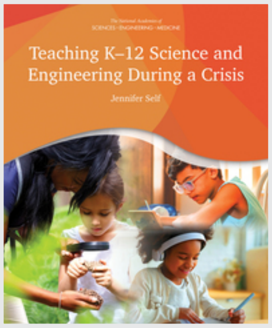


Teaching K-12 Science and Engineering During a Crisis (2020)

DETAILS

134 pages | 8.25 x 10 | PAPERBACK
ISBN 978-0-309-68194-0 | DOI 10.17226/25909

CONTRIBUTORS

Jennifer Self; Board on Science Education; Division of Behavioral and Social Sciences and Education; National Academies of Sciences, Engineering, and Medicine

SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2020. *Teaching K-12 Science and Engineering During a Crisis*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25909.

Teaching K–12 Science and Engineering During a Crisis

Jennifer Self

Board on Science Education
Division of Behavioral and Social Sciences and Education

Based on the following reports of the National Academies
of Sciences, Medicine, and Engineering:
A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas
Developing Assessments for the Next Generation Science Standards
Guide to Implementing the Next Generation Science Standards
Science and Engineering for Grades 6–12: Investigation and Design at the Center
English Learners in STEM Subjects

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS **500 Fifth Street, NW** **Washington, DC 20001**

This activity was supported by Grant No. G-20-57849 from the Carnegie Corporation of New York and the President's Committee. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

International Standard Book Number-13: 978-0-309-68194-0
International Standard Book Number-10: 0-309-68194-4
Digital Object Identifier: https:// doi.org/10.17226/25909
Cataloging-in-Publication OR Library of Congress Control Number: 2020949027

Additional copies of this publication are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2020. *Teaching K–12 Science and Engineering During a Crisis*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25909.

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.nationalacademies.org**.

The National Academies of

SCIENCES • ENGINEERING • MEDICINE

Consensus Study Reports published by the National Academies of Sciences, Engineering, and Medicine document the evidence-based consensus on the study's statement of task by an authoring committee of experts. Reports typically include findings, conclusions, and recommendations based on information gathered by the committee and the committee's deliberations. Each report has been subjected to a rigorous and independent peer-review process and it represents the position of the National Academies on the statement of task.

Proceedings published by the National Academies of Sciences, Engineering, and Medicine chronicle the presentations and discussions at a workshop, symposium, or other event convened by the National Academies. The statements and opinions contained in proceedings are those of the participants and are not endorsed by other participants, the planning committee, or the National Academies.

For information about other products and activities of the National Academies, please visit www.nationalacademies.org/about/whatwedo.

BOARD ON SCIENCE EDUCATION

Contents

List of Examples

Preface

In spring 2020, schools throughout the country were faced with an unprecedented challenge: continue to teach the nation's K–12 students without having them physically present in the classroom. Never before have such drastic and widespread changes to instruction been required. While remote instruction had long been on the rise, it was the exception rather than the rule. The COVID-19 pandemic changed all that.

States and districts rose to the challenge. They worked overtime to reimagine systems and processes, and teachers were asked to rapidly shift their approaches to instruction and respond creatively to the demands of remote teaching.

As school systems now prepare for the 2020–2021 school year, it is important that the measures implemented on an emergency basis in the spring of 2020 be carefully adapted to reflect acceptable, on-going procedures. As we make this transition, it is particularly important that science instruction receive its due emphasis. Never before has it been clearer that a scientifically literate populace is essential—a populace that can understand data and be able to critically weigh evidence.

This book aims to describe what high-quality science and engineering education can look like in a time of great uncertainty and to support science and engineering practitioners as they work toward their goals. It is designed to leverage the portfolio of work produced by the Board on Science Education (BOSE) at the National Academies of Sciences, Engineering, and Medicine to provide insights and guidance on how to maintain high quality K–12 science education in the face of the many challenges produced by the COVID-19 pandemic. The Carnegie Corporation of New York provided funding for the project and worked closely with BOSE staff to conceptualize the project.

BOSE contracted with Jennifer Self to create the book itself, drawing on past reports from BOSE consensus committees and supplementing them with insights from science educators from across the country. The book was written and produced on a tight timeline in an effort to draw on insights gained from the closures during spring 2020 that can inform how schools can adapt science instruction over the 2020–2021 school year. The BOSE reports that inform this book are:

A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012)
Developing Assessments for the Next Generation Science Standards (2014)
Guide to Implementing the Next Generation Science Standards (2015)
Science and Engineering for Grades 6–12: Investigation and Design at the Center (2018)
English Learners in STEM Subjects (2018)

Each of these reports was written by a committee of experts appointed by the National Academies. They provide a synthesis of research evidence and detailed conclusions and recommendations related to various aspects of science education with a focus on implementing the vision laid out in the *Framework*. The insights from these reports are supplemented with examples drawn from the work of science educators during spring and summer of 2020.

Heidi Schweingruber
Director
Board on Science Education

1

Introduction

The COVID-19 pandemic is resulting in widespread and ongoing changes to how the K–12 education system functions, including disruptions to science teaching and learning environments. Students and teachers are all figuring out how to do schooling differently, and districts and states are working overtime to reimagine systems and processes. These efforts are difficult and stressful in the middle of the already stressful and sometimes traumatic backdrop of the global pandemic. In addition, students with disabilities, students of color, immigrants, English learners, and students from underresourced communities have been disproportionately affected, both by the pandemic itself and by the resulting instructional shifts.

In spring 2020, many schools throughout the country shifted to remote instruction while having little or no time to plan out new expectations and procedures. Despite the challenges, there were many bright spots of innovation around the country. In a recent survey, some teachers reported that they were able to take advantage of new levels of flexibility and technological supports to provide engaging learning opportunities for their students. Educators throughout the country have been finding ways to maintain and improve science and engineering experiences, for example, by making more connections to students' homes and communities. These models can be instructive to the field as practitioners work together to support rich and engaging science and engineering teaching and learning for all students, including those who have been traditionally underserved.

However, the same survey of teacher practices during the first few months of the pandemic found that the disruptions to the education system resulted in instructional practices that did not always reflect the body of research on teaching and learning. For example, 88 percent of teachers indicated that their students were spending less time on science through remote learning than they had in the classroom, and only 38 percent of teachers reported that students had been engaged in experiments or investigations through remote learning.

The 2020–2021 school year will continue to be challenging. States and districts have been making difficult decisions about reopening and restructuring schooling, and these decisions will in many cases be continually revisited during the school year as the public health context changes in each community. Some are starting with remote learning; others are starting with hybrid environments, with some students connected remotely and others participating in person; some are starting with blended environments, with all students participating in both remote and in-person learning at different times; and still others are starting with fully in-person models with social distancing.

Whatever approach is used, it remains essential that all students have access to a high-quality science and engineering education. Currently, many economic and social inequities persist in students' access to supports such as broadband and computing devices. The 2020 report *Reopening K–12 Schools During the COVID-19 Pandemic: Prioritizing Health, Equity, and Communities* cautions: "Without careful implementation, virtual learning alone runs the risk of exacerbating disparities in access to high-quality education across different demographic groups and communities."

It is important to remember that during large and ongoing system disruptions, it is expected that adjustments will take time and may happen more than once. Even if all school plans were concrete and unchanging, the adjustment process would be similar to a sprinter being asked to run a marathon. Educators cannot be expected to run the marathon on day one. With uncertainty about future plans added to the equation, this process is even more difficult, forcing all educators to be flexible and innovative and to have back-up plans ready. However, it is important to lay out a vision of the end goal and to provide support for moving continuously in that direction. Throughout all of the ongoing adjustments that need to be made, the vision for high-quality science and engineering education does not change.

