What Your Colleagues Are Saying . . .

Simplifying STEM, PreK–5 addresses the challenge of persistent inequities in STEM education with an approach to teaching that draws strength from the complex ways in which identities, culture, and context intersect in the classroom and our world. Weaving theory and practice with rich classroom examples, this book unpacks with beautiful clarity inclusive and equitable approaches that value, cultivate, and leverage diverse perspectives and experiences so that meaningful learning is available for all!

Cathery Yeh
Assistant Professor of STEM Education
Core faculty for the Center for Asian American Studies
The University of Texas at Austin
Austin, TX

If you've been told that there either aren't enough or too many integrated STEM resources for practitioners, know that *Simplifying STEM, PreK–5* offers real-world examples that are complex yet accessible to all audiences. With "try this" teacher and scholar actions, the authors take novices to experts on an intellectual journey in STEM spaces. They weave information that further explains STEM in today's context that makes the reader excited to imagine as well as try something creative.

Andrea Borowczak
President of the Association of Science Teacher Educators
Director and Professor, School of Teacher Education
University of Central Florida
Orlando, FL

Simplifying STEM, PreK–5: Four Equitable Practices to Inspire Meaningful Learning provides a framework for teaching Integrated STEM Practices. It includes vignettes to show teachers how to integrate them into their lessons with grade-appropriate connections. I appreciate how the "So you've been told . . ." statements and "Reality Check!" responses throughout the chapters address many misconceptions and ideas educators confront.

Robert Q. Berry III
Past President of the National Council of Teachers of Mathematics
Dean of the College of Education
University of Arizona
Tucson, AZ

Simplifying STEM seeks to de-center whiteness and disrupt the STEM status quo. Readers are provided practical examples and essential strategies that can be used in their respective environments to create inclusive STEM environments that give all scholars opportunities to be successful.

Kristopher J. Childs
CEO
K Childs Solutions
Winter Garden, FL

The authors of this text bring attention to the growing need of equity-centered STEM education that rightfully positions children and learners as the impetus for integrative STEM. As a former teacher and current educational researcher, I am deeply impressed by the suggestions and tasks that are offered in this text. All STEM teachers both new and veterans, need to read this book. It offers a critical examination of our practices and offers implementable suggestions to ensure that every student develops a sense of belonging in STEM.

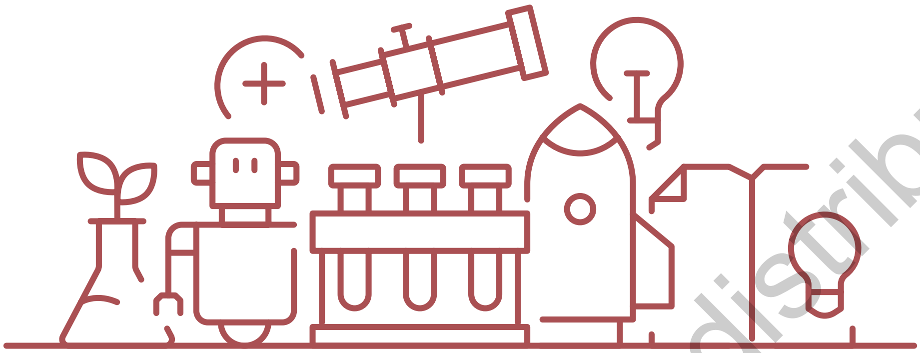
Daniel Edelen
Assistant Professor of Elementary Mathematics Education
Georgia State University
Decatur, GA

A must-read to ensure equity and engagement for all elementary STEM learners. This book provides step-by-step, easy to implement strategies to encourage critical thinking, collaboration, and communication.

Virginia R. Jones
Past President, International Technology and Engineering Educators Association
South Boston, VA

Simplifying STEM

Grades PreK–5



Simplifying STEM

Four Equitable Practices to Inspire Meaningful Learning

Christa Jackson • Thomas Roberts • Cathrine Maiorca
Kristin L. Cook • Sarah B. Bush • Margaret Mohr-Schroeder
with Julie A. Sicks-Panus and Tracy Young

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FOR INFORMATION:

Corwin
A SAGE Company
2455 Teller Road
Thousand Oaks, California 91320
(800) 233-9936
www.corwin.com

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SAGE Publications Asia-Pacific Pte. Ltd.
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CONTENTS

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LIST OF ACRONYMS USED THROUGHOUT THE BOOK

CAD: Computer-aided design

CCSSO: Council of Chief State School Officers

CER: Claims, evidence, reasoning

CNC: Computer numerical control

ISP: Integrated STEM Practices

ITEEA: International Technology and Engineering Educators Association

NCTM: National Council of Teachers of Mathematics

NGSS: Next Generation Science Standards

PGM: People of global majority

SEP: Science and Engineering Practices

SMP: Standards for Mathematical Practices

STEL:	Standards for Technological and Engineering Literacy
STEM:	Science, Technology, Engineering, and Mathematics
TEP:	Technology and Engineering Practices

PREFACE

Simplifying STEM: Four Equitable Practices to Inspire Meaningful Learning is a book born from our collective work in integrated STEM. Integrated STEM uses multiple STEM disciplines to collaboratively seek solutions to challenges faced in our communities, region, country, and even the world with the ultimate goal of increasing scholars' STEM literacy. To ensure integrated STEM actively positions each scholar as a valuable member of the STEM community, we center our work in the Equity-Oriented Conceptual Framework for STEM Literacy (Jackson et al., 2021), which provides opportunity and access to all scholars, especially those who have been historically excluded in STEM, to participate in high-quality integrated STEM learning experiences. High-quality STEM learning experiences provide scholars an opportunity to apply the content and practices when seeking solutions to challenges in our world that are meaningful and interesting to them. When scholars have access to these high-quality integrated STEM learning experiences, this helps to develop positive STEM identities and productive dispositions as they use reasoning and sense-making to apply ideas from STEM subjects. The high-quality STEM learning experiences provide authentic opportunities (Roberts & Chapman, 2017) for scholars to apply discipline-specific content in rigorous ways (Jackson et al., 2021). This often occurs through the engagement in the Integrated STEM Practices (ISPs) (Roberts et al., 2022). Because state content standards in science, technology, engineering, and mathematics are not generally aligned to integrated STEM initiatives (Bybee, 2018), a coherent set of integrated STEM practices is needed. It is through this need that we have collectively written this book. It is through our broader STEM commitment that we can transform STEM instruction to empower the next generation to be societal change agents.

