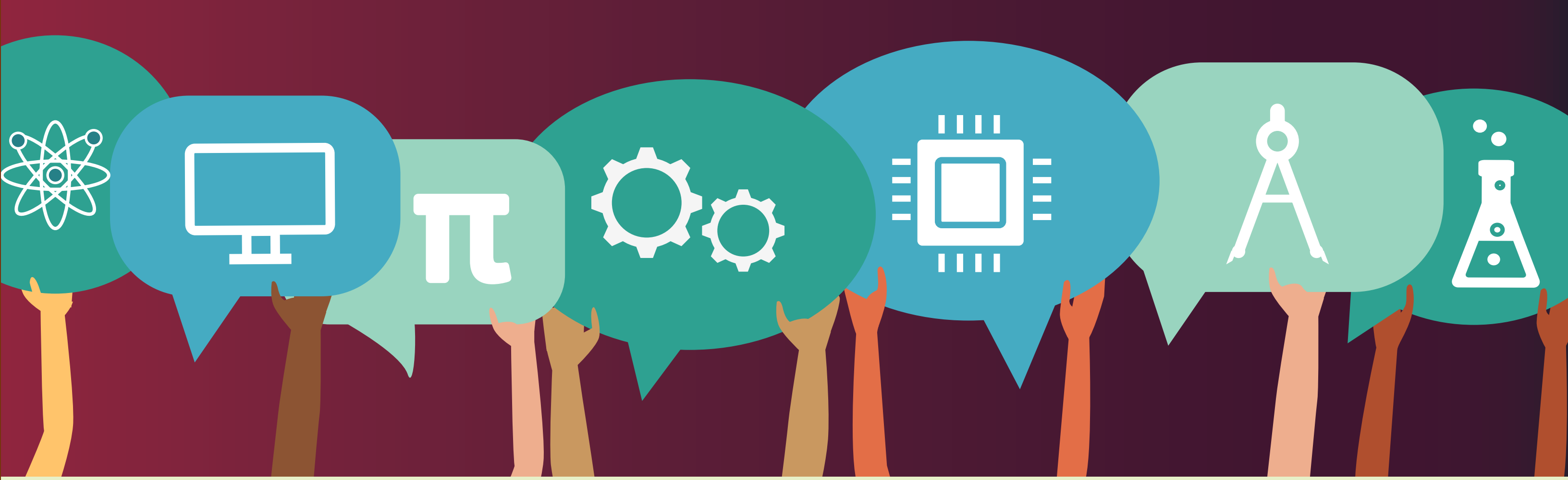

STEM, STANDARDS, AND STRATEGIES for High-Quality Units

RODGER W. BYBEE

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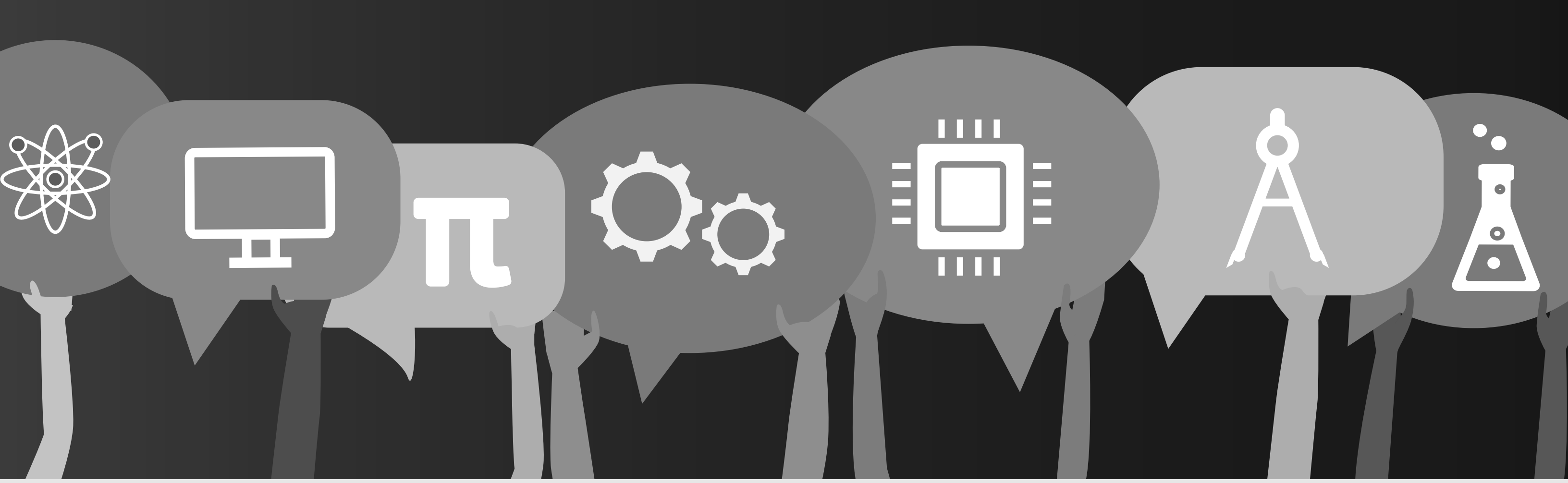