The global pandemic emphasizes the need for all citizens to be scientifically literate—to understand data and be able to critically weigh evidence. The accelerating changes to a job market that is rapidly transitioning to autonomous systems and machine learning highlights the need for students to learn to be knowledge creators and problem solvers. All students need a high-quality science and engineering education that will prepare them for success in school, careers, and in life.

> "Many of the challenges that face humanity now and in the future—related, for example, to the environment, energy, and health—require social, political, and economic solutions that must be informed deeply by knowledge of the underlying science and engineering."[1]

By working together to support students and their science and engineering learning, educators can help ensure that the next generation is equipped to address the challenges of the future.

PURPOSE OF THIS BOOK

This book aims to describe what high-quality science and engineering education can look like in a time of great uncertainty and to support science and engineering practitioners as they work toward their goals. It includes guidance—with an emphasis on the needs of district science supervisors, curriculum leads, and instructional coaches—about how K–12 science and engineering learning experiences can

- function during disruptions to education systems;
- adapt as needed to support students and their families dealing with ongoing changes to instructional and home environments; and
- remain at high quality or even increase in quality, even if some content coverage is reduced this year.

It is not the purpose of this volume to reiterate all of the many considerations related to reopening schools nor to focus on public health guidance, which

[1] For more information, see *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, p. 7. Available: https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts.

is available from many sources.[2,3,4] This volume also does not describe in detail many of the issues that are common to all areas of education, such as staffing needs. Several organizations have recently provided guidance related to these systems issues.[5,6]

This book is grounded in several previous reports of the Board on Science Education (BOSE) beginning with the *Framework for K–12 Science Education* (NASEM, 2012) and including subsequent reports the board produced to provide guidance on implementing the vision of the *Framework*. Links to the relevant portions of these reports are included throughout the book. These resources provide in-depth guidance about the vision of the *Framework* and the steps educators need to take to realize that vision.

This volume also incorporates multiple vignettes drawn from real classrooms and schools. These were shared by educators from across the United States. These vignettes provide concrete examples of how high-quality science and engineering education can be maintained and even strengthened, despite the current crisis and the resulting disruptions to the education system.

AUDIENCE FOR THE BOOK

This book is intended for all of the individuals who are involved in making decisions about curriculum and instruction for science and engineering education in schools. This includes curriculum supervisors, district and school administrators, instructional coaches, lead teachers, and classroom teachers. It will also be helpful for curriculum developers and providers as they modify their materials to respond to the constantly changing conditions during the pandemic. Many of the examples focus on planning for instruction because the vision for high-quality instruction needs to inform the broader decisions about curriculum, allocation of time, and staffing that are made by administrators.

[2]The Centers for Disease Control and Prevention (CDC) has provided guidance for school settings.

[3]See https://educatingthroughcrisis.org/meeting-students-and-families-needs/guidance-for-reopening-schools-covid/?utm_source=edaction&utm_medium=email&utm_campaign=covid19.

[4] For more information, see *Reopening K-12 Schools During the COVID-19 Pandemic: Prioritizing Health, Equity, and Communities*. Available: See https://www.nap.edu/read/25858/chapter/2#4.

[5]See https://ccsso.org/coronavirus.

[6]See https://www.sreb.org/covid-19.

ORGANIZATION OF THE BOOK

The next chapter lays out the foundational principles that serve as the lens through which all decisions about planning for science education during this crisis and others in the future need to be made. Each of the subsequent chapters (Chapters 3–7) includes guiding questions, relevant research, stories of implementation efforts and strategies by practitioners, and suggestions for next steps to take. In addition, where implementation is likely to look very different in different grade bands, those differences are discussed. Not every implementation idea will be directly applicable to all contexts, but they can help provide ideas that can be modified for local conditions and needs.

2

Foundational Principles

As students start school in fall 2020, it is likely that their learning experiences will be very different from what they have ever been and that they may even look different from one month to the next. However, the principles of high-quality science and engineering education remain the same. The 2012 report, *Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*[1] (hereafter referred to as the *Framework)* describes these principles of teaching and learning science and engineering based on evidence from decades of research about how people learn;[2] it is a foundational document for the science standards in 44 states as of August 2020, as well as the Next Generation Science Standards (NGSS).[3]

While making their adjustments to instructional plans, science and engineering education practitioners at all levels of the education system can use the four guiding principles listed below to ensure that teaching and learning is effective and stays true to the vision of the *Framework,* implementing the findings from education research. These principles outline the key ideas from the science education research to focus on during the current crisis. This research has been brought together in previous reports from the Board on Science Education, and the principles are derived from the conclusions and recommendations in those reports. They provide a lens for setting priorities and adjusting curriculum and instruction. This chapter describes these principles, and the rest of the guide applies them to provide guidance about science and engineering education in the time of a crisis.

---

[1]For more information, see *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts.

[2]For more information, see *How People Learn: Brain, Mind, Experience, and School: Expanded Edition.* Available: https://www.nap.edu/search/?term=How+People+Learn%3A+Brain%2C+Mind%2C+Experience%2C+and+School%3A+Expanded+Edition.+.

[3]For more information, see *Next Generation Science Standards: For States, by States.* Available: https://www.nap.edu/read/18290/chapter/1.

1. Maintain a focus on the *Framework's* vision for high-quality science and engineering education:

   1a. Learning science and engineering is essential for all students at all grade levels,
   1b. Instruction focuses on student engagement with real-world phenomena and problems, and
   1c. The three dimensions (practices, crosscutting concepts, and disciplinary core ideas) need to be integrated during learning and instruction.

2. Prioritize relationships, equity, and the most vulnerable students.

3. Recognize families and communities as critical assets for science and engineering learning.

4. Approach recovery from disrupted learning and adjustment to changing learning environments as ongoing processes that take time.

Principle 1: Maintain a focus on the *Framework's* vision for high-quality science and engineering education.

1a. Learning science and engineering is essential for all students at all grade levels.

"Arguably, the most pressing challenge facing U.S. education is to provide all students with a fair opportunity to learn" (*Framework*, p. 281)

The *Framework* is grounded in the idea that all students can and should learn complex science and engineering ideas and skills. However, inequities currently exist in students' educational opportunities.[4] The pandemic is not causing these inequities, but it is amplifying them.[5] Providing opportunities for all students to access high-quality science and engineering education—including throughout elementary school—is an equity issue and needs to be a priority for education systems.

[4]See https://www.commonsensemedia.org/digital-divide-stories#/state.
[5]For more information, see *Reopening K–12 Schools During the COVID-19 Pandemic: Prioritizing Health, Equity, and Communities*. Available: https://www.nap.edu/read/25858/chapter/3#13.

High-quality science and engineering learning cannot be restricted only to secondary school students or to students who have access to high speed broadband, to their own computing device, or to teachers who have ample training on special online teaching tools. It cannot be limited to students who read and do mathematics at grade level and speak English as their home language. With careful alignment of goals and plans to address equity and inclusion between the various levels of the education system (i.e., federal, state, district, and classroom), the quality of educational opportunities can increase for all students.[6]

1b. Instruction focuses on student engagement with real-world phenomena and problems.