While the predominant focus of this book is not on describing an array of high-quality STEM learning experiences, we draw upon high-quality STEM learning experiences to describe the ISPs evident within the STEM learning experience. As you read and engage with the book, you will experience what high-quality STEM experiences look like, sound like, and feel like in the classroom. You will take away several high-quality STEM learning experiences that you can adapt and use in your instruction as well as take your own STEM learning experiences and recenter them to focus on the ISPs. More important, though, you'll leave with a vision for implementing the ISPs in ways that are contextually responsive to your scholars, your school, and your community.

ACKNOWLEDGMENTS

We would like to thank the teachers who have allowed us to use their instructional practice to create the stories for Chapters 2–5 to introduce each Integrated STEM Practice.

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Virginia R. Jones
Past President
International Technology and Engineering Educators Association
South Boston, VA

Megan Burton
Past President
Association of Mathematics Teacher Educators
Professor of Elementary Mathematics and STEM Education
Auburn University
Auburn, AL

Daniel Edelen
Assistant Professor of Elementary Mathematics Education
Georgia State University
Atlanta, GA

Tamara Daughtery
Teacher
Zellwood Elementary
Zellwood, FL

Nancy Foote
Rock Star Teacher Emeritus
Higley Unified School District
Queen Creek, AZ

ABOUT THE AUTHORS

Dr. Christa Jackson, a former elementary and middle school mathematics and science teacher, is a Professor of Mathematics, Science, and STEM Education at Saint Louis University. She is the Founder and Director of the Institute for STEM Collaboration, Outreach, Research, and Education (iSCORE), where she focuses on transforming the STEM community one mind at a time through fostering scholars' STEM literacy development, STEM identities, and STEM sense of belonging. Dr. Jackson researches the development, use, and implementation of integrated STEM curriculum as well as understands the influence curricular materials and the related standards have on teachers' practices and the opportunities the curricular materials afford scholars to engage in STEM. Dr. Jackson served as a lead writer for *Catalyzing Change in Middle School Mathematics: Initiating Critical Conversations*. She recently completed her term as President of the School Science and Mathematics Association (SSMA) (2020–2022). Dr. Jackson is a professional developer and a mathematics and STEM consultant who has provided workshops to local, regional, national, and international communities.

Dr. Thomas Roberts, a former elementary school teacher, is an Associate Professor and co-program coordinator of the Inclusive PreK–5 Education Program at Bowling Green State University, where he teaches STEM education and mathematics education courses. He received his doctorate in Education Sciences specializing in STEM Education from the University of Kentucky. Dr. Roberts's research explores students' perceptions of STEM learning environments and ways to increase the effectiveness of teachers' instructional practices so that all students have the opportunity to participate in high-quality STEM learning. He is the Editor in Chief of *Technology and Engineering Education*, a peer-reviewed practitioner journal for integrated STEM teachers published by the International Technology and Engineering Educators Association (ITEEA).

Dr. Cathrine Maiorca, a former high school mathematics teacher, is an Assistant Professor of Mathematics Education at Oklahoma State University, where she teaches courses in mathematics education and STEM education. She received her doctorate in Curriculum and Instruction with an emphasis in Mathematics Education from the University of Nevada, Las Vegas. Dr. Maiorca's research interests include model-eliciting activities, effective STEM teaching and learning practices for every student, integrated STEM education in formal and informal settings, preservice teachers, and students' dispositions toward integrated STEM. Dr. Maiorca was an AMTE STaR fellow in 2018 and the 2020 School Science and Mathematics (SSMA) Early Career Scholar Award recipient. She is also an Associate Editor for *Technology and Engineering Education*, a peer-reviewed practitioner journal for integrated STEM teachers published by the International Technology and Engineering Educators Association (ITEEA).

Dr. Kristin L. Cook, a former high school science teacher, is a Professor of Science Education in the School of Education at Bellarmine University. She received her doctorate in Curriculum and Instruction specializing in Science Education and Environmental Sciences from Indiana University. Dr. Cook teaches courses in K–12 science methods and STEAM Education. In addition to teaching initial certification and advanced graduate classes, Dr. Cook serves as a professional developer and consultant for K–12 STEAM-focused school reform and project and problem-based learning development. Dr. Cook is actively involved in federal grants and research that focus on engaging students and teachers with the community of science through the exploration of socio-scientific inquiry and transdisciplinary STEAM instruction.

Dr. Sarah B. Bush, a former middle school mathematics teacher, is a Professor of K–12 STEM Education and the Lockheed Martin Eminent Scholar Chair at the University of Central Florida. At the University of Central Florida, she is the Director of the Lockheed Martin/UCF Mathematics and Science Academy and is the program coordinator of the Mathematics Education PhD track. She teaches primarily graduate courses in mathematics education. She is a prolific writer who has authored 12 books and more than 100 journal articles and book chapters. Dr. Bush recently completed a term (2019–2022) as a member of the National Council of Teachers of Mathematics Board of Directors. She served as the lead writer and task force chair for NCTM's *Catalyzing Change in Middle School Mathematics: Initiating Critical Conversations*. Dr. Bush was the recipient of the 2021 School Science and Mathematics Association (SSMA) Award for Excellence in Integrating Science and Mathematics and 2018 recipient of the Association of Mathematics Teacher Educators (AMTE) Early Career Award. Dr. Bush seamlessly integrates her practical experience as a middle school mathematics teacher in public schools with her innovative scholarship to serve as an instructional leader in the field of mathematics education and STE(A)M education.

Dr. Margaret Mohr-Schroeder, is a Professor of STEM Education and Senior Associate Dean in the College of Education at the University of Kentucky (UK). She received her doctorate in curriculum and instruction specializing in mathematics and science education from Texas A&M University. Since her arrival at UK in 2006, she has been involved in over $17 million in federal and state funding, helping to expand research and broaden participation in STEM Education. She is a coeditor of the first *Handbook of Research on STEM Education* and coeditor of *STEM 2.0*. Her research interests include the transdisciplinary nature of STEM education and how they can be applied to innovative preservice teacher education and K–12 school models. Further, she investigates ways to broaden participation in STEM, especially for underrepresented populations and the effects these mechanisms have on their STEM literacy. Through this work, she has gained perspective on how to create opportunity and access to STEM activities to populations who normally would not have the opportunity and has witnessed and studied the significant impacts these mechanisms have. She is President of School Science and Mathematics Association, the world's oldest STEM organization.

Teacher Contributors

Ms. Julie A. Sicks-Panus is a K–8 STEM Specialist at Plymouth Elementary School.

Ms. Tracy Young is a STEM Specialist/Engineering by Design K–5 at Benton Hall Academy Little Falls City School District.