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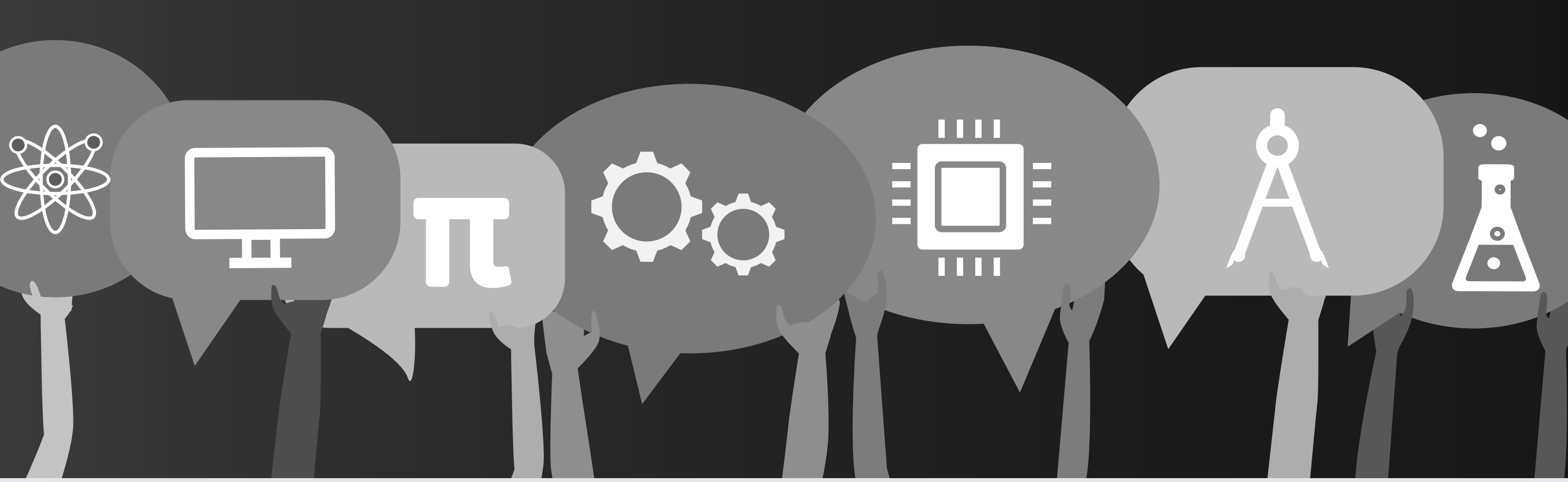

STEM, STANDARDS, AND STRATEGIES for High-Quality Units

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23 22 21 20 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Names: Bybee, Rodger W., author.
Title: STEM, standards, and strategies for high-quality units / Rodger W. Bybee.
Description: Arlington, VA : National Science Teaching Association, [2020] | Includes bibliographical references and index. | Identifiers: LCCN 2019054062 (print) | LCCN 2019054063 (ebook) | ISBN 9781681406268 (paperback) | ISBN 9781681406275 (adobe pdf)
Subjects: LCSH: Science--Study and teaching (Elementary) | Science--Study and teaching (Secondary) | Technology--Study and teaching (Elementary) | Technology--Study and teaching (Secondary) | Engineering--Study and teaching (Elementary) | Engineering--Study and teaching (Secondary) | Mathematics--Study and teaching (Elementary) | Mathematics--Study and teaching (Secondary)
Classification: LCC Q181 .B985 2020 (print) | LCC Q181 (ebook) | DDC 507.1/2--dc23
LC record available at *https://lccn.loc.gov/2019054062*
LC ebook record available at *https://lccn.loc.gov/2019054063*

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Preface

STEM is, to say the least, very popular. The acronym is used in the media as a reference to any or all of the respective disciplines—science, technology, engineering, and math. Educators use the STEM acronym when referring to a range of experiences, from a singular activity to the curricular emphasis of a school. Although quite popular, the acronym also is highly ambiguous. How exactly does STEM relate to a state's, district's, or school's programs and a teacher's classroom practices?

A majority of states have adopted new standards for science. But in apparent contrast with the widespread interest in STEM, there are few curriculum programs actually aligned to these new standards. What follows is a summary of that situation.

The release of *A Framework for K–12 Science Education* (the *Framework*; NRC 2012) and the *Next Generation Science Standards* (*NGSS;* NGSS Lead States 2013) signaled a new set of innovations for science teaching. Briefly, the innovations included the following:

- Teaching to three dimensions—science and engineering practices, crosscutting concepts, and disciplinary core ideas;
- Having students engage in explaining natural phenomena and solving design problems;
- Introducing science practices and crosscutting concepts in ways that include engineering and the nature of science;
- Including units or yearlong programs based on coherent learning progressions; and
- Making connections to the *Common Core State Standards* in mathematics and literacy (NGAC and CCSSO 2010).

The major innovations in contemporary state science standards like the *NGSS* present a complex array of changes for curriculum and instruction, and especially for the many curricular decisions made by classroom teachers and professional learning communities (PLCs). Some of the innovations directly relate to STEM disciplines. (This includes, for example, the practices of engineering design and using mathematics and computational thinking). Unfortunately, in some cases, the complexity of standards resulted in the omission of some innovations as they were translated to instructional materials. Here, the role of crosscutting concepts serves as a significant example.

In other cases, states omitted specific standards or did not adopt the *NGSS* because they included politically (but not scientifically) controversial topics, such as biological evolution and global climate change. The misperception that new science standards were national mandates also resulted in fewer states adopting the *NGSS*. However, most states did adopt new science standards that were influenced by the *Framework* and *NGSS.*

The *Framework* and *NGSS* created a demand for instructional materials and professional development for classroom teachers. But the supply of instructional materials and opportunities for learning about the curriculum reform implied by the new standards was marginal at best. Now, it is approaching a decade since the *Framework*'s release, and there is still a significant need for clarification and concrete discussions about the new directions for science education, especially in reference to instructional materials for grades preK–12.