> "The research is clear that usable knowledge—that is, learning that can be transferred to new situations—only occurs when individuals are actively making sense of the world" (*Science and Engineering for Grades 6–12: Investigation and Design at the Center,* p. 57)

One of the recent innovations in science and engineering education is the central focus on having students figure out puzzling phenomena and solving real-world problems. This idea builds on decades of research on how people learn and shifts the focus from "learning about" a science topic or the engineering design process to "figuring out" how to explain a phenomenon they see or solving a problem. With this focus, students learn ideas and skills because they realize they are missing some knowledge or skill that would allow them to answer their own questions—to satisfy their curiosity.[7]

Students' engagement in their own learning is a strong predictor of their achievement, and teachers often report that it is a challenge to engage students in learning when they are not face-to-face in a classroom. However, by centering students' experience on figuring something out that they are genuinely curious about, science and engineering learning can become the most engaging part of a student's day, even in remote learning environments. A phenomenon- and problem-centered focus provides opportunities to connect learning more closely to students' own lives and therefore to make it more relevant to them when they are at home.[8]

[6]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/12#274.
[7]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/2#5.
[8]For more information, see *Science and Engineering in Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/4#31.

If students explore a phenomenon or problem that they see in their own home, neighborhood, or community, they can more easily apply the learning in other aspects of their lives.

1c. The three dimensions (practices, crosscutting concepts, and disciplinary core ideas) need to be integrated during learning and instruction.

The *Framework* introduced a vision of "three-dimensional" learning to the education community. This kind of learning means that students are not just memorizing facts or separately learning laboratory techniques; instead, students are engaged in building toward three dimensions simultaneously: disciplinary core ideas, science and engineering practices, and crosscutting concepts.[9] Students build and use these three dimensions as a way to explain a phenomenon or solve a problem,[10] and they are integrated into student performance expectations in the NGSS and other *Framework*-based state standards.

One response to a reduction of class time for science instruction is to focus solely on what is deemed "content," such as the disciplinary core ideas, and to omit students' learning about the practices of science and engineering, such as planning investigations and analyzing data. Another response is to focus solely on investigation skills—having students ask questions, make observations, and argue from evidence—but without connections to deep disciplinary content. However, all three dimensions are critical parts of students' education, and any part alone is not sufficient. All students need rich and ongoing opportunities to build and use these three dimensions together over time. The nature of these deep three-dimensional learning experiences can be prioritized over "coverage" of content (see Chapter 5).

Principle 2: Prioritize relationships, equity, and the most vulnerable students.

"Providing equal resources to students and to schools that started out at a disadvantage could not result in equitable outcomes. Equitable outcomes require attention to how people think about student access, inclusion, engagement, motivation, interest, and identity, and about the actions and

[9]For more information, see *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/read/13165/chapter/2#2.

[10]For more information, see *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/read/25216/chapter/2#2.

investments required to achieve such outcomes" (*Science and Engineering for Grades 6–12: Investigation and Design at the Center,* p. 13)

In different school, district, and state contexts, educators and communities can work together during the pandemic to adjust instruction according to local needs. As decisions are made about these adjustments, it is important to focus on supporting underserved and marginalized students and their families. For example, specialized plans can be made to ensure that all students have appropriate and accessible technology, translations, instructional support, and physical and mental health care services to allow them to succeed in the current educational environment. Communications to and relationship building with families can prioritize the families of students with the greatest needs to ensure their needs are addressed.[11] This is fundamentally different from making instructional plans and then modifying them for students who might not have accessible technology: instead, it centers the realities of underserved and marginalized students and begins the instructional planning process with their needs at the forefront.

Principle 3: Recognize families and communities as critical assets for science and engineering learning.

Schools are integral parts of communities, and those communities and the families in them provide a wealth of resources that can be accessed to strengthen students' educational experiences. All students and their families have funds of knowledge that they carry with them and that frame their view of the world.[12] This includes knowledge about daily routines, local neighbors, and surrounding environments. Connecting to and understanding these rich resources is an essential part of connecting to and engaging students.[13]

Students are most authentically engaged when they can make sense of the world around them and solve problems that are meaningful to them and to their communities. Instructional experiences that make use of this kind of place-based learning can help increase personal relevance to students as well as their retention of the content.[14] It also helps promote social and cultural connectedness between

[11]See https://ccsso.org/coronavirus -> System Conditions.

[12]See Gonzales, N., Moll, L., and Amanti, C. (Eds.). (2005). *Funds of Knowledge.* Mahwah, NJ: L. Erlbaum Associates.

[13]For more information, see *How People Learn II: Learners, Contexts, and Cultures.* Available: https://www.nap.edu/read/24783/chapter/9#141.

[14]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center.* Available: https://www.nap.edu/read/25216/chapter/5#69.

students, their communities, and each other. Educators and curriculum developers might not always be aware of what the most engaging ideas or problems could be for particular students or what kinds of family and cultural practices would help contextualize learning for students (see Chapter 3).

Families and others in the community are uniquely positioned to provide feedback on what is working during implementation, what is not working, what barriers exist, and what opportunities are available to support students (see Chapter 6). There is clear evidence that family involvement in education can significantly improve students' academic performance, engagement, and emotional health. Students reap significant benefits when schools support families and caregivers, equipping them to be effective partners in their students' education.[15]

Principle 4: Approach recovery from disrupted learning and adjustment to changing learning environments as ongoing processes that takes time.

Implementation of high-quality science and engineering education in a context of shifting learning environments and constant uncertainty is complex and stressful. The changes that need to be made due to the pandemic in the 2020–2021 school year and likely in subsequent years as well will involve many different stakeholders working together to adjust professional learning programs, instructional materials, technological infrastructures, and assessment systems. Many schools systems were already in the midst of changing science instruction to reflect the vision of the *Framework*, a long-term process even when environments are not shifting continually.[16] It is important to focus on what can be done productively in the short term and to give everyone—students, teachers, administrators—time to adjust to the new contexts. As stated by the *Guide to Implementing the NGSS* (2015), "Appropriately sequencing and setting priorities for the many steps in implementation will be essential. For example, small changes in instruction to incorporate scientific and engineering practices are likely to be implemented more quickly than major redesign of an entire assessment system."[17] This is also true of a shift to remote, hybrid, blended, or asynchronous learning environments, and it will be true of a return to in-person learning when that occurs.

[15]See Henderson, A.T., and Mapp, K.L. (2002). *A New Wave of Evidence: The Impact of School, Family and Community Connections on Student Achievement: Annual Synthesis*. National Center for Family & Community Connections with Schools. Austin, TX: Southwest Educational Development Laboratory (SEDL).

[16]For more information, see *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/11.

[17]*Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/11.

Making all of these shifts and helping students fully recover from the associated disruptions to their learning will likely take more than 1 year. Therefore, changes can be made with a focus on long-term goals. Now more than ever, teachers need support to move forward little by little after every change to the instructional context without the pressure to implement perfectly right away.[18] Each large change, such as a switch from in-person classrooms to remote learning environments, and then from remote learning to hybrid environments, adds extra stress on both students and teachers and extra time to make adjustments to teaching and learning. After each change is announced, educators will need to build from their current practices, collaborate with their colleagues, and begin to incorporate necessary changes in a careful and prioritized way.

This also implies that students' unfinished learning does not have to be addressed immediately. It is likely that some instructional time will have been lost due to disruptions to the school schedule in spring 2020. In addition, instruction may be disrupted this year for individual students or for whole classes or schools. However, a focus on remediation as the approach to addressing unfinished learning—either this year or in future years—is likely to exacerbate inequities. Instead, unfinished learning can be addressed by focusing instruction on grade level–appropriate[19] content, along with careful and consistent monitoring of what each student needs to engage with that content.

As students engage in grade-level learning and discover that they need support to develop foundational content or skills necessary for further engagement, teachers can provide that support in an individualized, just-in-time manner (see Chapter 6). This approach can be especially effective after students and teachers have established relationships, trust, and understanding. Education experts recommend focusing on embedded classroom assessments throughout the school year rather than diagnostic assessments in the beginning of the year.[20]

---

[18]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/4#20; and *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/4#34.

