ENGINEERING INSTRUCTION

for High-Ability Learners in K–8 Classrooms

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Hawker Brownlow
EDUCATION

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Designing Innovative Engineering Instruction for High-Ability Learners in K–8 Classrooms

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In 2013, Rothwell reported that 20% of all U.S. jobs required a significant background in science, technology, engineering, or mathematics (STEM). Even more astonishing, 26 million jobs in the U.S. are dependent upon employees with some background in STEM. Due to these statistics and reports that our educational system is not adequately preparing workers for STEM jobs (Change the Equation, 2012), the Next Generation Science Standards (NGSS) were developed, released, and adopted by many states in hopes to improve STEM education (NGSS Lead States, 2013). The authors of *A Framework for K–12 Science Education*, the foundation for the NGSS, recommended the standards focus on disciplinary core ideas, crosscutting or overarching concepts, and science and engineering practices (National Research Council [NRC], 2012). This allows students to have an integrated study of science through content, concepts, and processes, a strategy long recommended by VanTassel-Baska (1992, 1998).

With the recent and continuous technological advancements in society, NGSS sought to add engineering practices to the standards (NGSS Lead States, 2013). The goal is not necessarily to increase the number of engineers but instead to use science and engineering practices to teach science content so that students will gain "sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives" (NRC, 2012, p. 12). Additionally, using engineering practices to teach science content engages students in active learning, allowing them to investigate the natural world and develop solutions to meaningful problems that they may encounter in the real world.

There are eight science and engineering practices (Table 0.1) in the NGSS that portray the real-world actions of scientists and engineers as they investigate the natural world or design and build models and systems to address a need (Achieve, Inc., 2014). The practices are designed to be integrated with content (disciplinary core ideas) and crosscutting concepts to explain a particular phenomenon and should not be taught in isolation. For example, the practices should not be presented in Chapter 1 of the textbook and never revisited again—as often occurred in past years with the scientific method. Instead, practices must be embedded in content to mimic real-world science and make the content more relevant and engaging to students. Teachers of advanced and gifted and talented students are not unfamiliar with engineering design practices—as many gifted students have engaged in activities such as building bridges or designing egg-drop containers. However, many times the activities were just activities and not embedded in the content of science or any other discipline. Throughout this book, we want to emphasize the importance of engaging students in the practices of science and engineering while addressing the content standards.

PURPOSE OF THE BOOK

The purpose of this book is to assist educators and practitioners in addressing engineering standards in their general and gifted K–8 classrooms, with a particular focus on students with a high affinity, interest, and/or talent for engineering design. As former classroom and gifted teachers and now teacher educators and researchers, we hope that practitioners will be able to use this book to overcome barriers they may face in implementing engineering in their classrooms. We are excited to bring together notable authors and researchers to assist us in this

TABLE 0.1
Science and Engineering Practices

Asking Questions (for science) and Defining Problems (for engineering)
Developing and Using Models
Planning and Carrying Out Investigations
Analyzing and Interpreting Data
Using Mathematics and Computational Thinking
Constructing Explanations (for science) and Designing Solutions (for engineering)
Engaging in Argument From Evidence
Obtaining, Evaluating, and Communicating Information

From National Research Council (2012).

endeavor—to help teachers engage students in engineering. As a previous director and coordinator of a United States Department of Education grant, STEM Starters, we have seen firsthand how difficult it is for teachers, in particular elementary teachers, to add science and engineering into their daily curriculum. There are many barriers that teachers face when seeking to improve science programs in their classrooms, including "(a) time constraints and scheduling conflicts, (b) insufficient resources, (c) inadequate teacher science knowledge and skills, and (d) poor teacher confidence" (Dailey, 2015, p. 21). With this in mind, the authors devote 13 chapters to focusing on applications of engineering design and practices, with special attention paid to designing engineering curriculum and instruction, integrating technology into engineering instruction, and assessing engineering practices for high-ability learners.

CHAPTER AUTHORS

This book has a wonderful mix of early career and distinguished senior scholars. Many of the authors come from gifted education, but science and engineering content experts are also represented. Additionally, a highly renowned science education scholar, Dr. Robert Yager, provided the forward for this book. We are honored to work with each of them.

BOOK ORGANIZATION

The book is organized into four sections. Section 1 addresses key components of engineering instruction for K–8 high-ability learners. In this section, Dr. Steve Coxon discusses the role of spatial ability in engineering, and Drs. Eric and Rachel Mann examine engineering design using gifted pedagogy. Dr. Laurie Croft suggests ways to integrate inventiveness, innovation, and creativity into engineering, and Dr. Rachelle Miller and Ms. Callie Slider encourage educators to engage students in art while teaching engineering and science.

Section 2 explicates how to use cutting-edge technology in engineering curriculum and instruction. Dr. Jason Trumble discusses ways to incorporate innovative technology tools, such as 3-D printers, and Ms. Irene Lee and Dr. April Degannaro suggest how to use computer science and coding for project-based engineering instruction. Additionally, Ms. Krissy Venosdale and Dr. Brian Housand present how to use the ever-popular Maker Movement to facilitate engineering problem solving in creative and gifted learners.

Section 3 focuses on the curriculum and how to design or integrate engineering practices into classroom instruction. Ms. Michelle Buchanan and Dr. Debbie Dailey share example scenarios to assist teachers in adapting their existing curriculum to include engineering practices. Drs. Joyce VanTassel-Baska and Bronwyn MacFarlane offer suggestions on how to create engineering problem-based learning lessons. To check for student progress and to guide instruction, Dr. Ann Robinson, Ms. Kristy Kidd, and Dr. Jill Adelson examine approaches and assessments for measuring student outcomes in engineering.

Section 4 addresses teacher professional development and student identification considerations when implementing engineering in K–8 classrooms. Dr. Alicia Cotabish, Dr. Umadevi Garimella, and Ms. Gina Howes Boshears examine the best methods for supporting teachers in implementing engineering in their classrooms through professional development. Additionally, Dr. Kinnaria Atit, Ms. Kay E. Ramey, Dr. David H. Uttal, and Dr. Paula Olszewski-Kubilius discuss the advantages of introducing engineering to students early on, examine specific skills that are necessary for engineering, provide avenues for integrating and differentiating engineering into K–8 curriculum, and consider the value of adding spatial skills to identify academically talented students.

The book concludes with Appendix A, which provides resources for educators, parents, and students, and Appendix B, which provides descriptions of engineering in both formal and informal environments.

We thank our esteemed colleagues, who diligently provided their expertise and knowledge in writing their chapters; the reviewers, who provided additional eyes to help ensure we produced a quality product; NAGC, which is always supportive in providing resources for educators; and the general education and gifted classroom teacher—for your time and effort in educating our children.

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