I wrote *STEM, Standards, and Strategies for High-Quality Units* with individual teachers, teams of teachers in PLCs, and professional development providers in mind. My thinking and subsequent approach for the book developed from a series of questions. First, what has the highest priority within states—STEM or science? I think the accurate answer is science. In large measure, this answer is supported by the fact that states align assessments with the new science standards. But doesn't STEM present a unique opportunity to address some other priorities and issues of educational and public interest and support? To this, I answer yes. So wouldn't it be efficient and productive to find appropriate connections between STEM and science? Educators need not perceive STEM and standards in competition for time and resources; rather, they can be seen as complementary.

Several STEM-related organizations and the federal government have policy statements recognizing the place of STEM in the education community. I refer you to the following list:

- *STEM4: The Power of Collaboration for Change*, a 2019 document authored by Advance CTE, the Association of State Supervisors of Mathematics, the Council of State Science Supervisors, and the International Technology and Engineering Educators Association
- *STEM Education Teaching and Learning,* a 2020 policy statement from the National Science Teaching Association
- *Building STEM Education on a Sound Mathematical Foundation,* released in 2018 by the National Council of Supervisors of Mathematics and the National Council of Teachers of Mathematics
- *Charting a Course for Success: America's Strategy for STEM Education,* released by the National Science and Technology Council in 2018

These policy statements clearly support STEM in K–12 education programs. However, the challenge of instructional materials remains. The current marketplace offers limited examples of high-quality, well-aligned science instructional materials, especially if one considers *variations* among states' science standards. There are efforts currently underway to increase the supply of and access to high-quality science instructional materials designed for the *NGSS.* One such effort is the OpenSciEd initiative, launched by the Carnegie Corporation of New York and supported by other private foundations. In August 2019, OpenSciEd announced the release of three units. And in February 2020, two more units were released. The units are publicly available and were externally evaluated by Achieve's EQuIP Peer Review Panel. Topics for the units include thermal energy, metabolic reactions, sound waves, matter cycling and photosynthesis, and forces at a distance; they are available as print-ready PDFs or editable Google documents. This is an encouraging advance for science education in general; and in particular, it helps meet the need for instructional materials.

As the field awaits a supply of instructional materials to fill the demand, curriculum reform can be accomplished through transitional strategies such as a systemic approach that requires educators to adapt current curricula or develop instructional materials and learn new ways of using them.

Putting curriculum reform into practice is a difficult and demanding process that requires a vision of instructional materials, knowledge of new standards, support for change, collaboration among teachers to learn, and leadership at different levels in the educational system. Contemporary state standards incorporate research on learning and challenge teachers to think differently about learning and teaching content knowledge and practices of the disciplines. Designing, developing, and implementing a high-quality STEM unit could be an initial transitional step in the process of the larger challenge of reforming STEM and/or science programs.

This book describes processes for teachers, teams of teachers, and professional developers to provide leadership for the design, development, and implementation of STEM units. The purpose is to present experiences, activities, and information that may be modified to accommodate unique priorities of classrooms, schools, and states. I go beyond the rhetoric of reform and offer a plan of action.

Some educators may perceive STEM and state standards as conflicting priorities. I do not. STEM represents creative and exciting possibilities, whereas new standards for science are clearly policy mandates for curriculum reform. I propose that STEM and state standards for science may well represent a complementary relationship with implications for both school programs and teachers' professional learning.

My proposal addresses an additional priority for the education community: connecting teachers' professional learning to the design, development, and implementation of instructional materials. Teachers' knowledge and skills have as much of an effect on student learning as the choice or development of instructional materials (Chingos and Whitehurst 2012).

As states, school districts, and schools decide to develop and implement STEM units, there likely will be simultaneous recognition of the need to provide professional learning experiences for teachers. Teachers may require additional knowledge, skills, and abilities to develop and implement STEM units—hence the need for professional learning.

Although professional learning experiences may be designed to support the development and implementation of STEM units, they should also address instructional strategies that promote learning for adults. Some of these strategies also mirror the methods to be used with students (Loucks-Horsley et al. 2010). The point of emphasis is that instructional materials designed to increase student learning in both STEM and science convey teaching largely as a process of provoking students to think, supporting them as they work, and guiding them to reach the content and competencies (i.e., the learning outcomes).

How can teachers learn the strategies and pedagogical content knowledge necessary to effectively implement STEM instructional units? The answer is professional learning experiences that model the instructional approaches intended for teaching students. Engaging teachers in the actual development and subsequent implementation of STEM units will require teachers to think clearly and directly about learning and teaching STEM disciplines. Professional learning experiences that support the development and implementation of the STEM units will challenge teachers' current beliefs about learning and teaching STEM.

So, what is the action plan presented in this book? Briefly, I propose that individual teachers or teams of teachers in PLCs work with professional development providers to create and implement a STEM unit. Before you reject this approach as undoable based on its requirements of time and specific skills, consider the following: As I have discussed, both STEM and standards have challenges and opportunities, and incorporating features of each will contribute to stronger science curricula and teaching practices. The identifiable challenges to STEM education can be balanced with opportunities of the *Framework* and *NGSS*. For example, the science and engineering practices, crosscutting concepts, and disciplinary core ideas of the *Framework* and *NGSS* can provide important content and skills, thus reducing some ambiguities of STEM programs. The *NGSS* also recommends making connections to math concepts from the *Common Core State Standards*. Three of the four disciplines in STEM (science, engineering, and mathematics) are included in the *NGSS,* and technology is easily incorporated as instructional materials and curricular programs are designed and implemented.