[19]In the *Framework,* discipline-specific concepts (e.g., related to life, Earth, or physical sciences) are divided by grade band (K–2, 3–5, 6–8, and 9–12). However, state standards, including the NGSS, often further subdivide them into expectations for a year or course or provide models for how districts can divide them into courses. Therefore, the term "grade-level appropriate" means student expectations that have been designated for use at a particular grade level.

[20]See Council of Chief State School Officers, *Restart & Recovery: Assessment Considerations for Fall 2020*. Available: https://ccsso.org/sites/default/files/2020-07/Assessment%20Considerations%20for%20Fall%20 2020.pdf; also see Lake, R., and Olson, L. (2020). *Learning as We Go: Principles for Effective Assessment During the COVID-19 Pandemic*. Available: https://www.crpe.org/sites/default/files/final_diagnostics_ brief_2020.pdf.

3

Prioritizing Relationships and Equity

Adjusting to large system changes means that difficult decisions about priorities need to be made. The first priorities need to be equity and the health, well-being, and connections among students, families, and teachers. Although these issues are not specific to science and engineering, they have deep implications for science and engineering education.

The guiding questions in this chapter are intended to help education practitioners consider how this volume's four foundational principles—in particular, Principles 2 and 3—can be applied to planning for building relationships and supporting the needs of all students.

How are relationships between educators and students and among students themselves being built, maintained, and strengthened?

After schools closed in spring 2020 due to COVID-19, many students reported that they missed being with their friends. These kinds of social connections are not frivolous: it is essential for students to stay connected to their peers and to their teachers and other supportive adults. What happens in classrooms is not only about content.

In either classroom or remote environments, building and strengthening interpersonal relationships is especially important for students in a time of upheaval.[1] Students thrive when they are in supportive environments where they feel

[1]Kirkland, D.E. (n.d.). *Guidance on Culturally Responsive-Sustaining School Reopenings: Centering Equity to Humanize the Process of Coming Back Together*. NYU Steinhardt Metropolitan Center for Research on Equity and the Transformation of Schools. Available: https://static1.squarespace.com/static/5bc5da7c3560c36b7dab1922/t/5ec68ebc23cff3478cd25f12/1590070973440/GUIDANCE+ON+CULTURALLY+RESPONSIVE-+SUSTAINING+RE-OPENING+%281%29.pdf.

known and valued by trusted peers and teachers.[2] Building relationships among class members and a classroom community helps students develop a sense of belonging. With these interpersonal connections in place, students are more likely to contribute to the work of idea building in class, whether remote or in-person.[3]

Box 3-1 describes the efforts an elementary teacher was able to make with his students during the first few months of remote instruction in spring 2020 to ensure that they stayed connected and that he made them feel valued.

BOX 3-1 CONNECTING WITH 1ST-GRADE STUDENTS

Steve is a 1st grade teacher in a small rural district in which greater than 50 percent of the students qualify for free or reduced-price lunch. Every year, Steve begins by focusing on team building in class for several weeks to allow kids time to build trust with their peers and with the teacher. When the school closed in the spring for the COVID-19 pandemic, Steve wanted to make sure his students were in a good place emotionally and that they would understand that their teachers were still there and still a part of their lives. He started contacting his students individually every week, alternating between phone calls and what he calls "porch visits," 15-minute in-person socially distanced visits to talk to the student, find out how they are doing, and ask them to read to him. These visits sometimes actually took place on a porch but more often they were next to the student's apartment building or under a garage overhang. During the phone calls, he first talked to the parent or other caretaker and then talked to the student.

During these connections, Steve was able to model to the family members some of his active listening methods so that they could learn how to support their students. Families reported that these visits and calls made the students feel important and valued because they were receiving their teacher's individual attention. With only 14 students in the spring, Steve was able to make these personal connections every week. Other teachers in Steve's area who had more than 30 students in their classes used the same model at a slower rate, connecting with each student individually every other week.

[2]See Darling-Hammond, D., Flook, L., Cook-Haarvey, C., Barron, B., and Osher, D. (2020). *Implications for Educational Practice of the Science of Learning and Development*. Available: https://www.tandfonline.com/doi/pdf/10.1080/10888691.2018.1537791?needAccess=true.

[3]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/5#72.

BOX 3-1 CONTINUED

To begin school in the fall with a new class of students, Steve plans to schedule in-person visits (with masks and social distancing) with each family to introduce himself. He will do this whether his district starts the year in person or remotely. Steve also uses weekly newsletters and personal emails to parents, many of whom are essential workers and cannot stay home with their children during the day. He aims to help each parent and caretaker feel like a valuable part of the education team. He also focuses on helping students know their teacher believes in them.

For the teachers, Steve and his seven team members in the pre-K–2 part of his school had weekly coffee time Google meetings in the spring. During these meetings the teachers were able to connect socially, support each other professionally, and share teaching ideas, as they would have done in person in the school building. If their district starts the school year remotely, this coffee meeting time will continue. The team wants to work together to support the students: as one said, "None of us can do everything but we all can do something, and we all can benefit from each other's efforts."

SOURCE: Interview with Steve Blomberg, July 24, 2020.

Although it is not likely that all teachers would be able to have the frequency and level of one-on-one contact with their students as Steve does in the story, many other types of personal connections can be made to ensure students feel supported. For example, teachers could send weekly emails to each student to invite students to talk if they would like to.

In addition to the social and emotional health and well-being students derive from their social connections, they also benefit academically from these social connections. Inherent to the *Framework* and the NGSS is the need for students to communicate their developing ideas with others as they use the three dimensions to explain phenomena and solve problems. Consensus about phenomena and problems requires social interaction and discourse[4] (see Chapter 4). This need emphasizes the importance of using synchronous class time for dialog and collaboration when classes are held remotely. When synchronous class time is not available or when some students cannot participate in synchronous class time, one

[4]For further information, see *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/read/13165/chapter/16#283.

of the first priorities for teachers will be exploring different strategies for enabling student discourse asynchronously or offline (see Chapter 4). Learning is collaborative—students cannot engage in *Framework*-based science and engineering education alone.[5]

Learning is also cultural. From the preface of the 2019 report *Investigations and Design at the Center*:

> "Learning is more meaningful when investigation and design are relevant to student lives. Investigation and design that are connected to students' culture and place tend to increase student interest in learning. Culturally responsive teaching requires teachers to understand the students' culture and place, use inclusive pedagogies to meet the needs of all their students, and adapt instruction by using phenomena and challenges that are linked to students' place and culture." (*Science and Engineering for Grades 6–12: Investigation and Design at the Center*, p. vii)

When teachers get to know students, their families, and their cultures, they can better tailor instruction that makes connections to their students' existing knowledge, helping to foster the student engagement that is more critical and often more difficult to maintain in remote, blended, or hybrid learning environments. These personal connections also support the development of deep learning and the ability to apply knowledge and skills to novel situations.[6] When all students can see connections between their existing knowledge and what they are doing in class, learning experiences become more equitable. In addition, students can begin to see more easily how science and engineering apply to their everyday lives.[7]

If teachers do not have much in-person time with their students, building relationships and learning about students' lives may not happen as naturally as it would in a full-time classroom setting. Setting aside focused time to get to know each other may be necessary to set up a trusting learning environment. In addition, to help make connections to students' lives and cultures, teachers may need support and guidance for recognizing the assets that students from diverse backgrounds bring to science and engineering classes, including their prior experiences

[5]For more information, see *How People Learn II: Learners, Contexts, and Cultures*. Available: https://www.nap.edu/read/24783/chapter/9#152.
[6]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/11#248.
[7]For more information, see *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/read/13165/chapter/16#284.

and cultural perspectives.[8] Professional learning can help teachers begin developing the knowledge and skills necessary to support inclusion of diverse perspectives and to use them to increase relevance for all students.[9]

How are relationships being built, maintained, and strengthened among educators, families, and communities?