STEM ACROSS THE DISCIPLINES AS MUTUALLY SUPPORTIVE

Congratulations! If you're reading this book, you are on your way to start, focus, or extend your STEM journey. In this book, you will learn how to simplify STEM by using four equitable practices to inspire meaningful learning. This will transform your teaching as well as the lives of your scholars for both today and their future!

You may have noticed that we refer to students as "scholars." We recognize that students have not yet achieved "scholar status" in the academic sense, but rather we refer to students as scholars to embody the empowering nature of adopting asset-based, equitable STEM teaching.

You likely know that the acronym STEM stands for **S**cience, **T**echnology, **E**ngineering, and **M**athematics. In the 1990s, the STEM acronym was first used by the National Science Foundation to describe projects, policies, programs, practices, and events related to one or a combination of the STEM disciplines (Bybee, 2010a, 2010b). Instead of focusing on individual STEM disciplines, we intentionally ground our practice within integrated STEM.

In this book, we define integrated STEM from an authentic interdisciplinary perspective. We view the STEM disciplines as being naturally intertwined and simultaneously needed to engage in STEM thinking to reach solutions for very real issues in our communities, nation, and the world. When applying content from multiple STEM disciplines, we don't mean that it must be all the STEM disciplines all the time but rather have the context to drive what STEM disciplines are needed to provide ideas or solutions.

Stop, Think, Reflect (1A)

1. What does integrated STEM look, feel, and sound like?
2. What does it look like for scholars to do integrated STEM?
3. What does it look like for educators to facilitate integrated STEM?
4. Why should integrated STEM be implemented in our instructional practice?

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Why Are Integrated STEM Learning Experiences Vital in PreK–12?

There is a critical need for PreK–12 high-quality and meaningful integrated STEM learning experiences. Every year, our society becomes more dependent on STEM content and process skills, thanks to a range of advances in technology, medical discoveries, big data, advanced mathematical modeling, computer science, artificial intelligence, advanced air mobility, and more—as well as a range of global challenges such as climate change, a global pandemic, growing cybersecurity threats, pollution, and so on. STEM occupations continue to grow at exponential rates, especially compared to non-STEM-based occupations. As of this writing in 2024, STEM occupations are projected to continue to increase by at least 11% over the next 10 years (Krutsch & Roderick, 2022). This growth is considered substantial because it's faster than the average growth rate for all occupations. It is important to remember that specific growth rates may vary for different STEM fields and regions. It's also important to recognize that STEM knowledge and skills are becoming increasingly valuable within any career and a necessity in our rapidly changing world, so providing scholars with a solid foundation in these areas can benefit them in numerous ways (Graf et al., 2018). But beyond the future jobs our scholars will fulfill in traditional STEM occupations, society now also relies heavily on scholars to take on jobs that are transdisciplinary (moves beyond the disciplines while at the same time respects disciplinary expertise to generate new knowledge) in nature and incorporate many facets of STEM such as innovators, designers, and creators. This necessity of transdisciplinary understanding of STEM holds for jobs that require a college degree as well as those that do not—for example, jobs in automobile manufacturing and repair have become increasingly technological as our automobiles are more dependent on computer technology and artificial intelligence.

Because of these future (and current) demands for STEM understanding and application, it is important for all scholars, regardless of whether they ultimately pursue a STEM career, to have access to and develop a strong sense of STEM literacy (Mohr-Schroeder et al., 2020). STEM literacy is essential to be an informed consumer and member of society. STEM literacy informs what we eat, what we buy, how we interact with our local community and the world, and how we seek solutions to real-world challenges we encounter. It is through the continual development of STEM literacy that scholars can collaborate, question, and engage in the utility of STEM concepts as they are challenged to provide solutions that cannot be readily solved using a single discipline (Bush & Cook, 2018). Approaching integrated STEM learning through rigor, discourse, and purpose can help scholars develop a deep understanding of discipline-specific content and how it can be applied in different contexts. This approach can also foster a sense of curiosity and a desire to learn more about STEM topics, which can lead to lifelong appreciation and interest in these areas.

Access to High-Quality Integrated STEM Education

Not everyone has had access to high-quality STEM education. Historically, STEM disciplines have been taught whole class with a value on right answers and little room for individuality or creativity. Integrated STEM curricula are still relatively new and, to implement well, can be cost prohibitive for schools and school districts to support. Thus, both through the way STEM disciplines are traditionally taught and the access teachers need to resources, including professional development, systemic barriers remain in place that maintain the STEM status quo (Love et al., 2017). As a result, the historical inequities many of our scholars continue to face in STEM are not new. Still further, much of the curriculum found in schools across the nation often does not consider the needs of their local communities (Bullock, 2017). It is time to completely change our approach to integrated STEM! It is essential that we provide all our scholars with meaningful opportunities and access to integrated STEM during PreK–12 to counter the racial, socioeconomic, regional, cultural, ability-centric, and gender inequities that exist within STEM. This commitment will empower all scholars to see that they are capable of doing STEM (Edelen & Bush, 2021). See Figure 1.1.

The National Research Council in 2011 established three goals for STEM education to address inequities, which include the following:

1. Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.
2. Expand the STEM-capable workforce while broadening the participation of women and minorities.

3. Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines (pp. 4–5).

As educators, instructional coaches, leaders, and policymakers, we must ask ourselves what we can do to disrupt the STEM status quo and ensure we are providing high-quality integrated STEM learning experiences to all of our scholars. Through the years, data and research have pointed to the lack of individuals from historically excluded populations in the STEM fields (Bybee, 2013). Standardized test scores remain a focus, yet policy expectations for what and how to teach maintain traditional pedagogy. In the United States, since the 1970s, there has been great attention paid to providing access to STEM disciplines and increasing a sense of belonging in STEM. This was an important step forward, of course, but continuing to use comparative terms such as *underrepresented* and *historically excluded* perpetuates and promotes the notion that there is an accepted norm against which to measure. In the United States, this norm has usually

Figure 1.1

A Scholar Engages in an Integrated STEM Learning Experience

Source: Julie Sicks-Panus.

been (and often continues to be) whiteness-centered, male, cisgendered, ableist, heteronormative, and Eurocentric. In fact, those who are often described by policymakers and others in the United States as "underrepresented" or "historically excluded" are actually part of the global majority. The term *global majority* is a term that has emerged in recent years to describe the world's population, which is predominantly nonwhite, non-Western, and non-European. Likewise, *people of the global majority* (PGM) is a term that encourages those of African, Arab, Asian, and Latin American descent to recognize that together they make up close to 80% of people in the world (Maharaj & Campbell-Stephens, 2021). *Global majority* in this sense, then, includes, but is not limited to, people of color, women, members of the LGBTQIA+ community, people with disabilities, people whose incomes are below the federal poverty threshold, indigenous people, and other historically marginalized groups. The term *global majority* is meant to highlight the importance of acknowledging and respecting the experiences and perspectives of people from all corners of the globe and to challenge the idea that Western culture and values are universal. We encourage a discussion of the term *global majority* and how conversations in your setting can be recentered with additional perspectives.