Conversely, the complexities of implementing the *NGSS* can be offset by the options of different STEM activities. The education community can address innovations included in new state science standards (for example, engineering design) and even topics omitted from some standards (for example, global climate change) through the implementation of integrated approaches to STEM education.

Though I recognize that balancing STEM and standards will not be perfect, this perspective will help educators with responsibilities for reform to think creatively and strengthen the implementation of school programs and classroom practices.

In conclusion, U.S. education has a long history of large and small innovations that have influenced policies, programs, and practices. STEM education is one example that holds promise of improving students' interest and achievement. Unfortunately, we have also developed a perspective that all such innovations carry equal importance and our work is finished once we have implemented the new ideas. First, innovations like STEM education cannot be equated with other innovations such as the *NGSS* and new state standards because the latter are dominant organizers that influence all significant components of the educational system. For an innovation such as STEM to be sustainable, it must be included as part of these significant components. In the case of STEM, that means connecting to both state standards and the instructional materials for school programs and classroom practices. The important point here is that educators cannot assume that we are finished with the work of making STEM a continuing aspect of education. The steady work of STEM-based reform is nearer to the beginning than the conclusion, and integrated STEM units are an essential place to begin the process of making STEM a sustainable component of education.

The opportunities for STEM and the responsibilities of implementing state science standards can be addressed together, creating more coherence and high-quality school programs and classroom experiences for all students.

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Acknowledgments

I have had, and continue to have, colleagues whose ideas, criticisms, and recommendations established the foundation for this book. I acknowledge their inspiration and patience as I learned about STEM, standards, and professional development, as well as what goes into the design, development, and implementation of instructional materials.

This book benefited from initial discussions with, reviews by, and recommendations from Chris Chopyak, Dora Kastel, John Spiegel, Kathy Stiles, Susan Mundry, Kathy DiRanna, Peter McLaren, Bonnie and Herb Brunkhorst, Harold Pratt, Bob Pletka, and Corey Bess.

I will give very special appreciation to Cassie Bess, a sixth-grade teacher at Solana Highlands Elementary School in Solana Beach, California. Ms. Bess developed a STEM unit that is the basis for Chapter 19. I am sure other elementary teachers will share much gratitude for her work and contribution.

I am grateful to the NSTA Press staff for their understanding and support. My appreciation goes to Claire Reinberg, Rachel Ledbetter, and Andrea Silen.

Four individuals completed formal reviews of an early draft. I found those reviews thorough and challenging. The book is, in my opinion, much improved by my responses to criticisms and suggestions from Harold Pratt, James Bader, Nathan Auck, and Anne Moore.

Jim Short of the Carnegie Corporation of New York dedicated several days to review the draft and provide valuable feedback. My appreciation for his time and effort is far beyond the usual acknowledgment to a colleague or reviewer.

Byllee Simon's contributions to the final manuscript were superior. Her dedication and knowledge immeasurably improved the book.

Finally, my deepest appreciation and enduring gratefulness goes to Kathryn Bybee. Kathryn's support, contributions, and recommendations brought the book into alignment with the needs and challenges of classroom teachers and professional developers.

About the Author

Until his retirement in 2007, Rodger W. Bybee was executive director of Biological Sciences Curriculum Study (BSCS), a nonprofit organization that develops curriculum materials, provides professional development, and conducts research and evaluation.

From 1986 to 1995, Rodger was associate director of BSCS, where he served as the principal investigator for four National Science Foundation (NSF) programs. These included an elementary school program called *Science for Life and Living: Integrating Science, Technology and Health*; a middle school program called *Middle School Science & Technology*; a high school program called *Biological Science: A Human Approach*; and a college program called *Biological Perspectives*. Prior to joining BSCS, Rodger was executive director of the National Research Council's (NRC) Center for Science, Mathematics, and Engineering Education in Washington, D.C.

Rodger participated in the development of the *National Science Education Standards* (NRC 1996), and from 1993 to 1995 chaired the content working group of that NRC project. He also contributed to *A Framework for K–12 Science Education* (NRC 2012) and served on the leadership team and as a writer for the *Next Generation Science Standards* (NGSS Lead States 2013). From 1972 to 1985, he was professor of education at Carleton College in Northfield, Minnesota. He has been active in education for more than 50 years and has taught at the elementary through college levels.

Rodger's bachelor's and master's degrees are from the University of Northern Colorado, and his doctorate degree is from New York University. In 1989, he was recognized as one of 100 outstanding alumni in the history of the University of Northern Colorado. In April 1998, the National Science Teaching Association (NSTA) presented him with NSTA's Distinguished Service to Science Education Award. In 2007, he received the Robert H. Carleton Award, NSTA's highest honor for national leadership in the field of science education.

Since retiring from BSCS, Rodger has continued working as a consultant and contributing to education through presentations and publishing. With NSTA Press, he has authored *The Teaching of Science: 21st-Century Perspectives* (2010); *EVO Teacher's Guide: Ten Questions Everyone Should Ask About Evolution* (2012), with John Feldman; *The Case for STEM Education: Challenges and Opportunities* (2013a); *Translating the* NGSS *for Classroom Instruction* (2013b); *The BSCS 5E Instructional Model: Creating Teachable Moments* (2015); *Perspectives on American Science Education: A Leadership Seminar* (2017), with Stephen Pruitt; and *STEM Education Now More Than Ever* (2018).