In addition to building direct relationships with their students, educators currently have an opportunity to reimagine stronger relationships to students' homes and communities. Building and strengthening these relationships can result in powerful partnerships with allies who are committed to supporting their students. These partnerships can also provide opportunities for teachers to better understand students' background, culture, and funds of knowledge. These student assets can be the basis for increasing engagement by connecting learning to students' prior knowledge and experience.[10]

Family members, caregivers, and other people involved in students' lives can also be assets for other students in their child's class. For example, when instruction focuses on some outdoor environments, the class could seek out and make use of knowledge about the historical connections of these environments to native communities. When the class is working to solve problems, students could survey their families and other community members to gather information about practices that could help inform the design of a solution.

Box 3-2 tells how Carina, a bilingual ESL teacher, engages immigrant families with their students in remote learning conversations and how the input from family members is valued by her and her students.

When the teacher in the story intentionally invited participation by students' families, she was communicating that she valued the family members' input and that students' experiences at home are relevant to what they are learning at school. The parents who shared ideas with this class might not have realized the

---

[8]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#31. Also see *English learners in STEM subjects: Transforming classrooms, schools, and lives*. Available: https://www.nap.edu/read/25182/chapter/5#102.

[9]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#141.

[10]See Basterra, M., Shaffer, S., and Self, J. (In press). *STEM Education: Engaging Families and Communities*. Council of Chief State School Officers. Also see *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/12#270. Also see *English learners in STEM subjects: Transforming classrooms, schools, and lives*. Available: https://www.nap.edu/read/25182/chapter/7.

BOX 3-2 AN ESL TEACHER, HER STUDENTS, AND THEIR FAMILIES

Carina supports 28 English learners and bilingual students in two schools across grades 2 through 5; they all qualify for free or reduced-price lunch.

Before the pandemic, Carina taught science as part of English one time per week in each school. During the remote learning months, Carina offered an online science project to 3rd, 4th, and 5th graders in small groups three or four times a week in 30-minute sessions. Since the rollout of online classes on April 6, Carina noticed that some of her students have been more accountable and more secure with their families around them, and that the families have been able to be more involved in their students' learning. This environment has given Carina new insights into her students' lives, allowing for a more substantial connection between home and school science.

Often Carina asked her students whether others in the home wanted to join them, and the students would tromp off to find other family members and bring them to the computer. There was activity present in most homes, and there were loud conversations, television, and other commotion, but when parents joined in they showed a reverence for the class by hushing those around them and participated, sometimes saying that their child was engaged in something important. The science lessons had the attention, overt or peripherally, of many family members.

In one lesson, Carina showed images of a cardinal, a duck, and a red-tailed hawk. This lesson had the goal that students recognize that bird species live in different habitats and look and act differently. One of the students, Himbirti, was participating with her mom sitting next to her, and her mom said, "The legs of the duck are different. Not the same as the cardinal. They are for swimming."

Carina then told the group, "Pamela es de El Salvador" (Pamela is from El Salvador) and she invited the child and the adult sitting next to her, in Spanish, to share a bird that was native to El Salvador. The adult greeted Carina, and said, "No recuerdo muy bien" (I don't remember very well).

Next, Carina invited Himbirti's mom to share. "Your family is from eastern Africa and there is a big lake there. Are there any interesting birds there?" The mom corrected Carina that the lake is a sea, called the Red Sea. "A lot of birds. I know birds. I don't know how can say the English but I will figure it out."

The lesson closed with a Venn diagram of the characteristics of a male cardinal and a female cardinal. The class agreed that they were very much alike, but an important differ-

BOX 3-2 CONTINUED

ence was color. The driving question was repeated by everyone: "What are the features of the cardinal and how do the features help it survive?"

Carina spoke slowly and amiably, "It's interesting to look at the different body parts and features of animals to think about their lives and how they survive another day." After nodding and agreeing wholeheartedly, the students clicked off.

Most rewarding to Carina was the interest that the science lessons generated in the families of her students. She says that there is not the same involvement in other subjects: "It's interesting to see. The kids came to see that they like the science more than the math, it's more about real life. They know it's unscripted. They can see that it is more interesting and it makes sense! They see their moms getting interested too, now. That's great."

SOURCE*:* Teachers are enacting an adaptation of ML-PBL grant at Michigan State, grant RC104702 from the Lucas Education Research Foundation. Adapted from Miller, E.C., Berland, L., and Krajcik, J. (In Review). Opportunities for Project-based Learning During Social Distancing of the COVID-19 Pandemic.

effects their support and participation had on their children simply by making connections between schoolwork and family background and culture.

To feel empowered as full partners in supporting their students' science and engineering learning, families and community members may need help understanding the importance of science and engineering education. Some families view science as less important than other subjects, such as reading, writing, and math.[11] They may not realize how much science and engineering are already used in their daily lives, whether they are cooking, gardening, troubleshooting a broken doorknob, or making sense of claims in the news. They also may not understand the critical role they play in supporting their students with science and engineering learning experiences and may believe that they do not know enough to be able to help.

There is evidence to suggest that changing parents' attitudes toward science can affect student learning outcomes.[12] Once families share a vision of the critical role science and engineering play in their children's lives, they can also be powerful

[11]For more information, see *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#230.

[12]For more information, see *Science and Engineering for Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/5#66.

advocates in districts and states to ensure that science and engineering coursework is available for all students—including throughout elementary school. Resources, including in multiple languages, are available to support family understanding of and involvement in student science and engineering learning: for example, the Council of State Science Supervisors offers resources and suggestions for family science learning, translated into six different languages.[13] Family learning resources are also available in which families can engage in real-world activities building toward cross-curricular learning goals; one example is *Learning in Places*.[14]

Communication between families and schools will be essential throughout the school year. Families will need to learn about school and district plans, and teachers and schools need to learn about families' needs and receive feedback from them.[15] In particular, hearing from families from underrepresented groups needs to be a priority.[16] Sometimes language barriers hinder open communication between families and educators, and then neither families' nor schools' needs are met. When communication materials are provided in families' own languages, the families can become equal partners in supporting students.

If relationships between families and the school were not in place before the COVID-19 pandemic, there may be challenges related to contacting the families. It can be helpful to make use of community partnerships, such as those created by community schools, to reach all families and establish relationships (see Chapter 7). However, families cannot be required to engage with schools, so it is important that support for students and their learning experience does not depend on close relationships between families and the teacher. Detailed suggestions for supporting families can be found in the Council of Chief State School Officers document, *Restart & Recovery: Considerations for Teaching and Learning*: Systems Conditions.[17]

How are students' individual needs being met?

> "Attention to equity also requires consideration of how to meet the differing needs of students, including those who have special learning needs, do not have access to technology, are learning English as a second language,

[13]See http://cosss.org/projects.
[14]See http://learninginplaces.org/.
[15]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/10#84.
[16]See Ishimaru, A.M. (2018). Re-imagining turnaround: Families and communities leading educational justice. *Journal of Educational Administration*, 56(5), 546–561.
[17]See https://docs.google.com/document/d/1gGXFnFPnVdy-pBIGiiztG0_3QRucEhx0iaSvoESnWJQ/edit.

are living in difficult economic circumstances, or are from nondominant cultural backgrounds." (*Guide to Implementing the Next Generation Science Standards*, Ch. 4, p. 21)

Students and teachers are all learning how to do schooling differently. This is a difficult and stressful process in the middle of the already stressful and sometimes traumatic backdrop of the COVID-19 pandemic. With a shift to remote instruction in many schools, students may have less access to some of their normal networks and support systems, including peers and school faculty. In particular, students with disabilities, students of color, immigrants, English learners, and students from underresourced communities may be disproportionately affected.