Stop, Think, Reflect (1B)

1. What will you need to consider to ensure all your scholars have access to high-quality STEM learning experiences? (Reflect on instructional supports, access to materials, language supports, etc.)
2. What classroom norms will you establish to ensure all scholars feel safe?
3. What does it look like to cultivate a sense of belonging in STEM in your classroom?
4. What positive outcomes can occur when we work with people from different backgrounds?
5. How can we leverage scholars' varied backgrounds in a STEM learning environment?

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Our aim in this conversation about the STEM status quo is to raise awareness and, more important, address direct actions we can take as educators to create a more inclusive environment. Becoming STEM system disruptors requires recognizing and challenging the norms and practices that have been historically exclusive and promoting inclusive and equitable approaches that value, cultivate, and include diverse perspectives and experiences. As educators, we need to connect to our scholars' lived experiences and bring them into the STEM conversation. When we do this, our scholars feel safe, valued, and empowered to do STEM.

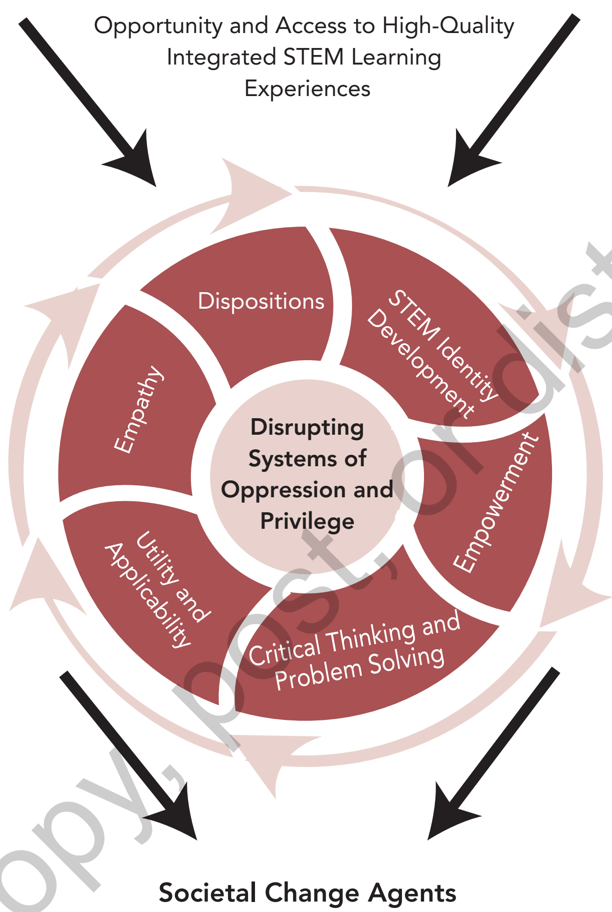
Becoming STEM System Disruptors: An Equity-Oriented, Culturally Responsive Approach

To disrupt the STEM status quo, every scholar must have access to high-quality integrated STEM learning opportunities, but access alone is not enough. It is also necessary to focus intentionally on equity to counteract the deeply rooted traditions in STEM education, which have privileged a few and marginalized many. When we refer to privilege within the context of STEM communities, we are referring to having certain advantages or benefits that provide persons with a head start or easier access to opportunities within the STEM fields. This can range from having a financially stable background, to being a part of a demographic group that is traditionally overrepresented in STEM fields, to having access to influential networks or connections. When we refer to marginalized within the context of STEM communities, we are referring to individuals or groups that typically face barriers, discrimination, and/or limited access to opportunities within the STEM fields (Aish et al., 2018). This can be based on a number of factors, including, but not limited to, geography, race, gender, ethnicity, ableness, financial stability, and other forms of social identity. Further, persons from marginalized communities often encounter more obstacles than those who are not, especially around representation, access to resources, inclusion, educational opportunities, and equitable treatment. Recognizing and talking about privilege and marginalization within the STEM community is important because it can help to directly disrupt the STEM status quo, address systemic inequities, and create pathways to more inclusive environments. By addressing and having conversations, we recognize that not everyone starts with the same advantages and thus we can begin to disrupt the systems that have continued to oppress marginalized populations. Together, and through the work in this book, we can become STEM system disruptors by leveling the playing field and ensuring equitable opportunities for individuals from all backgrounds to thrive in STEM and their communities.

Our work is guided by the Equity-Oriented STEM Literacy Framework (Jackson et al., 2021; Figure 1.2), which goes "beyond platitudes of 'diversity, equity, and inclusion' and the traditional focus on access by illuminating the complexities of disrupting the status quo and rightfully transforming integrated STEM education in ways that provide equitable opportunities and access to all learners" (p. 5). See Figure 1.2.

Figure 1.2

Equity-Oriented STEM Literacy Framework



Having access to high-quality STEM learning experiences fosters the **development of STEM identity** whereby all scholars begin to view themselves as STEM learners, doers, and thinkers as they engage in **critical thinking to seek solutions.** We have all been asked, "When am I ever going to use this?" More times than not, we have responded, "You need to know this because it is important for you to know," or "To be successful in the next subject," or "Just because." By engaging scholars in high-quality STEM learning experiences, they see the **utility and applicability** of the STEM disciplines and the concepts and material they are learning. Thus, scholars are positioned to understand the *why* of their learning, why this is important, why it is relevant to their lives, and why knowing this information is empowering. Within high-quality integrated STEM learning experiences—think about examples such as designing a prosthetic leg for another scholar in need or designing a structure to combat a food desert in a local community—scholars develop **empathy**. Empathy embodies equity as it builds scholars' interest, ensures relevance and meaning to STEM, and empowers scholars as someone who can be part of the solution. Approaching STEM from an empathetic lens also provides more equitable solutions to our communities and the world. Historically, empathy has typically not been strongly associated with STEM or STEM learning experiences. We intentionally incorporate empathy as one of the components because empathy fosters humanization and care within STEM. It makes the STEM learning experience more meaningful to scholars and provides the passion and purpose (Bush & Cook, 2019; Bush et al., 2022).). Empathy illuminates the utility and applicability of the STEM learning experience. Through high-quality integrated STEM learning experiences, scholars develop productive STEM **dispositions** whereby they become interested in and have a positive attitude toward learning STEM. In this way, all scholars are **empowered** to ask questions, solve challenges, and be societal change agents in the world in which they live.