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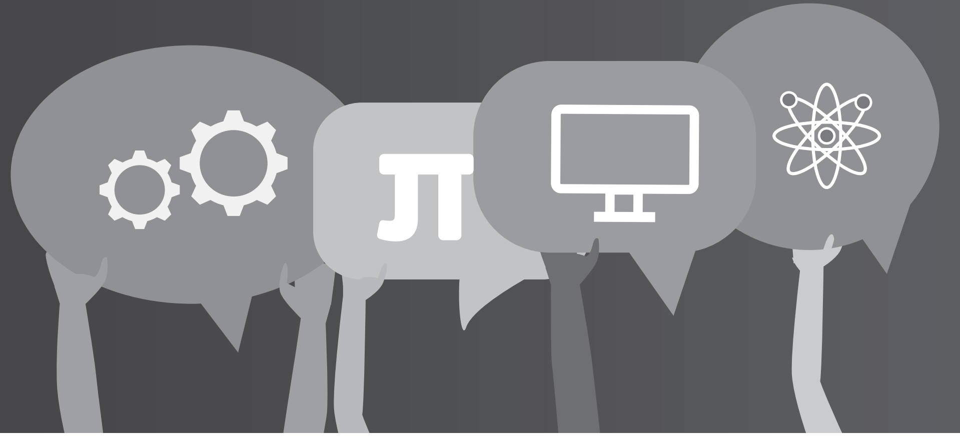
CHAPTER 1



USING THIS BOOK

An Introduction and Guide

This chapter presents an introduction to the book's themes and reviews the structure and possible uses of the chapters by individuals, teams of teachers, and professional developers.

CHAPTER OVERVIEW

Purpose: To provide an introduction, background knowledge, and suggestions about the use of this book for those who plan to create STEM units

Outcomes: Individual teachers, professional learning community (PLC) teams, and professional developers will understand

- the book's major themes;
- the general structure of the book; and
- various options for the use of chapters based on the readers' available time, needs, and individual school or district priorities.

CHAPTER 1

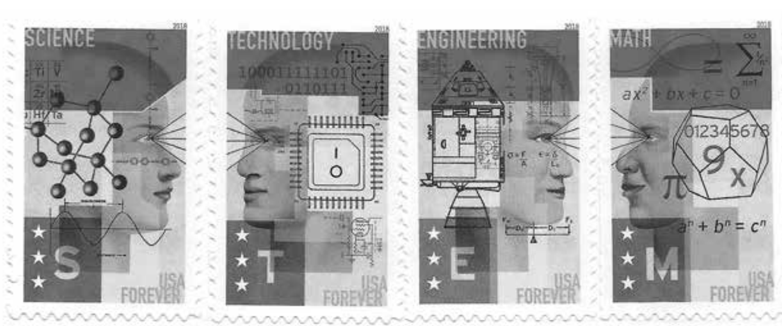
I begin this introduction with a few words about the book's title, *STEM, Standards, and Strategies for High-Quality Units.* I did not include a verb such as *developing*, *producing*, *inventing*, or *creating* after the preposition *for* in the title. This creates some ambiguity, which is intentional. The book's primary emphasis is indeed on the creation of STEM units and the incorporation of content and practices from state science standards. However, the ambiguous title conveys a secondary objective; namely, that developing a high-quality STEM unit also contributes to the knowledge and skills needed to select or adapt instructional materials.

The Book's Themes: STEM and Standards

The title *STEM, Standards, and Strategies for High-Quality Units* summarizes key themes for the book. What follows are brief discussions about two of these themes.

Why STEM? STEM—which of course stands for science, technology, engineering, and mathematics—has a significant presence in schools, districts, and states. STEM has also attained a symbolic recognition in American education. In 2018, the U.S. Postal Service even released STEM-related postage stamps! (See Figure 1.1.) Despite this achievement, there still exists a need for clarification of STEM education in the specific contexts of new college and career-ready science standards, school programs, and classroom practices.

Figure 1.1. STEM Postage Stamps



Source: U.S. Postal Service, public domain.

Although the acronym STEM is widely used, the meanings attributed to it vary. For example, it may refer to a single discipline such as science; the recognition of careers; a robotics competition; connections among the disciplines of science, technology, engineering, and math; or all four disciplines, collectively. Moreover, engineering and technology often are not included in science courses, even though the acronym's ambiguity provides opportunities to include topics and approaches that are broader and deeper than state standards. Nevertheless, STEM is already a part of many school programs, thus opening the door for greater substance, connections to standards, and long-term sustainability of STEM education.

Why standards? Since 2013, a majority of states have either adopted the *Next Generation Science Standards* (*NGSS*; NGSS Lead States, 2013) or approved new science standards based on the *NGSS*, most of which include connections to engineering and mathematics. These standards reflect the influence of *Common Core State Standards* (NGAC and CCSSO 2010) and *A Framework for K–12 Science Education* (NRC 2012). As mentioned, many of the new science standards clearly include connections to the STEM disciplines.

The architecture and expected outcomes of the *NGSS* differ significantly from the National Research Council's 1996 *National Science Education Standards* and state standards developed before 2013. In the *NGSS*, science and engineering practices, disciplinary core ideas, and crosscutting concepts form the three content dimensions of learning. The learning outcomes associated with the three dimensions are clearly identified by means of performance expectations—statements of competency that describe and integrate the content and skills to be assessed.

A comprehensive instructional program should provide opportunities for students to develop their understanding of disciplinary core ideas through their engagement in science and engineering practices and their application of crosscutting concepts. This three-dimensional learning leads to eventual mastery of the competencies expressed in the performance expectations.

There is no postage stamp for the *NGSS* or new state science standards. However, there is a need for new instructional materials that address the requirements of these standards. High-quality instructional materials should clearly show how the cumulative learning experiences work coherently to build the competencies. Because most states have new science standards, it only makes sense to incorporate various aspects of those standards in STEM activities. Many states have included engineering and connections to mathematics in the science practices. The fact that *Common Core State Standards* includes nonfiction reading and writing and mathematics makes a further connection to state standards.