> Students' emotional experiences will influence their approach to learning. Providing mental and emotional supports will be critical, and building relationships is key to supporting students' mental and emotional well-being. As discussed above, students benefit when teachers have built relationships and are able to check in frequently. Keeping open lines of communication with students is a top priority to ensure teachers stay aware of their students' needs. This will help provide opportunities for teachers to identify students who are struggling with trauma or chronic stress and who need individualized supports.

Providing students with explicit instruction in social and emotional skills, habits, and mindsets can also be a very valuable investment of time.[18] Districts and schools can provide guidance, support, and structures for teachers to help them learn how to provide this kind of instruction, how to support student well-being, and how to identify students who would benefit from intensive supports and connect them to the resources they need.[19,20] This guidance and training can be tailored to the specific needs of a school's students, which might also affect decisions about instructional models, such as whether buildings are open or closed and which students need in-person instruction. For example, students who have difficulties reading and writing may need more face-to-face support, and families

[18]See Darling-Hammond, D., Flook, L., Cook-Haarvey, C., Barron, B., and Osher, D. (2020). *Implications for Educational Practice of the Science of Learning and Development*. Available: https://www.tandfonline.com/doi/pdf/10.1080/10888691.2018.1537791?needAccess=true.

[19]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/9#205; and https://www.sreb.org/mental-health-and-well-being.

[20]See https://www.sreb.org/mental-health-and-well-being.

of students with special needs may not be equipped to provide the care students can receive at school. Other students may benefit from the use of assistive technology, whether remotely or in school, providing materials in multiple formats, or allowing them to participate through multiple modalities.[21] Whether in remote or in-person environments, following the principles of universal design for learning can maximize students' opportunities to engage in scientific and engineering investigations.[22]

Box 3-3 tells the story of high school chemistry teachers Mary and Gavin and their coteachers, who worked together to provide remote supports and modifications for their students with disabilities.

BOX 3-3 MAKING A CHEMISTRY CLASS ACCESSIBLE TO ALL STUDENTS

In the classes that Mary and Gavin teach, high school students are given the opportunity to do chemistry in their kitchens and make meaningful connections to a chemistry phenomenon. In general, Mary and Gavin design their experiments to be accessible to students by using common household items, while encouraging alternatives based on what is available in students' homes. Each of the lessons is informed by universal design for learning, in this case allowing students to access information through video, reading, and a hands-on experiment.

One week, students were challenged to put an (unbroken) egg into a liquid of their choice, such as vinegar, soda, or juice, and leave it in for 24 hours or more. They were then asked to collect data about what happened over several days until the class had a Zoom call to compare results by the different kinds of liquids students used. The approach of Mary and Gavin provided students with choice during the experiment, which resulted in students reporting multiple liquids they chose and how long they left the egg in. Students also liked the feeling of holding the egg after it had been in the liquid. They were surprised that the eggshell reacted in vinegar but not soda or isopropyl alcohol. It brought up many interesting questions about the nature of acids and bases that they addressed in the following week's lesson on pH indicators.

---

[21]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#163.

[22]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#233.

BOX 3-3 CONTINUED

Mary's and Gavin's students with disabilities said that accessing multiple platforms, creating new accounts, and using new technologies made the content more difficult to access. Therefore, the teaching team embedded all materials within Google Classroom and used the consistent strategy of Google Forms, embedded videos, and articles adapted from Newsela* to ensure that their learners could focus on that week's content and not on learning a new online tool.

Instructional materials (e.g., videos, student instructions, readings, and Google Forms for collecting student input) are developed collaboratively and housed in a shared Google Drive folder where Mary's and Gavin's coteachers can access them for additional modifications, including Spanish translation, preparation of visual vocabulary aids, and sentence frames for scaffolded open-ended responses. These modifications are distributed through Google Classroom to bilingual students, English learners, and students with an Individualized Education Program or a 504 plan requiring additional supports. Assignment deadlines are flexible, allowing all students the time needed to complete assignments around other obligations during this time. A Zoom meeting with all teachers on Friday afternoon confirms that assignments are ready for Monday morning posting in Google Classroom. According to Mary, "Our Zoom meetings are a critical component of our approach to cooperative planning, maintaining the synergy that truly only comes during real-time interactions where we play off each other's thoughts and ideas."

Working with coteachers and consultant teachers is an enormous help for teachers and for students. Mary's and Gavin's special education consultant teachers and bilingual coteacher allow for very specific and targeted interventions to take place either in the classroom or online. Each week, one of their special education consultant teachers includes annotated copies of articles, sentence starters for questions, and videos or visuals to help reteach concepts each week. Additionally, each week their bilingual coteacher translates the chemistry article into Spanish or finds a comparable article in Spanish. For Mary and Gavin, this work reminds them of the phrase "it takes a village to raise a child" and that collaboration is essential to make sure that their students with specific needs have those needs met both in person and virtually.

*See https://newsela.com/.

SOURCE: Adapted from https://www.educatingalllearners.org/projects/Chemistry-at-Home%3A-Accessible-Experiments-and-Science-Literacy.

This story highlights many different strategies teachers are using to support students' individual needs in remote environments, such as minimizing the number of different technological programs students have to use and access, providing translations and English conversation scaffolding, and allowing flexible scheduling and deadlines. The story also shows that several educators working together can provide all of these supports, and that no one teacher was expected to do everything alone.

> Promoting equitable participation across different student populations means an emphasis on making meaning, on hearing and understanding the contributions of others, and on communicating ideas in a common effort to build understanding of the phenomenon or to design solutions for the system being studied. (*Science and Engineering in Grades 6–12: Investigation and Design at the Center*, p. 164)

Another way to help ensure that students can participate equitably in science and engineering is to center teaching and learning on phenomena and problems that connect to students' everyday lives and interests. This is one reason it is important for teachers to get to know students, their families, and their cultures as discussed in the beginning of the chapter—it allows them to plan instructional experiences that build on students' funds of knowledge and cultural practices, supporting their learning and making them feel respected[23] (see Chapter 4).

Box 3-4 describes how a teacher, Ma. Soulyvic, connected with students' interests both to engage them in engineering design projects and as a strategy to maintain relationships among students and between the student and the teacher. The story also describes how the teachers and students in this urban school were supported to take time during the school day to relax, socialize, and relieve stress during the first couple of months of shifting instruction to remote environments, supporting their social and emotional well-being.

By modeling the importance of engagement and self-care to his teachers, the principal in the story equipped the teachers to guide their students, in turn, in this kind of self-care. As a result, the students in this school began to learn techniques

[23]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#163.

BOX 3-4 BUILDING RELATIONSHIPS AND PRACTICING SELF-CARE

Ma. Soulyvic is a K–5 science specialist in an East Coast urban school that primarily serves students from low-income families. After the school moved to remote classes in the spring, she continued supporting teachers in their day-to-day remote classes and delivering science instruction. She also began to provide weekly informal engineering engagement times for interested students. She initiated partnerships with local stores, such as Walmart, Costco, and Home Depot, that donated supplies for her students to use to explore and build their engineering designs at home, such as buckets, rulers, building blocks, and modeling clay. Students focused on real-life problems and tried to identify solutions. The classes were scheduled for 6–7 p.m. on Friday nights, but students often requested to stay online talking together and sharing ideas and plans for future engineering investigations until at least 9 p.m. About 90 percent of the students who had originally shown interest in these optional classes continued to attend every week.