As educators, we have an obligation to ensure every scholar, and specifically every person from the global majority, has a sense of belonging in STEM (Jackson et al., 2021). However, white, Eurocentric norms often maintain the STEM status quo, in many ways, including, but not limited to

- An emphasis on individual achievement and competition, rather than collaboration and community building
- Hierarchical, authoritarian, and similar power structures, where those in positions of power are less likely to listen to and incorporate perspectives of those in positions of less power
- Focus on objectivity and neutrality, which can ignore the influence of cultural biases and assumptions in research and decision-making

To become STEM system disruptors, the education community has used the approach known as culturally responsive teaching. Culturally responsive teaching uses "the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them" (Gay, 2018, p. 36). This approach acknowledges that scholars from different cultural backgrounds may have unique ways of learning, communicating, and understanding the world, and it seeks to create a learning environment that values, elevates, and sees these differences as strengths. Adopting this approach provides scholars with opportunities to learn more about their own cultures as well as the cultures of their classmates. We contend this empowers scholars to become global thinkers who are passionate and knowledgeable and therefore able to solve challenges to make the world better, help their communities thrive, create a better life for themselves and others, and compassionately analyze situations from multiple perspectives. This also cultivates a way of being that is empathy-centric and altruistic. Culturally responsive teaching challenges the standardization driven by the dominant cultural norms. Table 1.1 provides common characteristics of the STEM status quo, why it's harmful in the STEM contexts, and how it is addressed in this book. Throughout this book, you will see explicit and intentional focus on culturally responsive teaching practices that move to disrupt the STEM status quo.

Table 1.1

Be on the Lookout: STEM Status Quo Characteristics

STEM STATUS QUO CHARACTERISTICS	WHY IT'S HARMFUL IN STEM	HOW WE ADDRESSED IT IN THIS BOOK
Perfectionism	In STEM, we tend to focus on right or wrong and the final solution rather than the progress, and the mistakes that move us toward progress. When we focus on being perfect, or getting it right the first time, we lose out on the learning opportunities. Further, it causes additional anxieties that often build upon each other through subsequent learning experiences. While we can certainly strive for excellence, excellence can be a messy winding road, which is not equivalent to perfection.	We address process, multiple iterations, embracing mistakes, and productive struggle. The chapter-opening stories provide examples of building a culture within the learning experience that embraces messiness, pivots, and an openness to share and learn new things by all participants, including the educator.

(Continued)

(Continued)

STEM STATUS QUO CHARACTERISTICS	WHY IT'S HARMFUL IN STEM	HOW WE ADDRESSED IT IN THIS BOOK
Objectivity	In STEM, there is often the belief that you have to be objective or stay "neutral," especially as it relates to emotions. It can often show up when you are asked to make a "logical" decision, which often means linear decision-making without regard or thoughts of others.	We emphasize and encourage empathy in solution seeking. Empathy is often how our scholars connect with each other—within and outside their lived experiences. Listening, getting feedback, and researching the impact of an idea or solution on others helps to take in all perspectives and voices.
One Right Way	In STEM, most often in mathematics, there is often the belief or underlying notion that there is only one right way or a preferred way to complete something. When someone doesn't do it the same way as others, the others assume the other way is the wrong way.	We share examples and stories that embrace scholars' sharing multiple solutions and ideas. The rubrics make explicit that the expectation is multiple iterations of trials. We are more focused on the process rather than the final solution.
Paternalism	In STEM, this shows up as someone who holds a position of power and controls the decision-making and defines rules, criteria, policy, and so on. This shows up in education, especially when scholars know they do not have the power and are marginalized from decision-making processes.	It is easy to think that in education, a teacher is always going to be paternalistic. However, we point out direct ways to give choice to scholars, elevate their voices, and provide open spaces for them to give input in deciding success criteria.
Qualified	In STEM, when we talk of someone being "qualified," the criteria are not always consistent or clear, and the notions can be based on antiquated definitions of success (e.g., the one speaking the loudest must be confident and thus correct; the one who is the first to take credit must be the one who knows the most). We also might incorrectly think that only adults with specialized degrees and skills can contribute solutions to authentic STEM obstacles.	We present inclusionary language when sharing stories and positioning scholars within the suggested learning experience. Within the learning experiences, the scholars are the experts. They are the ones carrying out the practices, producing the various solutions or ideas, and communicating them to the various stakeholders. The only qualification a scholar needs in your classroom or setting is to be present, in whatever way that looks for them.

STEM STATUS QUO CHARACTERISTICS	WHY IT'S HARMFUL IN STEM	HOW WE ADDRESSED IT IN THIS BOOK
Either/Or and the Binary	In STEM, this positions ideas, solutions, options, issues, and so on as yes or no; either/or; right or wrong; for or against; and so forth. In STEM especially, this type of thinking tends to oversimplify, in a negative way, the complex tasks or experiences our scholars often face in their life.	We encourage the use of multiple options (beyond two) and an openness to what these options or scenarios look like.
Progress Is Bigger/ More and Quantity Over Quality	In life and in STEM, we live in a more is better, bigger is better society. However, sometimes solutions in STEM involve taking away factors, simplifying processes, and taking less actions rather than more. In other words, subtracting can also be a solution, not just adding. Sometimes more people, materials, or money are associated with progress, but this isn't always the case.	We include a focused emphasis on progress being more about the quality of the product, idea, or trial. Further, there is less emphasis on doing something repeatedly over and over again until you achieve "memorization" or "retainment." Rather, we focus on meaningful interactions with the content that will help to forge a connection between the scholar, the content, and the experience.
Defensiveness	In STEM, this usually shows up in the response to feedback to an idea, solution, scenario, and so on. Instead of thinking and taking in the feedback, we are prone to get defensive and start forming our defensive answers in our head, thus taking away the ability to listen and reflect. Further, when defensiveness shows up, it will often shut down those who are participating as it makes it difficult to raise new ideas, and thus those who are met with defensiveness may be afraid to speak their ideas or truth.	We include various ways scholars' voices are and can be elevated, especially in giving feedback. We also include strategies for how feedback can be received in a more useful way.
Power Hoarding	In STEM, this is most often seen in collaborative settings, or settings where multiple people engage with one another. It is harmful in that someone tries to exert their power or control into or over a situation. Many times, they see themselves as doing what's "best" for the group and others.	We share stories about collaborative experiences where scholars are working together and sharing ideas. In the examples and diving deeper, there is a continued focus on collaboration. In real-world contexts, collaboration is a key component within the community or workplace. Creating shared, positive, collaborative experiences with scholars can help define and provide examples to scholars of how groups can function together toward their main goal or focus.