The Book's Themes: Strategies, High Quality, and Units

Why strategies? By definition, a strategy includes the planning and conducting of a large-scale mission. A strategy can be contrasted with tactics. The strategy (i.e., plan of action) in this book is for designing, developing, and implementing STEM units that incorporate content and practices of state standards.

Why high quality? Well, medium, moderate, or "just OK" quality certainly doesn't cut it! The approach in this book is based on answering the following question: What counts as high-quality instructional materials? My answer is this: High-quality instructional materials are materials that enhance student learning. I included ideas in this book about student learning, an instructional model, information on the design and development of materials, and suggestions for improvement of the unit based on practical experience and feedback from colleagues. In addition, I included evaluative criteria based on what is used by the education organization Achieve in its EQuIP initiative and by EdReports in its 2019 *Science Quality Instructional Materials Rubric*. These criteria help to explain what I mean by *high quality* and what high-quality units look like in practical terms.

Why units? A unit is a common category of instructional materials, and developing a unit is doable in a reasonable amount of time. That said, a unit is enough instructional time to accomplish meaningful change. As the result of creating such material, you—and perhaps colleagues from your school or district—will have a unit you can use as well as new understandings and abilities that will help you make the best choice when selecting a new program, adapting current materials, or creating your own curriculum materials, depending on your approach to new instructional materials.

Conclusion to Discussion of Themes

I conclude this discussion by clarifying several points about the book's themes and outlining its major proposals. First, I propose STEM units of several weeks in length, rather than entire curricular programs. The rationale for doing this is to begin with a small and manageable task. Second, the units could be revisions of current science units. For instance, they could elaborate on activities such as egg drops or building and testing structures; place-, problem-, or project-based units; and capstone projects. The challenge with revisions is providing a clear context, as well as addressing appropriate concepts and practices from STEM disciplines and state college and career-ready standards for science. Third, the professional learning involved in creating units should include guidance and analysis of strong curricular models and field-testing of the new STEM units. Finally, I note that this discussion is an introduction. The chapters that follow provide more details on the background, goals, and processes of the aforementioned ideas. One place teachers can begin their work is on the creation of high-quality STEM units. This book can be the basis for one approach for curriculum reform.

In summation, this book introduces practical ideas for creating STEM units and directs users through the processes of development. While waiting for the supply of instructional materials to catch up to the demand, it seems reasonable and logical to create STEM units that are both doable and usable. Creating these units will also contribute to a teacher's knowledge and to his or her ability to make informed selections, modifications, and continued developments to instructional materials. The book is structured around the topics of leadership, design, development, and implementation of STEM units. It represents a synthesis of contemporary educational ideas such as the 5E Instructional Model, backward design, and lesson study. Table 1.1 presents a graphic summary of the book's major sections and chapters. Each chapter includes (1) the purpose and outcomes of the section and (2) a narrative of key ideas. Some chapters include activities and worksheets (many of which are available on the book's Extras page—*www.nsta.org/stem-standards-strategies*), examples of emerging units, resources for further information, and references.

Table 1.1. Organization of *STEM, Standards, and Strategies for High-Quality Units*

PART I: Your Leadership for Creating STEM Units *Effective leadership requires both a vision and a plan.*
Chapter 2: A Vision This chapter provides a vision for STEM units, setting the stage and introducing the need and rationale for these materials.
Chapter 3: A Plan Here, you will find a plan to address practical issues of STEM unit development—the who, what, when, where, and budget.
PART II: Making Decisions About Selecting, Adapting, and Developing STEM Materials *You have three options for meeting the need for materials aligned with your state's science standards.*
Chapter 4: Clarifying and Assessing Choices This chapter explains how choices should be clarified and analyzed.
Chapter 5: Recommendations for Selecting and Adapting Materials Detailed suggestions are provided in this chapter for those who decide to select or adapt STEM units.
PART III: Beginning the Design of a STEM Unit *High-quality STEM units begin with an architect's blueprint—you are the architect.*
Chapter 6: An Engagement This chapter covers the preparation of a preliminary design.
Chapter 7: An Exploration You will now explore the question "What did you already know and what do you want to learn about designing a STEM unit?"
PART IV: Contemporary Ideas for High-Quality STEM Units *This section will help identify a STEM unit's critical elements.*
Chapter 8: Innovations This chapter discusses innovations in *NGSS* and state standards.
Chapter 9: Learning The focus of this chapter is on how students learn STEM content.
Chapter 10: Skills Here, you will receive information about 21st-century skills.
Chapter 11: Practices This chapter goes over STEM practices.
Chapter 12: Discourse Civil discourse in the classroom is discussed in this chapter.

Continued

Table 1.1. (*continued*)

PART V: Practical Recommendations for Completing Your Unit Design *It's time to complete the design. This section will introduce you to two important ideas for the process.*
Chapter 13: Using Backward Design The process introduced in this chapter will increase your unit's quality.
Chapter 14: Using an Instructional Model This chapter covers the BSCS 5E Instructional Model.
Chapter 15: Completing the Design In this chapter, you just get it done.
PART VI: Developing a STEM Unit *The STEM unit moves from a blueprint to actual construction, and you are the general contractor coordinating various parts of the development.*
Chapter 16: Science and Engineering in Standards and the Curriculum You will now review concepts from science and engineering, central disciplines of the *NGSS* and multiple states' science standards.
Chapter 17: Planning, Conducting, and Communicating Investigations This chapter uses two practices as a way to incorporate even more practices into a STEM unit.
Chapter 18: Principles and Processes for Curriculum Development This chapter introduces principles and processes for developing instructional materials.
Chapter 19: A High-Quality STEM Unit in Practice In this chapter, a classroom teacher describes a STEM unit that she implemented.
Chapter 20: Developing Your STEM Unit You will begin work on the specific details of your STEM unit and apply your knowledge and abilities to create the unit.
PART VII: Implementing Your STEM Unit *Construction of your STEM unit is complete. Now it's time to make changes based on your needs and the needs of others.*
Chapter 21: Lesson Study This chapter covers planning a lesson study.
Chapter 22: Teaching, Reviewing, Improving In this chapter, you will implement the lesson study.

