A graphic featuring several black silhouettes of hands of various sizes reaching up to hold a large orange rectangular sign. The sign contains the text 'STEM EDUCATION' in large, bold, purple letters. Below the orange sign is a smaller red rectangular sign with the word 'NOW' in white, bold, sans-serif letters. The background is a light yellow gradient.

STEM EDUCATION


NOW

More Than Ever

RODGER W. BYBEE


NSTApress
National Science Teachers Association

STEM EDUCATION

The image features a central graphic with a light gray background. At the top, the words "STEM" and "EDUCATION" are written in large, bold, black, sans-serif capital letters. Below this, the word "NOW" is written in white, bold, sans-serif capital letters on a dark gray rectangular background. The entire graphic is framed by black silhouettes of hands. Two large hands are positioned on the left and right sides, appearing to hold up the top banner. Below the "NOW" banner, several smaller hands are raised, some pointing towards the center. At the bottom of the image, a dark gray curved banner contains the text "More Than Ever" in a light gray, bold, sans-serif font.

NOW

More Than Ever

The image features a central graphic of four black silhouettes of hands holding up signs. Two hands on the left and right hold a large rectangular sign with the words 'STEM EDUCATION' in bold, black, sans-serif capital letters. Two hands at the bottom hold a smaller rectangular sign with the word 'NOW' in white, rounded, sans-serif capital letters. Below these signs is a large, dark, curved banner with the text 'More Than Ever' in a light gray, rounded, sans-serif font.

STEM EDUCATION

NOW

More Than Ever

RODGER W. BYBEE

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Claire Reinburg, Director
Rachel Ledbetter, Managing Editor
Deborah Siegel, Associate Editor
Andrea Silen, Associate Editor
Donna Yudkin, Book Acquisitions Manager

ART AND DESIGN
Will Thomas Jr., Director, cover and interior design

PRINTING AND PRODUCTION
Catherine Lorrain, Director

NATIONAL SCIENCE TEACHERS ASSOCIATION
David L. Evans, Executive Director

1840 Wilson Blvd., Arlington, VA 22201
www.nsta.org/store
For customer service inquiries, please call 800-277-5300.

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INNOVATIONS AND OPPORTUNITIES FOR STEM EDUCATION

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Preface

The development of this book from idea to its current form has an interesting history. This book began in March 2012, when, as I was in final preparations for my book *The Case for STEM Education: Challenges and Opportunities* (2013a), I had dinner with Greg Pearson, a senior scholar at the National Academy of Engineering. Greg had reviewed *The Case for STEM*, so I summarized the chapters and, of course, my responses to his suggestions. That book expanded on various themes, such as our “Sputnik moment,” and helped the reader clarify his or her own perspective on STEM education. While I provided information and suggestions, my goal in writing the book was to help others understand the context and perspective for STEM-oriented education reform. I explained all of this to Greg with great enthusiasm. After a few minutes, he asked, “Aren’t you going to say what you would do?” He asked what I would say if others asked about my ideas for STEM education, so I talked about the need for a discussion of curriculum materials related to STEM domains, an emphasis on contemporary challenges, and an orientation that differs from, but complements, the discipline-based programs in most schools. Greg told me I had to include my ideas in *The Case for STEM Education*.

When I returned to work on that manuscript, I tried adding these innovative ideas, but it just did not work. In *The Case for STEM Education*, I developed the theme of helping others think through and strengthen their STEM programs. That theme was offset by adding several final chapters that proclaimed, “Here is what I would do.”

This book—*STEM Education Now More Than Ever*—does present my ideas. These ideas about STEM differ from other approaches, but I try to present a reasonable view, one that is timely and will have value in the coming years. Let me continue with a discussion of this book’s development.