Ma. Soulyvic was supported in this work by her principal, who emphasized the importance of relationship building. For example, the principal hosted a schoolwide virtual hangout every Friday where teachers and students dance and play guessing games, with the winner each week receiving a gift card for at least $25. During faculty meetings, the principal also emphasized to teachers the importance of self-care, taking breaks between classes for breathing exercises and playing music. Many teachers in the school started incorporating these techniques with their students, using breathing exercises and dance breaks between class Zoom sessions.

Ma. Soulyvic said that the spring 2020 transitions provided proof that teachers have resilience and can adapt and be innovative when they work as a team and support each other.

SOURCE: Interview with Ma. Soulyvic Luzaran, July 25, 2020.

that could help them cope with stress and trauma. The students who participated in the evening engineering classes also had additional opportunities to relieve stress and connect with one another weekly, driven by their engagement with the learning.

Detailed guidance about supporting student needs is available in the CCSSO document *Restart & Recovery: Considerations for Teaching and Learning: Wellbeing and Connection*,[24] from the National Association of Family, School, and Community Engagement,[25] and from Educating All Learners.[26] Guidance for improving accessibility of materials is available from the National Center on Accessible Educational Materials.[27] In addition, *Next Generation Science Standards: For States, by States*. includes seven case studies that offer examples of equitable instruction related to economic disadvantages, race and ethnicity, students with disabilities, English learners, girls, alternative education, and gifted and talented students.[28]

How are teachers' individual needs being met?

Teachers are bearing much of the burden of adjusting to the new contexts for schooling. It is important to remember that teachers are human beings first and foremost. They have children and vulnerable family members, as well as their own needs. They are in many cases being asked to completely transition their curriculum in one summer or at the beginning of the school year, and to either use or be prepared to use two different styles of teaching (e.g., both remote and classroom based) at the same time for all their lessons. Many teachers had already been in the process of transitioning their instruction to meet the goals of the *Framework* and were still working to figure this out for their in-person classrooms. In addition, as is the case with students, teachers may be experiencing traumatic situations related to COVID-19 and may have different learning needs for adapting to the new teaching environments. They may need guidance about self-care[29] and may need mental and emotional care and support.

In many cases, schools are setting up support systems for teachers, and providing information and training about self-care, such as the guidance from the

---

[24]See https://ccsso.org/coronavirus -> Wellbeing and Connection.

[25]See https://nafsce.org/page/ResourceLibrary/#/?t=all&to=all&ty=37&py=all&ln=all&page=0. https://edtrust.org/resource/10-questions-for-equity-advocates-to-ask-about-distance-learning/.

[26]See equityatthecore.org.

[27]See http://aem.cast.org/about/aem-center-covid-19-resources.html.

[28]See: https://www.nextgenscience.org/appendix-d-case-studies.

[29]See https://docs.google.com/document/d/1-VtVFG3nb2u2PdXe5FejE91vxJkxN4OTszyprSBLxnA/edit.

principal in Ma. Soulyvic's story in Box 3-4, above. Many schools are also working to maintain a sense of community among school faculty. Opportunities are often provided for informal socializing among teachers, providing much-needed social connections, in addition to more formal opportunities to work together and collaborate through professional learning communities (see Chapter 7). In some cases, teachers organize these opportunities on their own, as was the case with the pre-K–2 teacher story in Box 3-1.

Another way to build community and connections is to set aside dedicated time for community-building in the beginning of teacher meetings or professional learning. Box 3-5 provides an example from Stanford University's Center to Support Excellence in Teaching.

BOX 3-5 BUILDING COMMUNITY DURING REMOTE TEACHER PROFESSIONAL LEARNING

The Center to Support Excellence in Teaching (CSET) at Stanford University has spent several months ensuring that its professional learning programs could be effectively adapted to create high-quality remote learning experiences. It merged key ideas from the research on teacher learning with recommendations about remote learning from Stanford Online High School to structure the learning experiences, including leveraging synchronous learning time for dialog and making sense while creating tasks for asynchronous time that helped teachers prepare for the sense-making activities. CSET found that it was important to carefully coordinate the synchronous and asynchronous work so it was meaningful for the teachers, responsive to their needs, and created an arc of learning that was transparent to the teachers.

Another aspect of the program that is appreciated by the teacher participants is the 30-minute block that launches each day. This block is set aside purely for teachers and facilitators to get to know each other, reconnect, and build community. These sessions include interactive experiences, such as building a poem wall collectively, responding to prompts in PollEverywhere, or sharing images from participants' lives.

SOURCE: Interview with Janet Carlson, July 22, 2020.

In this story, relationship building between teachers is valued by both the teachers and the professional learning facilitators. It is seen as beneficial enough for teacher well-being that a significant portion of time every day, 30 minutes, is dedicated solely to this kind of activity.

More detailed guidance about supporting the individual needs of teachers and other school staff members is available in the CCSSO document *Restart & Recovery: Considerations for Teaching and Learning: Wellbeing and Connection*.[30]

How are inequities related to students' access to broadband, devices, and instructional supports being recognized and addressed?

> Approximately 15 million to 16 million K–12 public school students, or 30 percent of all public K–12 students, live in households either without an internet connection or device adequate for distance learning at home, a higher number than previously recorded; and of these students, approximately 9 million live in households with neither an adequate connection nor an adequate device for distance learning. [31]

A significant portion of U.S. schools are operating remotely during at least the beginning of the 2020–2021 school year, and even those operating fully in person are planning for what to do if they have to move to remote instruction. As a result, student access to devices and high-speed broadband is likely to be necessary for learning. With the existing inequities in devices and broadband access, a shift to remote instruction could further limit underserved students' access to educational supports. For example, if classes use simulations and some students do not have access to a device with enough speed or broadband to engage with the simulation, they could miss out on essential parts of the instructional progression.

Moreover, disparities exist between families in which one or more parent is able to work from home and provide some support to a child during remote learning and other families in which parents are essential workers and cannot stay home.[32] Disparities in resources are also not limited to remote learning environments. Schools receive significantly different levels of funding for facilities, staffing, science and engineering supplies and equipment, and computing technologies

---

[30]See https://docs.google.com/document/d/163ZNDs7sZ0FWOT7-1JFxQ9Lbo6zbQNJhaHSs0LbljCE/edit

[31]See Chandra, S., Chang, A., Day, L., Fazlullah, A., Liu, J., McBride, L., Mudalige, T., and Weiss, D. (2020). *Closing the K–12 Digital Divide in the Age of Distance Learning*. Available: https://www.commonsensemedia.org/kids-action/publications/closing-the-k-12-digital-divide-in-the-age-of-distance-learning.

[32]For more information, see *Reopening K–12 Schools During the COVID-19 Pandemic: Prioritizing Health, Equity, and Communities*. Available: https://www.nap.edu/read/25858/chapter/5#30.

for classroom use;[33] these differences will affect schools' abilities to adapt to the pandemic and provide services for students.

The National School Boards Association defines educational equity as "intentionally allocating resources, instruction, and opportunities according to need."[34] Many school districts embraced this idea in spring 2020, partnering with technology companies to provide devices or hotspots to students who needed them.[35] These kinds of programs are available from some states and broadband providers and have been compiled by the State Education Technology Directors Association.[36]

Where devices or broadband are not available, districts have often been focusing efforts on providing packets of physical materials to students to allow asynchronous learning without the need for devices or broadband. These are often made available for students to pick up or are sometimes delivered along with school lunches. When these packets support deep and meaningful science and engineering sense-making and problem solving, they can help bolster the development of important knowledge and skills. However, packets of materials cannot alone fully substitute for the student dialog and community necessary to build all of the science and engineering practices and concepts.