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STEM STATUS QUO CHARACTERISTICS	WHY IT'S HARMFUL IN STEM	HOW WE ADDRESSED IT IN THIS BOOK
Urgency	In STEM, this shows up often in timelines and deadlines. How fast can we get something finished, even if it's poor quality. Further, timed tests or events create a sense of urgency that is unreasonable and unrealistic in real-world contexts.	We emphasize the practices as processes that don't necessarily have an end point. Or if there is an end point, it can look different for different groups of scholars. When addressing urgency, it's important to underscore setting realistic expectations and including scholars in the conversation about realistic expectations. This not only helps to elevate their voices and disrupt the STEM status quo characteristic—paternalism—but also helps them to have ownership in creating a realistic timeline or expectations to complete within a given time period.

Source: Adapted in part from the ideas in Okun (2021); Hawthorne (2022). See these for more examples and antidotes.

By explicitly addressing and challenging the STEM status quo, especially as educators, we are challenging our own power dynamics, listening to and valuing diverse perspectives, educating ourselves, and, most important, holding ourselves accountable. Regardless of our own racial identity, gender, social class, abilities, and other personal identifying factors, it is important to recognize and understand our own privilege so that we can all be STEM system disruptors and work toward a more equitable and inclusive society.

Integrated STEM Practices Unpacked

You are likely familiar with the Standards for Mathematical Practices (SMPs), Science and Engineering Practices (SEPs), and the Technology and Engineering Practices (TEPs). Table 1.2 identifies each practice for mathematics, science, and technology and engineering and the things to look for regarding scholar engagement and outcomes within each practice.

Table 1.2

Science and Engineering, Technology and Engineering, and Mathematics Practices

PRACTICE STANDARD	STANDARD	WHEN ENGAGING IN THE STANDARD, SCHOLARS SHOULD:
Science and Engineering Practices (Next Generation Science Standards [NGSS Lead States], 2013)	1. Ask questions (science) and define problems (engineering)	Start the first steps of the scientific inquiry process and engineering design process by asking questions and defining problems.
	2. Develop and use models	Construct models to represent explanations and ideas.
	3. Plan and carry out investigations	Investigate and observe the world using a systematic process to determine questions that need to be expired or problems that need to be solved.
	4. Analyze and interpret data	Use data to look for patterns and structures that can be used to make design decisions or inform investigations.
	5. Use mathematics and computational thinking	Use mathematics to represent data and find solutions to problems.
	6. Construct explanations and design solutions	Find the outcomes of science (explanations) and engineering (solutions).
	7. Engage in arguments from evidence	Engage in the process used to find explanations and solutions to problems.
	8. Obtain, evaluate, and communicate information	Engage in meaningful discourse and dialogue.
Technology and Engineering Practices (International Technology and Engineering Educators Association [ITEEA], 2020)	1. Systems thinking	Recognize how technologies are interconnected.
	2. Creativity	Use innovative thinking and skills to solve problems.
	3. Making and doing	Design and build products and systems.
	4. Critical thinking	Engage in reasoning to make informed decisions.
	5. Optimism	Improve the world around you and view that in every challenge, there are opportunities.
	6. Collaboration	Work as part of a team to find solutions to problems.
	7. Communication	A tool to understand the needs of others and a process used to engage in problem solving.
	8. Attention to ethics	Focus on the impact decisions make on the world around them.

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PRACTICE STANDARD	STANDARD	WHEN ENGAGING IN THE STANDARD, SCHOLARS SHOULD:
Standard for Mathematical Practice (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010)	1. Make sense of problems and persevere in solving them	Make sense of problems and engage in sustained problem-solving experiences.
	2. Reason abstractly and quantitatively	Contextualize and decontextualize problems.
	3. Construct viable arguments and critique the reasonings of others	Engage in meaningful mathematical discourse and dialogue.
	4. Model with mathematics	Use mathematics to solve problems in everyday life, society, and the workplace.
	5. Use appropriate tools strategically	Know and use appropriate mathematical tools.
	6. Attend to precision	Communicate mathematical understanding clearly using different representations.
	7. Look for and make use of structure	Find patterns that can be applied to new situations.
	8. Look for and express regularity in repeated reasoning	Recognize and make sense of patterns.

Each of these existing practice standards focuses on problem solving. In science, scholars solve problems as they engage in the scientific inquiry process. They formulate hypotheses, design and conduct experiments, and interpret the results. The SEPs are designed to increase scholars' curiosity, interest, and motivation as they develop proficiency in understanding how to investigate problems and explain phenomena occurring in the world (National Research Council, 2012). In the mathematics SMPs, scholars make conjectures, justify conclusions, represent solutions, and evaluate the reasonableness of their results when solving problems. In the technology and engineering practices, scholars design and create solutions to improve existing technology and better the world around them as they engage in the engineering design process. While all three sets of practices (i.e., SMPs, SEPs, and TEPs) engage scholars in problem solving in their respective disciplines, solution seeking of challenges (small and large) in our community and society necessitates a more holistic and flexible approach (Roberts et al., 2022).

The focus of this book is on solution seeking through integrating the practices of the STEM disciplines in ways that create impactful STEM learning experiences that position all scholars as STEM thinkers and doers. We identify these practices as the Integrated STEM Practices (ISPs). We synthesized the Standards for Mathematical Practices, Science and Engineering Practices, and the Technology and Engineering Practices to develop the ISPs. The ISPs are grounded in the Equity-Oriented STEM Literacy Framework (see Figure 1.2) and culturally responsive STEM pedagogy. The four ISPs are

1. use critical and creative thinking to seek solutions,
2. collaborate and use appropriate tools to engage in iterative design,
3. communicate solutions based on evidence and data, and
4. recognize and use structures in real-world systems (see Figure 1.3).

ISP 1: USE CRITICAL AND CREATIVE THINKING TO SEEK SOLUTIONS

Scholars use creativity and critical thinking to explore and solve nonroutine, real-world challenges (Henriksen, 2014). Scholars persevere and actively use models as they work toward understanding and seeking a solution to a particular challenge. As scholars seek solutions, they work to understand the challenge and have the fortitude to continue when they encounter difficulties or obstacles along their journey toward finding a solution (SMP 1, SEP 1, TEP 5). They persist. They engage in scientific inquiry by asking questions to critically reason and make sense of the challenge (SEP 1, TEP 4). As scholars creatively work (TEP 2) toward their solution(s), they use models (SMP 4), and mathematics and computational thinking (SEP 5). As the scholars critically and creatively think, they also use reasoning to make informed decisions toward their solution (TEP 4). By engaging in these practices, scholars ultimately view the challenges they encounter as opportunities to improve their world (TEP 5).