This book was conceptualized during that original discussion with Greg; however, the book’s development took much longer than anticipated. After doing some initial work on a new STEM book, I engaged in other projects. From time to time, I would work on the manuscript, but not with a clear focus or deadline. My other projects resulted in the books *Translating the NGSS for Classroom Instruction* (2013b) and *The BSCS 5E Instructional Model: Creating Teachable Moments* (2015).

During this period, I kept an eye on various publications, meetings, and projects related to STEM education. In my view, however, many STEM initiatives suffered from one significant shortcoming: They used the acronym in broad and ambiguous ways. Basically, STEM had become a slogan. Recognizing this shortcoming did not mean that STEM education lacked potential and an important role in American education, but STEM education’s potential and role were not clear, at least to me.

All of this changed with the election of Donald J. Trump as the 45th president of the United States. I realized then that the aspirations and innovations I had considered all came together in this urgent time for STEM education.

Preface

The ideas I present in this book provide something of a corrective measure for the weaknesses I perceive in STEM education. My enthusiasm and motivation center on responses and remedies to concerns that emerged during the presidential campaign—for example, I was appalled by the disdain displayed toward women, minorities, and individuals with special needs. From a STEM point of view, I was especially dismayed by the misuse of evidence, assaults on the integrity of the STEM disciplines, dismissal of the contributions of science and engineering (many supported with government funds), and the disregard for civil discourse.

Now more than ever, we need a reminder of the documents and themes that have made America great, as well as ways to address STEM issues at the local, national, and global levels and emphasize how essential education is to a strong citizenry. These themes lead directly to STEM education and the need to address questions that guide the development of programs and practices for the 21st century. The additional challenge for me was to address all of these needs with a positive, constructive, and diplomatic approach. So, here is a summary of the result.



Part 1 of this book provides a context for contemporary STEM education, my response to President Trump's rhetoric and reasoning about STEM-related issues, and my motivation for writing this book. I do believe there is a new and urgent need for STEM education, and that need emerged from numerous challenges that arose from the 2016 presidential campaign and the new administration. STEM education must express new aspirations that complement traditional approaches to the respective STEM disciplines.

In Part 2, chapters on the Enlightenment, the Constitution, democracy, citizenship, and American science and technology serve as reminders of the effects that STEM disciplines have had on America's foundational ideas and values and how these concepts extend to education, including contemporary STEM education. Although these chapters do not look or seem like typical chapters in a book on STEM, they are timely and useful as background for understanding why this book on STEM education has the theme "Now more than ever." Please read these chapters and think about these foundational ideas and values and their implications for STEM education in general and the recommendations I make in this book in particular.

In Part 3, I address the question, "What should we do to advance STEM education?" The chapters in Part 3 move beyond contemporary politics and center on the purposes of STEM education and constructive recommendations for the translation of the purposes into curriculum units. Rather than present a large, all-encompassing view, I make what I hope are practical recommendations: Begin with design and develop STEM units for the classroom, then use the development of those units as the basis for teachers' professional learning. The chapters in Part 3 direct attention to the simultaneous need for instructional materials and professional development. I recommend that teachers engage in a series of working seminars with the aim of developing STEM units for their use. The working seminars also are designed as complementary professional learning experiences.

Part 4 provides a brief but important conclusion for the book. The first chapter in Part 4 answers questions about the themes and recommendations from prior chapters, and the book's final chapter discusses the need for leadership by classroom teachers and the STEM education community.

This book draws on my past themes and works that some readers may recognize. I do not apologize for this use of previously stated ideas and publications. For *STEM Education Now More Than Ever*, the ideas have a new context and are timely in how they address the challenges faced by STEM teachers and the community.

As we navigate these unconventional and uncertain years, I hope this book will provide a guide for a positive and constructive response by the STEM education community.



Acknowledgments

Although this book was completed over a short period of time in 2016 and 2017, the resources and ideas I drew upon have been in development for many years. The individuals who advised and supported the work are many and diverse. I especially wish to acknowledge and thank the following individuals.