Table 1.1 reveals a detailed description of the book's structure: an introduction followed by sets of chapters on leadership, design, background information, development, and implementation of STEM units. There is an underlying logic to the sequence of chapters. For example, the chapters on design precede those about development. This is because a well thought out design will enhance the development of units.

The chapters in Parts I–VI are designed for individuals, school teams, and professional development providers interested in improving their understanding of and skills with curriculum development, instructional strategies, and assessment methods in general and the development of STEM units in particular. The chapters build on knowledge and skills beginning with initial decisions and ending with the implementation and evaluation of the units. The sequence of chapters and activities is based on the following:

- Making decisions about your unit
- Getting started with preliminary designs
- Improving the designs using new knowledge and skills
- Developing your unit
- Teaching and improving your STEM unit

As I am well aware of the constraints on individuals, limitations of schools, and varying priorities of districts, I have not used a time frame for the program. It may be offered as online work, a series of sessions at professional meetings, or as part of other opportunities that occur in professional settings. To be clear, the professional learning is not a single, one-day workshop or lecture. This book is a program for the development and implementation of STEM units that involves work across an extended period of time. Important experiences and processes for the professional learning program are listed in Figure 1.2.

Figure 1.2. Outcomes and Processes for the Professional Learning Process

- Establish norms for collaborative work with your professional learning community (PLC).
- Clarify learning outcomes for STEM units in general and at grade levels.
- Identify topics and coordinate units across grade levels and courses.
- Review opportunities to address state standards.
- Introduce the BSCS 5E Instructional Model.
- Create design assessments for the STEM units.
- Introduce lesson study.
- Introduce backward design.
- Learn about argumentation in presentations of STEM investigations.

I encourage users of this book (especially individual teachers, professional learning teams, and professional developers new to the outcomes and processes) to complete the chapters' various exercises, activities, background discussions, and worksheets. That said, if you already know about components of the overall work and outcomes, you may find some experiences unnecessary. I do encourage you to keep in mind the final goal—a coherent, high-quality STEM unit.

Using the Chapters and Activities

A range of individuals and groups may use this book. For those new to the processes of design, development, and implementation of instructional materials, I encourage working within a professional learning community (PLC). For those with some experience, I trust your professional judgment to make decisions about which chapters and activities will be most helpful.

This book can be used in different ways, depending on your leadership role. For the following discussion about these uses, I focus on local leaders (e.g., teachers, STEM coordinators, science supervisors, department chairs, school and district administrators). I encourage teachers to take up the mantle of leadership, especially in rural districts. I also focus on individuals who hold leadership roles outside local districts but who may be directly involved in district initiatives through provisions of professional development (e.g., state and regional educational leaders, college and university personnel, members of informal education communities, and specialists in professional development).

First, some general recommendations. Although teachers and teams may already have lessons or units on hand, I suggest beginning with new designs and topics. Developing units "from scratch" opens possibilities for new and creative ideas. This said, it also works for teachers to begin with currently available materials. Other options would be to start by searching for open educational resources or available materials to purchase. If these latter options are used, I still recommend some of the processes in the program described in this book.

Now, I will list some specific ways for the aforementioned groups to use the book. For local leaders and PLC teams, I suggest the following:

- Use Part I for initial discussions and to create commitments to develop and implement STEM units.
- Review the program described in Parts II–IV to identify priorities for planning and budgeting.
- Consider needs, gaps, and opportunities in your local schools and district. What do you need to do? Who do you need to talk to? Who will be on the teams of teachers? What do you need for support? How will you communicate the program to develop a STEM unit to colleagues and the community?
- Review chapters to determine what is available and what you might need for additional background material.

- Build support and capacity by presenting the program and your plans at local, regional, and state meetings of informal educators and STEM-related organizations.

For professional development providers, college and university faculty, regional leaders, and STEM organizations, I suggest the following uses of this book:

- As the basis of and guidance for creating a course, curriculum, or institute for the development and implementation of STEM units
- As a way to introduce others in the educational system (e.g., policy makers, business leaders, and the general public) to the importance of and need for STEM in education

A Plan of Action for STEM and Standards-Based Reform

I have pointed out the necessity for new instructional materials that address both the needs of teachers who want to pursue STEM and the requirements of implementing standards-aligned science curricula. States, school districts, and science teachers looking to fill the demand for such materials eventually realize that their decisions are limited to selecting commercially or openly available instructional materials; adapting current instructional materials; or developing new instructional materials. There are, of course, variations on these options. But in the end, the choices boil down to these three actions: selecting, adapting, or developing the materials.

In simple and direct terms, this book is a call to action to both the STEM and science education communities. With support from the extended educational community, I propose a process that centers on teachers developing STEM units for use in their classrooms. With guidance and support, the design, development, and implementation of STEM units will

- complement needed curriculum reforms aligned with new state science standards,
- respond to teachers' concerns about the relevance of instructional materials,
- contribute to teachers' roles as educational leaders, and
- enhance students' learning as they become informed citizens.