ISP 2: COLLABORATE AND USE APPROPRIATE TOOLS TO ENGAGE IN ITERATIVE DESIGN

Scholars collaborate to use appropriate tools to plan, test, and refine their solutions to nonroutine, real-world problems. Collaboration (TEP 6) is essential when solving challenges. We learn from one another. As scholars plan and carry out investigations (SEP 3) using a systematic process, they strategically draw upon appropriate tools to use (SMP 5). They are fully invested in the process

Figure 1.3

How the ISPs Are Situated Within SMPs, SEPs, and TEPs

Technology & Engineering Practices (ITEEA, 2020)	Science & Engineering Practices (NGSS, 2013)	Standards for Mathematical Practice (CCSSO, 2010)	Integrated STEM Practices (Roberts et al., 2022)
2. Creativity 4. Critical Thinking 5. Optimism	1. Asking questions and defining problems 5. Using mathematics and computational thinking.	1. Make sense of problems and persevere in solving them 4. Model with mathematics	→ Use critical and creative thinking to seek solutions
3. Making & Doing 6. Collaboration	3. Planning and carrying out investigations	2. Reason abstractly and quantitatively 4. Model with mathematics 5. Use appropriate tools strategically 6. Attend to precision	→ Collaborate and use appropriate tools to engage in iterative design
7. Communication	4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in arguments from evidence 8. Obtaining, evaluating, and communicating	3. Construct viable arguments and critique the reasoning of others 4. Model with mathematics	→ Communicate solutions based on evidence and data
1. Systems Thinking 8. Attention to Ethics	2. Developing and using models	4. Model with mathematics 7. Look for and make use of structure 8. Look for and express regularity in repeated reasoning	→ Recognize and use structures in real-world systems

of making and doing (TEP 3) and are intentional on refining their model (SMP 4). They showcase their knowledge through reasoning abstractly and quantitatively. When they do this, they attend to precision (SMP 6) and continue their collaboration (TEP 6) with one another.

ISP 3: COMMUNICATE SOLUTIONS BASED ON EVIDENCE AND DATA

Scholars communicate to gather information needed to solve a challenge, share ideas and strategies to create a plan, and share solutions using effective presentations. Communication is an essential skill for scholars. Scholars actively listen to others (TEP 7) and look for patterns and structures that can be used to make design decisions or inform investigations (SMP 4, SEP 4, SEP 6). They articulate, justify, and critique their and others' reasoning (SMP 3, SEP 4, SEP 8) using evidence (SEP 7).

ISP 4: RECOGNIZE AND USE STRUCTURES IN REAL-WORLD SYSTEMS

Scholars look for structures within and across content areas to apply known ideas to new real-world situations and evaluate the reasonableness of their proposed solutions within the context of the system. Scholars apply structures within and across disciplines to solve challenges within today's society (SMP 8). To do so, scholars develop models to represent systems and test their solutions for success and failures (SEP 2). The world is interconnected. Scholars work toward finding solutions to challenges focused on the entire system (TEP 1). They look for patterns (SMP 7) and use these patterns to help determine the reasonableness of their solutions (SMP 4). Scholars care about the world and consider the impact their solutions have on the world (TEP 8).

The ISPs are not designed to replace the important disciplinary learning that occurs in mathematics and science classrooms. Instead, the ISPs focus on practices scholars exhibit that are important to STEM as an integrated discipline where they apply disciplinary content knowledge to seek solutions to authentic challenges. These practices will be evident in performance tasks where mathematics and science teachers collaborate, in technology and engineering projects, in STEM classrooms, and in informal STEM learning settings. In all of these settings, the specific content addressed can change, but a constant is scholars' use of the ISPs.

●●● SO YOU'VE BEEN TOLD . . .

REALITY CHECK!

Throughout the book you will find informative boxes that contain "So You've Been Told" statements and "Reality Check" responses from our team. These boxes will combat misconceptions and help you reframe your approaches to integrated STEM teaching. You'll usually find them sprinkled throughout each chapter throughout the rest of the book, but here we've presented several for you to consider at this point in our discussion.

●●● SO YOU'VE BEEN TOLD . . .

STEM tasks take too much time and include too many components.

REALITY CHECK!

Meaningful STEM tasks can be small yet mighty! The context can stem (pun intended!) from a single curiosity from a scholar, something they have noticed outside, at school, in their community, or a wondering from a current event. Sure, you can implement large-scale, long-term STEM tasks, but it doesn't have to be of that magnitude. STEM tasks are only as big as you make them. We suggest first doing what you can with the time you have and let the excitement spread throughout your classroom and school. Reaching out to your colleagues could be beneficial. It is very possible that others in your building (or network outside of your building) have some great ideas that could complement your task or spark your imagination for a new task. They may even want to help and work on it with you! These conversations will build buy-in as you work to advocate for more support and time for integrated STEM! ●

●●● SO YOU'VE BEEN TOLD . . .

There is no time—we are already rushed to teach mathematics and science; there is no time for integrated STEM.

REALITY CHECK!

Integrated STEM IS Mathematics and IS Science. STEM is a pathway to working smarter, not harder. STEM learning experiences grounded in the ISPs help you to engage your scholars in the STEM disciplines simultaneously. In other words, it's not adding to your plate; it's instead a more meaningful approach that saves time in the long run. A teacher who implemented an integrated STEM unit in her second-grade classroom exclaimed,

"We definitely don't talk a lot about angles going into like what are the specific angles, 90 [degrees] and 180 [degrees]. And they know that there are angles to shapes, but we don't talk about what they are. They actually learned a lot about angles and enjoyed that, with the launcher and putting all that together. So I thought a lot of our math ideas were ones that the kids kind of picked up on it on their own. It wasn't something that we had taught yet. So that was cool to see. Because we hadn't done shapes, we haven't done measurement. And so it was like a quick, 'Okay, when we go to measure our shadows, this is what you're going to do.' And then they had to automatically go and do it, but they were doing something real world. So they had actually picked up on it very quickly as opposed to just measuring something on their paper. So I thought that was cool that they were learning some of those skills, just by doing it and trying it, but not really with my telling them, this is exactly how you do it. They went and tried it and learned it."

The key is intentionally drawing out scholars' learning through the STEM tasks you implement, the probing questions you ask, and the authentic assessments you plan. We are working smarter and not harder. You'll learn more about how to do this throughout the book. ●

●●● SO YOU'VE BEEN TOLD . . .

Not all students can do STEM.

REALITY CHECK!

