appeal to students who enjoy collaborative activities.
- Engineering design challenges have more than one answer, and creativity is a plus. So the activities themselves tend to be fun and engaging.
- There are many more jobs available for engineers than there are for scientists. NASA, for example, hires 10 engineers for every scientist (NASA Workforce, 2013). So students see engineering as offering real future job prospects, especially when they see role models of different genders and racial backgrounds who enjoy their work.
- Failure of a design to work as expected does not mean being "wrong." Failure is a natural part of the design process, leading to improved designs, so students are encouraged to try out their ideas without worry.

In the past, few students were exposed to engineering as a school subject. In rare cases, when students were given engineering activities at school, it was likely to have been called "science," and engineering skills were not made explicit. Even in those cases where they *were* given engineering opportunities, it is likely to have been in the physical sciences, such as robotics or building bridges and towers that boys tend to favor rather than topics such as medical or environmental engineering that appeal equally to girls (Cunningham & Lachapelle, 2011).

So, now that we have science education standards that call for engineering to be deeply integrated into all science classes, how do we get from here to there? If you are reading this book it is likely that you are interested in an answer to that question. And not surprisingly, there is more than one answer.

How to Get Started

First, you will need instructional materials. Such materials do exist, and many of them can be found on the Web. A variety of websites with engineering activities are listed in Table 1. Each of the chapters in this book reference additional websites associated with a particular engineering curriculum.

Second, it will be helpful to have at least one colleague, and hopefully several who can work with you to comb through instructional materials, consider how your school's curriculum might change to implement the new standards, and perhaps establish a professional learning community to examine your first efforts as you try new approaches.

Third, you might be invited to spend a summer writing new curriculum materials that are fully aligned with the NGSS. Having spent a long career developing instructional materials in science and the related STEM fields, let me caution you to think carefully about how you might undertake such a project. Curriculum development is a labor-intensive process that often takes years, and the assistance of many other teachers, to develop an effective lesson that will engage your students' enthusiasm and that also has clear educational objectives and assessment tools. Nonetheless, I have found curriculum development to be a creative and rewarding experience, and you may too.

Fourth—and now we get to the reason this book has come into being—you will very likely find it to be a valuable and enriching experience to listen to the voices of the pioneers, the people who held the vision of "engineering as a partner to science" long before these documents were written and who have spent decades developing engineering curricula.

In the chapters that follow, you will see how engineering educators build on students' innate interests by presenting them with challenging problems, engaging them in designing creative solutions, and helping them understand how science and mathematics apply in their everyday lives. While many of the curricula do concern physical sciences, as a whole they span the entire spectrum of science disciplines.

How This Book Is Organized

Each chapter describes one set of instructional materials with vivid examples of what the curriculum looks like in the classroom, what learning goals it is intended to accomplish, how it can help you address the vision of the *Framework*, and the performance expectations in the NGSS.

Perhaps more importantly, the instructional materials described in these chapters do more than spark students' interests. They help students develop skills in defining and solving problems, in working on collaborative teams to brainstorm creative ideas, to build prototypes and use controlled experiments to compare different ideas, to design an optimal solution, and to learn about a wide variety of engineering professions.

All the materials in the collection have been under development for several years, tested by teachers and their students from a wide range of communities, and revised based on feedback. In many cases, they are also supported by research studies of effectiveness. A listing of all the curriculum materials included in this 3-volume sequence can be found in Table 2, which illustrates the full range of grade levels for which the curriculum can be used.

If you are looking for engineering curricula to try out, you will undoubtedly find something of interest on these pages. If you are part of a group of teachers interested in exploring engineering and science curricula, these chapters could provide stimulating topics for discussion. And if you are challenged with developing new instructional materials, these chapters will help you avoid the need to recreate the wheel.