Typically, as new priorities such as STEM or state science standards are adopted and put in place, educators select instructional materials aligned with the innovations in these new priorities. Professional learning may be provided by publishers and school districts that adopt new curricula programs. Based on my history of work on national standards and curriculum development projects, my original approach would have been to wait for curriculum development organizations to partner with publishers and release new curricula. This response has not been the case since the release of the *NGSS*. Even the recent reviews of middle school science instructional materials by EdReports show the limited supply of high-quality curricula aligned with the *NGSS*.

While teachers wait for the field to respond and produce better instructional materials, I propose a different approach—one that recognizes leadership by classroom teachers and represents a departure from the continued use of outdated curricula. As teachers engage in more productive strategies to address *NGSS* innovations and the integration of STEM, they also will help build demand for better instructional materials and aligned curricula.

So, what exactly am I proposing? I begin with the basic curricular element of the proposal. Development efforts would concentrate on STEM units. These units would be more than a lesson and less than a full program. They would be one- to three-week integrated instructional sequences for elementary, middle, or high school students.

STEM units could be developed as replacements for current activities, lessons, or units. They would therefore require only a small increase on time constraints of the current system or no increase at all. Moreover, if implemented in current science courses, these units could address two priorities: STEM and standards. That is, they would support the content and processes of separate STEM disciplines using the *NGSS* or state science standards as a blueprint. This would result in an integrated approach to STEM. Integrated STEM units could also serve as capstone projects at the end of science courses to provide students with opportunities to apply what they have learned from previous science units. Including these units in current science courses is a first step toward making integrated STEM a sustainable component both in a district's science program and in the educational system at large.

Who develops the units? My answer to this question is teams of teachers from school districts, with support from facilitators of professional learning. The approach combines teachers' professional learning and the development of STEM units.

At this point, I wish to make my position absolutely clear—the proposal is not to simply have teachers develop STEM units without professional, administrative, and public support. Most educators recognize the critical role of teachers at the interface between instructional materials and students; however, other components of the educational system must also be involved in the process that I am proposing. I am placing confidence in professional teachers and the providers of professional learning for teachers. Responsibility also resides in schools, districts, and state administrators to provide the time and support needed for professional learning.

Conclusion

This book describes the steps that may be taken as individual teachers, teams of teachers, and professional developers elect to design, develop, and implement STEM units as a complementary option to either selecting instructional materials or adapting current materials.

I assume most teachers have the initiative to do as teachers have done for decades—develop units based on their interests, knowledge, and understanding of their students. I also strongly recommend that PLCs use the ideas and approach presented in this book with teams of teachers within schools and districts. Finally, there is a critical role for professional development providers to facilitate and guide the creation of high-quality STEM units. No matter who is creating these units, they will provide the education community with an extremely powerful tool—an effective and exciting way to enhance student learning through STEM and standards.

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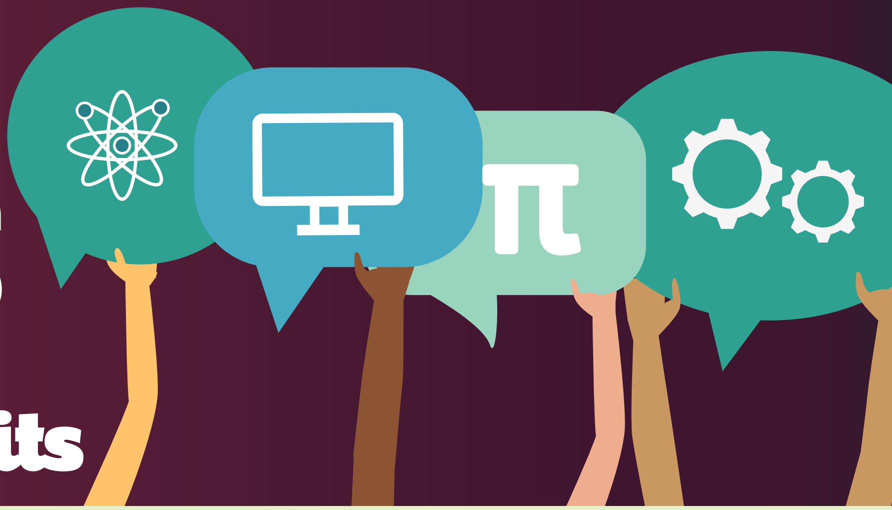
STEM, STANDARDS, AND STRATEGIES for High-Quality Units



Do you, your school, or your school district want to align your science curriculum with state standards while meeting the growing demand for STEM instruction? If so, this is the book for you. It's a guide to creating coherent, high-quality classroom materials that make standards and STEM work together in ways that are both effective for learning and practical for teaching.

The author of *STEM, Standards, and Strategies for High-Quality Units* is thought leader and curriculum expert Rodger W. Bybee. He wrote it to be useful for individual teachers, professional learning communities, and professional developers. The book offers explicit directions for how these different groups can use the book's background information and activities at each step of developing a standards-based STEM unit. Book sections discuss the following:

- Making decisions about selecting, adapting, and developing STEM materials
- Getting started with preliminary unit designs
- Improving your design with new knowledge and skills
- Developing your STEM unit
- Teaching and improving your unit

Throughout the book, Bybee draws on contemporary educational strategies such as the 5E Instructional Model, backward design, and lesson study.

"Because most states have new science standards, it only makes sense to incorporate various aspects of those standards in STEM activities," Bybee writes. *STEM, Standards, and Strategies for High-Quality Units* can help you do this, whether your school is developing a new STEM program, adapting current instructional materials, or creating new materials of its own.

PB453X
ISBN: 978-1-68140-626-8

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