All scholars should be empowered and given the agency to be STEM thinkers, tinkers, and doers. As educators, we must provide opportunity and access to high-quality integrated STEM learning experiences. To ensure integrated STEM actively positions every scholar as a valuable member of the STEM community, we draw upon the *Equity-Oriented STEM Literacy Framework* (Jackson et al., 2021). The model disrupts the STEM status quo by providing opportunity and access for scholars to participate in high-quality learning experiences. For the scholars who typically think they cannot do STEM, they see the rationale for their learning experience through the utility and applicability of STEM through their engagement of the ISPs. We know you will be astonished with what your scholars can do as they engage in the ISPs. ●

Jumpstarting Your Work: Integrated STEM Educator Check-in Tool

We'd like to invite you to now jumpstart your journey! We provide an Integrated STEM Educator Check-in Tool (available in the online implementation toolkit) as a "pulse check" to use throughout your integrated STEM journey. This tool holistically embodies our Equity-Oriented STEM Literacy Framework and focuses on your current thoughts and open-ended prompts that can be used in whole or part to obtain feedback, gain deeper insights, or plan. This tool is not a formal survey instrument and is not intended to be used as an evaluation tool; rather, it is meant to be used as a tool to gauge starting points and growth. Figure 1.4 is a snapshot of the Integrated STEM Educator Check-in Tool.

Figure 1.4

Snapshot of the Integrated STEM Educator Check-in Tool

BELIEFS		
1	I believe integrated STEM learning experiences have great value.	1 2 3 4 5
2	I believe scholars can play a key role in leading their own learning regarding integrated STEM while the teacher acts as a facilitator.	1 2 3 4 5
3	I believe integrated STEM learning experiences are a place where I can draw and leverage the strengths of each scholar.	1 2 3 4 5
4	I believe integrated STEM learning experiences increase scholars' interest in STEM careers.	1 2 3 4 5
5	I believe integrated STEM learning is critical to the development of the next generation of thinkers, advocates, and creators.	1 2 3 4 5

online resources Available for download at **qrs.ly/s9f1lux**

We provide access to the full tool in the online implementation toolkit. We envision the Integrated STEM Educator Check-in Tool could be used

- as a self-check of your own personal growth as you read this book;
- if you are embarking on this journey as part of school or district initiative, every educator involved (including administration and paraprofessionals) could use the check-in at the beginning of the journey and every few months to gauge individual and collective shifts in thinking and implementation;
- as a pre, midpoint, and post check-in to gauge shifts in thinking and implementation from a long-term sustained professional development initiative;
- as a pre, midpoint, and post check-in for an integrated STEM education course for preservice or in-service teachers and coaches; and
- in many other ways.

In each chapter, we provide a collection of discussion questions that can be used to reflect and ponder on the ideas discussed within the chapter. The questions could also be used as book study prompts to spark rich discussion with your team!

Questions to Ponder/Book Study Prompts

What are some real challenges in your community that integrated STEM learning experiences could equip scholars to help seek solutions?

What aspect of the Equity-Oriented STEM Literacy Framework are you the most familiar/comfortable with? Least familiar/comfortable? What information would be helpful and how might you seek it?

What is one first step we can take to increase *all* scholars' access to integrated STEM learning experiences?

What did you read in Chapter 1 that pushed your thinking or provided you a new perspective? What surprised you the most?

What dominant culture characteristic might we work on addressing first in our setting? What steps/strategies can we take?

online resources Available for download at **qrs.ly/s9f1lux**

Organization of This Book

Although multiple high-quality STEM learning experiences are featured throughout the book, the purpose is not to focus on the specific STEM content. Instead, we provide very tangible examples of the ISPs in action! Content will shine through indirectly as we share stories of each ISP. Similar to the Standards for Mathematical Practices (SMPs), Science and Engineering Practices (SEPs), and the Technology and Engineering Practices (TEPs), the ISPs are relevant for scholars in grades PreK–12. We offer both an elementary (PreK–5) volume and a secondary (6–12) volume of the book to exemplify what the ISPs look like, sound like, and feel like at the elementary and secondary levels. To recap, in this chapter, we shared our core beliefs about integrated STEM learning, introduced you to the Equity-Oriented STEM Literacy Framework, and provided an overview of the ISPs. Now you might be wondering, what do high-quality STEM learning experiences look like, sound like, and feel like in the classroom? Throughout this book, we draw upon and highlight high-quality STEM learning experiences to describe the ISPs and their importance within the STEM learning experience. We encourage you to visit our online implementation toolkit as you journey through this book. It contains helpful resources you can adapt, adopt, and use along the way!

Planning, implementation, and assessment of impactful STEM learning experiences leveraging the ISPs warrants a nontraditional approach to "lesson planning." In Chapters 2 to 5, we take a deep dive into each of the four ISPs. In each of these chapters, we provide real-life examples of STEM learning experiences focused on a specific ISP. We recognize that scholars' lived experiences vary, and so what is real life to one may not be real life to another. We encourage you to consider how to connect the ideas and contexts to all scholars. This could be through videos, pictures, researching a topic, and so on. In this book, you will be able to visualize the ISP in action. Our goal is to help you translate this visualization to your scholars and their learning experiences. Importantly, these chapters will leave you with a strong understanding of the innovative, deep, and impactful contributions of scholars when their strengths are leveraged (see Kobett & Karp, 2020) and they are positioned as belonging in STEM. Throughout the chapters, we will highlight the connections between the ISP and the Equity-Oriented STEM Literacy Framework. We include in each of these chapters helpful resources to guide your work, both in the book and in the online implementation toolkit. We unpack common misconceptions about STEM instruction within each ISP. We also intentionally focus on assessing scholars' STEM learning in authentic ways. We provide additional examples and resources that showcase how scholars might develop their abilities within each ISP. After reading Chapters 2 to 5, you will have a strong understanding of each of the four ISPs; have a firm grasp of the key components of planning, implementing, and assessing meaningful high-quality STEM learning experiences; and begin to see how the ISPs are actually quite intertwined.

Chapter 6 focuses on reimagining STEM tasks. We consider the characteristics of high-quality STEM tasks and how they embody the ISPs. We provide examples and resources that showcase how scholars might develop their abilities across multiple ISPs simultaneously. We include a roadmap and conversation starters that will walk you through the planning, implementation, and assessment of an ISP learning experience. Importantly, we ground this work in the components of the Equity-Oriented STEM Literacy Framework. In Chapter 6, you'll have an opportunity to complete the STEM planning tool, try out some of the resources, and plan for how you will assess learning. In Chapter 7, we explore the heart and spirit of the ISPs and Equity-Oriented STEM Literacy Framework. We discuss shifting away from a checklist approach to an ISP mindset and why it's up to us as educators to embark on this work. Finally, we leave you with a sense of collective action! Share your thoughts to our online sharing space using the hashtag #STEMISPs.