As you read through these chapters, you may find that several strike you as top candidates for enriching your classroom or school science program. Although too many options is far better than too few, you may need some help in deciding among the top contenders. Happily, a new and very useful tool, with the acronym EQuIP has popped up on the www.nextgenscience.org website. Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for Lessons and Units: Science is designed to help you review and select materials based on how well the lessons and units align with the NGSS and provide instructional and assessment supports.

Before you can use the EQuIP rubric, you will need to have samples of the materials to examine. Contact information is provided in each chapter to allow you to do that. You will also need to be familiar with the *Framework* and the NGSS. The next section of this book provides an overview of engineering in these two important documents. If you are already familiar with these documents (which can be downloaded free of charge from the National Academies Press website www.nap.edu) and want to move on to the main business of this book, which is to learn about existing engineering curricula as described by the people who created them, you can get started with Chapter 1, The INSPIRES Curriculum.

The *Framework* and the NGSS have the potential to change the face of science education in the country but only if educators like you embrace the opportunity and begin to imagine what it may mean for the students in your care.

Table 1 A Selection of K–12 Engineering Education Websites

A Framework for K–12 Science Education—http://www.nap.edu/catalog.php?record_id=13165#
Building Big—http://www.pbs.org/wgbh/buildingbig/
Center for Innovation in Engineering and Science Education—www.ciese.org
Design Squad—http://pbskids.org/designsquad/
Discover Engineering—http://www.discovere.org/
Dragonfly TV—http://pbskids.org/dragonflytv/show/technologyinvention.html
Engineering Education Service Center—www.engineeringedu.com
Engineering Go For It (ASEE)—http://teachers.egfi-k12.org/
Engineering Our Future—https://sites.google.com/site/engineeringourfuture/
Engineering Pathways—http://www.engineeringpathway.com/
How to Smile: All the Best Science and Math Activities—www.howtosmile.org
Institute for (P-12) Engineering Research and Learning (INSPIRE)—http://www.inspire-purdue.org/
Intel Design and Discovery—http://educate.intel.com/en/DesignDiscovery/
International Technology and Engineering Education Association (ITEEA)—www.iteaconnect.org
Materials World Modules—http://www.materialsworldmodules.org/
Museum of Science, Boston (NCTL)—http://www.mos.org/nctl/
My NASA Data Lesson Plans—http://mynasadata.larc.nasa.gov/my-nasa-data-lesson-plans/
National Science Digital Library—http://nsdl.org/
Next Generation Science Standards—http://www.nap.edu/ngss
Oregon Pre-Engineering and Applied sciences—http://opas.ous.edu/resourcesEngCurricular.php
Project Infinity—http://www.infinity-project.org/
Project Lead the Way—pltw.org
Sally Ride Science Academy—https://sallyridescience.com/
Science Buddies—sciencebuddies.org
Spark Plug into Science: http://www.gse.upenn.edu/spark/sparkkits.php
Stuff That Works (CCNY)—http://citytechnology.ccny.cuny.edu/Design_Tech.html
Teach Engineering—http://www.teachengineering.org/
Try Engineering—http://www.tryengineering.org/
Women in Engineering—http://www.wepan.org/displaycommon.cfm?an=1&subarticlenbr=39
Zoom: http://pbskids.o rg/zoom/activities/sci/

Table 2 Instructional Materials in the *Go-To Guide for Engineering Curricula Series*