Greg Pearson, a colleague at the National Academy of Engineering, gave me the original advice to step up and write something innovative. He has continued to reinforce that original recommendation. Greg DeWit, a friend and neighbor, has listened patiently while I explained the book's themes and my progress with the manuscript. Chris Chopyak asked me to join her and several colleagues for a project called *Instructional Materials and Implementation of Next Generation Science Standards* (Bybee and Chopyak 2017). Our work resulted in many opportunities to discuss the relationship between business and education. Most important, our work helped me formulate ideas about the importance of teachers' professional learning and instructional materials.

For several years, I have been a consultant for the Hands-On Science Partnership, a small group of commercial publishers. I met with the group shortly after the 2016 presidential election, and my presentation at that meeting contributed immeasurably to the themes in this book.

I extend special appreciation to Robert Pletka, superintendent of the Fullerton School District in California, for the ideas, support, and friendship he has provided.

Seven individuals completed detailed reviews of a preliminary draft of this book. NSTA supported five of those reviews. The NSTA reviewers included James Brown, Andrés Henríquez, Harold Pratt, James Short, and Jeff Weld. Peter McLaren and Kathryn Bybee also read and commented on the entire draft. In addition to the written reviews and recommendations, I also had extended discussions with Harold, Jim, Peter, and Kathryn, all valued colleagues. In preparing the final manuscript, I responded to most of the reviewers' recommendations. I thank the reviewers, as this book is stronger and more balanced because of your feedback.

Once again, I thank the NSTA staff for their support, in particular Claire Reinburg, Rachel Ledbetter, and Jodi Peterson, as well as Wendy Rubin, who carefully edited and substantially improved the book.

This is the seventh book that I have had the pleasure of working on with Byllee Simon. Her understanding of my ideas and work habits has been, and continues to be, deeply appreciated.

I thank my family, especially Margaret Herbert, Corey Bess, and Cassie Bess, all of whom taught or are teaching in public schools. On several occasions, they listened to my ideas and gave advice.

Kathryn Bybee gave me unending support and encouragement based on her experiences as a classroom teacher and in leadership as Director of Science in the

Acknowledgments

San Diego Unified School District and San Diego County Office of Education. My appreciation of Kathryn's extensive discussions, forbearance, and recommendations is beyond expression.

About the Author

Until I retired in 2007, I was the executive director of Biological Sciences Curriculum Study (BSCS), a nonprofit organization that develops curriculum materials, provides professional development, and conducts research and evaluation for the education community.

Before joining BSCS, I was the executive director of the National Research Council's (NRC) Center for Science, Mathematics, and Engineering Education (CSMEE) in Washington, D.C. From 1986 to 1995, I served as the associate director of BSCS, where I was the principal investigator for four new National Science Foundation (NSF) programs: 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 *BSCS Biology: A Human Approach*; and a college program called *Biological Perspectives*. I also served as the principal investigator on several other programs to develop frameworks for teaching about various topics, including the nature of science and technology and curriculum reform based on national standards.

I chaired the Science Forum and Science Expert Group (2006) for the Programme for International Student Assessment (PISA) by the Organisation for Economic Cooperation and Development (OECD).