Book	Elementary							Middle School			High School			
Curricula	**P**	**K**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
E1 Seeds of Science/ Roots of Reading				■	■	■	■							
E2 Physical Science Comes Alive!	■	■	■	■	■	■	■							
E3 Engineering byDesign TEEMS, K–2		■	■	■										
E4 BSCS Science Tracks		■	■	■	■	■	■							
E5 A World in Motion		■	■	■	■	■	■	■	■	■				
E6 FOSS Full Option Science System		■	■	■	■	■	■	■	■	■				
E7 Engineering Is Elementary			■	■	■	■	■							
E8 Tangible Kindergarten	■	■	■	■										
E9 Engineering Adventures (OST)					■	■	■							
E10 Engineering byDesign ™ TEEMS, 3–5 & I^3					■	■	■	■						
E11 Design It! (OST)					■	■	■	■	■	■				
E12 Junk Drawer Robotics						■	■	■	■	■				
E13 PictureSTEM		■	■	■	■	■	■							
E14 STEM in Action	■	■	■	■	■	■	■							
M1 Design Squad (OST)					■	■	■	■	■	■	■	■	■	■
M2 Models in Technology and Science							■	■	■	■				
M3 Everyday Engineering							■	■	■	■	■			
M4 SLIDER								■	■	■				
M5 Teaching Engineering Made Easy								■	■	■				

Book	Elementary							Middle School			High School			
Curricula	**P**	**K**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
M6 Fender Bender Physics														
M7 Technology in Practice														
M8 IQWST														
M9 Project-Based Inquiry Science														
M10 Issue-Oriented Science														
M11 Techbridge (OST)														
M12 Waterbotics (OST)														
M13 Engineering Now														
M14 Engineering byDesign™ 6–8														
H1 INSPIRES														
H2 Active Physics														
H3 Active Chemistry														
H4 Engineering the Future														
H5 Engineer Your World														
H6 Global Systems Science														
H7 Science and Global Issues														
H8 Engineering byDesign™														
H9 Science by Design														
H10 Biology in a Box														
H11 Voyage Through Time														
H12 EPICS														

Note

* *Next Generation Science Standards* (NGSS): *For States, By States* is a registered trademark of Achieve, Inc. Neither Achieve, Inc. nor the lead states and partners that developed the NGSS were involved in the production of, and do not endorse the *Go-To Guide to Engineering Curricula 9-12!* However, Achieve, Inc. has granted permission for the authors of this book to quote extensively from the NGSS.

References

American Association for the Advancement of Science (AAAS). (1989). *Science for all Americans*. Project 2061. New York: Oxford University Press.

American Association for the Advancement of Science (AAAS). (1993/2008). *Benchmarks for science literacy*. Project 2061. New York: Oxford University Press.

Carr, R. L., Bennet, L. D., & Strobel, J. (2012). Engineering in the K–12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education 101*(3), 539–564.

Cunningham, C., & Lachapelle, C. (2011). Designing engineering experiences to engage all students. Boston: Museum of Science. Retrieved from: http://www.eie.org/sites/default/files/2012ip-Cunningham_Lachapelle_Eng4All.pdf

Lachapelle, C., Phadnis, P., Hertel, J., & Cunningham, C. (2012). What is engineering? A survey of elementary students. Boston: Museum of Science. Retrieved from: http://www.eie.org/sites/default/files/2012-03_WE_Paper_fo_P-12_Engineering_Conference.pdf

Lewis, T. (2004). A Turn to engineering: The continuing struggle of technology education for legitimization as a school subject. *Journal of Technology Education*, *16*(1), 21–39.

Meade, S., & Dugger, W. (2004, September). The second installment of the ITEA/Gallup Poll and what it reveals as to how Americans think about technology. *Technology Teacher*, *64*(1), 1–12.

NASA Workforce. (2013). Data on NASA workforce. Retrieved from http://nasapeople.nasa.gov/workforce/default.htm

NGSS Lead States. (2013). *Next generation science standards: For states, by states, Volume 1: The standards* and *Volume 2: Appendices.* Washington, DC: National Academies Press.

NRC. (1996). *National science education standards.* Washington, DC: National Academies Press.

NRC. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1097.

Sneider, C. (2011, September). *Reversing the swing from science: Implications from a century of research.* Presented at ITEST Convening on Advancing Research on Youth Motivation in STEM, Boston College, Boston, Massachusetts. Retrieved from http://itestlrc.edc.org/youth-motivation-convening-materials, and from the Noyce Foundation at: www.noycefdn.org/news.php