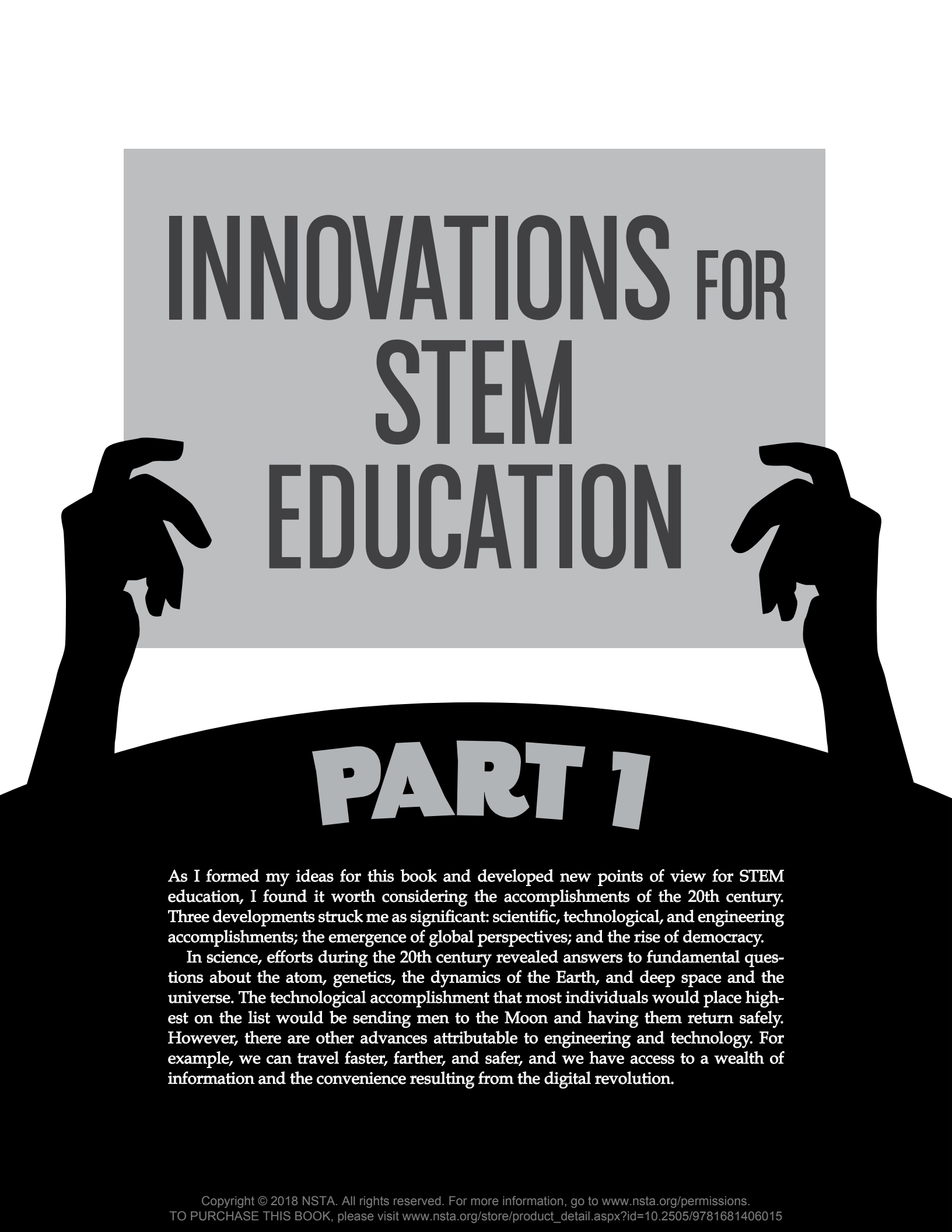
I participated in the development of the *National Science Education Standards* (NRC 1996), and from 1993 to 1995, I chaired the content working group for that NRC project. I also contributed to *A Framework for K–12 Science Education* (NRC 2012) and served on the leadership team and as a writer for the *Next Generation Science Standards* (NGSS Lead States 2013). From 1990 to 1992, I chaired the curriculum and instruction study panel for the National Center for Improving Science Education (NCISE), and from 1972 to 1985, I was a professor of education at Carleton College in Northfield, Minnesota. I have been active in education for more than fifty years and have taught at the elementary through college levels.

My bachelor's and master's degrees are from the University of Northern Colorado, and my doctorate degree is from New York University. I have written about topics in both education and psychology and received awards. In 1989, I was recognized as one of one hundred outstanding alumni in the history of the University of Northern Colorado. In April 1998, the National Science Teachers Association (NSTA) presented me with NSTA's Distinguished Service to Science Education Award, and in 2007, I received the Robert H. Carleton Award, NSTA's highest honor, for national leadership in the field of science education.

After stepping down from BSCS, I continued working as a consultant and contributing to education through presentations and publishing. With NSTA Press, I have written *The Teaching of Science: 21st-Century Perspectives* (2010); *EVO Teacher's Guide: Ten Questions Everyone Should Ask About Evolution* (2012), with John Feldman;

About the Author

Translating the NGSS for Classroom Instruction (2013b); *The Case for STEM Education: Challenges and Opportunities* (2013a); *The BSCS 5E Instructional Model: Creating Teachable Moments* (2015); and *Perspectives on Science Education: A Leadership Seminar* (2017), with Stephen Pruitt.

The image features two black silhouettes of hands, one on the left and one on the right, holding up a rectangular sign. The sign has a light gray background and contains the title text in a bold, sans-serif font. The hands are positioned as if they are presenting the sign to the viewer.

INNOVATIONS FOR STEM EDUCATION

PART 1

As I formed my ideas for this book and developed new points of view for STEM education, I found it worth considering the accomplishments of the 20th century. Three developments struck me as significant: scientific, technological, and engineering accomplishments; the emergence of global perspectives; and the rise of democracy.

In science, efforts during the 20th century revealed answers to fundamental questions about the atom, genetics, the dynamics of the Earth, and deep space and the universe. The technological accomplishment that most individuals would place highest on the list would be sending men to the Moon and having them return safely. However, there are other advances attributable to engineering and technology. For example, we can travel faster, farther, and safer, and we have access to a wealth of information and the convenience resulting from the digital revolution.

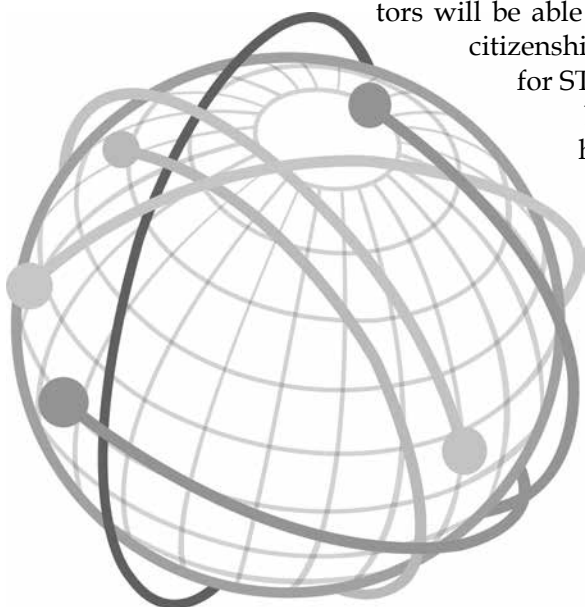
PART 1

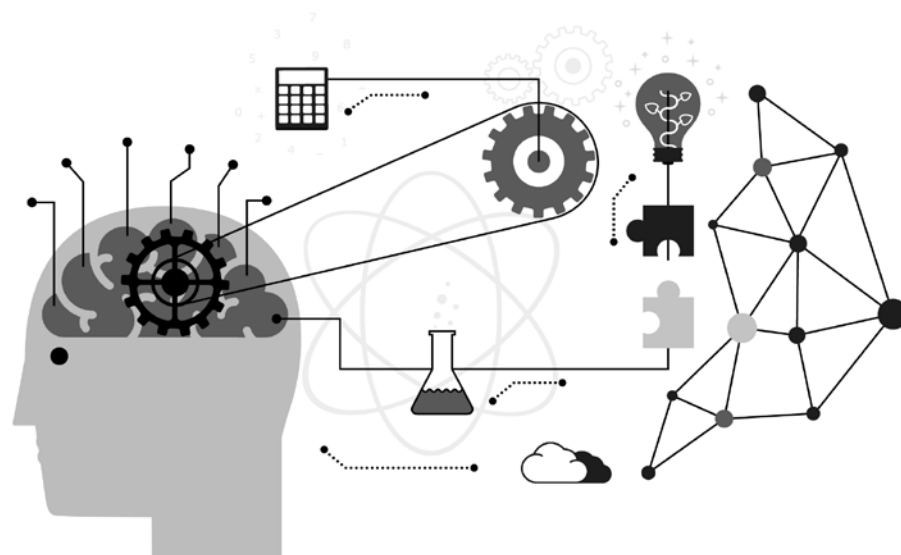
Advances in science, technology, and engineering have contributed to broader and deeper global perspectives. We understand more about what is happening in the world when it comes to health and disease, peace and war, economics, and politics. Some global information has been good, and some has been less positive. We have been able to reduce the occurrence of some diseases, and we now understand the greatest consequence of increased carbon emissions: global climate change. From a STEM education point of view, an important contribution to our expanded global perspective has been the information gained from international assessments such as Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), including about how each nation's students understand certain subjects.

The rise of democracy as a political reality in many countries must be considered a major change during the 20th century. While the political ideal has not been fully realized, we have witnessed advances in civil rights and a decline in the number of dictatorial governments. As I noted in the statements regarding the environment and resources, however, there is still work to do relative to our democratic ideals. We need to explore in greater depth the relationships among democracy, citizenship, and STEM education, as these connections have not been discussed as much as problems related to health, resources, and the environment.

Democracy, citizenship, and education all have historical links to STEM, and I propose there should be connections between these topics and STEM, as well as new points of view about what is needed in contemporary STEM education. What are the new points of view? STEM education should consider the applications of concepts and practices to local, national, and global contextual issues such as health, resources, hazards, and the environment. As students come to understand the contextual issues and the importance of STEM concepts and practices in addressing problems, educators will be able to promote the values and principles of democracy and citizenship. In this book, I will focus on recommending innovations for STEM education.

During the first decades of the 21st century, societies have continued to experience positive outcomes of work in the STEM disciplines. For example, science continues to advance our achievements in medicine, technology provides better transportation and communication, engineering brings increased safety and security, and mathematics increases our understanding of the dimensions and dynamics of change. Economic progress supports our basic needs through goods and services. While issues related to the economy, equality, and civil rights continue to challenge us, our social and political systems work to address these problems. To be clear, we





still have significant concerns, but our STEM disciplines have contributed to progress for individuals, nations, and the global community.

However, contemporary perspectives on the causes and consequences of antibiotic resistance or climate change, for example, are concerns for all citizens. Yes, these general and complex problems relate to social and economic priorities, cultural differences, and political will. Developing solutions to these issues is necessarily complicated by an emphasis on personal values, respect, and compassion for others. STEM education can promote these perspectives for our students, so let's discuss the innovations that will bring about these changes.

Paradoxically, science, technology, engineering, and mathematics have contributed to both our progress and our problems. The use of scientific and technical knowledge varies as citizens make decisions about the application of knowledge. As citizens' understanding and decisions vary, consequences may be positive or negative, as we see related to conservation or uses of natural resources, justice and injustice for different social groups, and prosperity for and burdens on future generations. Different lifestyles; social, political, and national priorities; and global agreements all result in new issues to address.

The Trump administration certainly has not addressed issues such as the fact that U.S. factories are in the process of a robotics revolution and the consequence is fewer jobs and higher technical requirements for jobs that do exist; the need to pay more attention to education in rural communities; the continuing issue of recruiting and retraining minorities in STEM-related careers; and the level of citizens' understanding and support of STEM.

I must mention several specific concerns related to the current administration. The dismissal of scientific consensus that climate change is real, not a hoax, is a major concern, as are efforts to rescind longstanding environmental regulations. Not unrelated to these concerns are a lack of recognition of the difference between facts and opinions and reduced civility in public discourse.