Another idea used in some areas is to make use of students' or their guardians' cell phones.[37] Access to phones is typically more widespread than access to computers at home, but there are limitations to using phones for learning engagement, including the screen size and the way various apps block each other such that only one can fully function at one time. It also is not clear that all students' cell phone bills will be paid every month or that their phone plans will cover the increased data use needed for remote learning.

When new technologies are used for instructional purposes, teachers need training in their use for engaging students and in managing the new learning environment. In addition, as with any adoption of new technology or methodology, questions and concerns will arise from students and families about the use of the technology itself, as well as the specific class procedures. Providing easy-to-access multilingual support to families will support their engagement.

[33]For more information, see *Science and Engineering in Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#235.

[34]National School Boards Association. (2018). *NSBA's Vision for Equity in Public Education*. Available: https://www.nsba.org/Advocacy/Equity.

[35]For more information, see *Reopening K–12 Schools During the COVID-19 Pandemic: Prioritizing Health, Equity, and Communities*. Available: https://www.nap.edu/read/25858/chapter/5#32.

[36]See https://www.setda.org/main-coalitions/elearning/off-campus-access/.

[37]See Garcia, A. (2017). *Good reception: Teens, teachers, and mobile media in a Los Angeles high school*. The MIT Press.

Making decisions about remote, in-person, hybrid, or blended learning environments, as well as the support structures needed for each, requires careful considerations of the effects on underserved students and on their access to high-quality science and engineering teaching and learning.[38] Many districts and schools are formalizing these considerations through guidance documents and trainings.

Box 3-6 describes the efforts of a district supervisor to ensure that his science curriculum team was making social justice and racial equity the top priority in its planning process.

BOX 3-6 SOCIAL JUSTICE AND RACIAL EQUITY AS THE PRIORITY

Scott is a supervisor of curriculum and instruction for K–12 math and science in a school district of around 11,000 students. The majority of the teachers in his district have been through NGSX* training, where they have learned and practiced discussion on norms and talk moves that focus on valuing all students and the assets they bring to class. However, with a shift to remote instruction in the district and a subsequent flurry of emergency planning activity, Scott realized that it was important to make sure that the district clearly communicated the importance of an explicit emphasis on social justice and racial equity.

To begin planning for longer term curriculum changes in summer 2020, Scott pulled together his science curriculum committee and used a two-part training he had developed based on the principles in a STEM Teaching Tool on supporting equitable home-based science learning. He wanted to create a common vision of equity and justice with the team. The curriculum committee members worked in breakout groups during the first training to gather information jigsaw-style on different aspects of the system they would need to consider in their work, such as using appropriate technology, partnering with families, and supporting learners who are furthest from educational justice. In their second meeting, the committee members focused more deeply on issues of racial equity and social justice and how this lens can support all of their work. After the meetings, committee members continued to meet in small groups to plan how to implement the ideas in all parts of their work. Scott sees these conversations with the curriculum committee as only the first step to trying to change inequities, and he plans to continue this work throughout the rest of the system.**

*See https://www.ngsx.org/.

**See https://drive.google.com/file/d/1t5UjlFtHzR-Efl1eRodfHD_CExEje0e5/view.

SOURCE: Interview with Scott Goldthorp, July 29, 2020.

[38]For more information, see *Science and Engineering in Grades 6-12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/2#7.

This story illustrates the stepwise approach a district leader took to ensure equity and justice were the focus of decision making in his district. He did not try to do everything himself; he brought together his science curriculum committee so that the team could do the work together. After building a common vision, the team was then able to plan for incorporating these ideas at multiple levels of the education system, supporting the teachers and students in the district.

NEXT STEPS TO CONSIDER

- Set aside time in classes and professional learning courses specifically for relationship building in the beginning of the school year.
- Integrate opportunities for building relationships throughout science instruction.
- Support educators to begin learning about their students' cultures and backgrounds and how to leverage these to make learning more engaging and meaningful for students.
- Connect with families as much as possible to encourage and equip them as partners in their children's learning.
- Provide information and training for teachers on supporting social and emotional well-being, both for themselves and for their students, and on how to recognize signs of students' mental distress.
- Make all planning decisions, including about instructional tools, pedagogies, and provision and use of technological resources, through a lens of social justice and racial equity.

4

Adjusting Instruction in Changing Environments

In order to maintain the health of students, teachers, and their communities, school districts are implementing measures that dramatically change the learning environment. This includes a wide variety of combinations of remote and virtual environments with classroom-based learning, including going completely virtual. Classroom environments themselves are also changing due to the need for social distancing and other safety measures. Some education communities are choosing to initially keep physical classrooms closed for some or all students and finding alternate environments for learning and teaching. Others are using physical classes for a few days a week for reduced numbers of students and engaging students remotely for the rest of the week.

Whether in-person, remote, hybrid, blended, or other flexible and innovative models have been chosen initially, other models may be used later, so it is helpful to plan for them ahead of time. Whatever model is used, good teaching and learning principles will need to be followed. The guiding questions in this chapter are intended to help education practitioners consider how this volume's four foundational principles can be applied to planning for and adjusting instruction in changing environments:

How are the assets of each learning environment being leveraged?

Assets of home and school

Many students will be spending more of their time on formal schooling while at home during the pandemic, but this change does not mean the beginning of learning at home. Home has always been a setting for learning, but learning at home often looks different from learning in school. The shift to doing formal schooling at home may mean that students, families, and teachers will need to revise how they think about the relationship between school and home and focus more on the experiences and resources that students can access outside of classrooms. This is a valuable opportunity to recognize the assets that families have in their communities, including the natural environment, designed structures, and knowledgeable family and community members. This is particularly true for science and engineering, which focus on explaining phenomena and solving problems in the real world.

There are advantages of both school-based and home-based learning environments for students' formal education. For example, in school, there are typically materials, time, and dedicated space for learning. In addition, classes have established routines and norms that are familiar to students and teachers, and students have immediate contact with professional educators who can monitor and support their learning. However, in home environments, it may be easier to ground learning in places and scenarios that are relevant and meaningful to students. For example, when students are asked to examine the differences between living and nonliving things around them, using objects and organisms in their home and neighborhood might be more meaningful to them than would objects and organisms in their school yard. Students are more likely to be able to see how their learning experiences relate to their daily lives and to build a deeper connection to the resources in their neighborhoods and communities. There are also more opportunities to incorporate families and communities in the learning process when students do their schooling at home, supporting multigenerational communication and cultural transmission. In addition, remote learning is generally more flexible in terms of schedules, workspaces, and routines.[1]

School systems that choose a blended model, having students spend some time in classrooms and some time in home or other remote environments, could take advantage of the strengths of each. For example, when in remote environments, students could gather information about a phenomenon and take the time they need to think through their initial models for how the phenomenon works. Then students could come together in the classroom to test their models, potentially conducting investigations that require expensive or hazardous materials under the supervision of the teacher. In school systems that choose a hybrid model, where some students learn remotely and others participate in person, it

[1]See https://docs.google.com/document/d/1kZKeoxn_APWn8qw572j1gK5oQ5aTSpw9xezhSmoljUY/edit.

could be helpful to prioritize the use of classroom space for students who might have difficulties self-directing their learning outside of school, such as young children or students who have difficulties using the technology needed for remote learning.

Assets of synchronous and asynchronous learning

In remote, blended, hybrid, or other flexible learning models, instruction time will likely be divided between synchronous and asynchronous time. Synchronous remote learning—when students and the teacher work at the same time—can help provide real-time interactions between students and a teacher, allowing the teacher to shift instruction immediately in response to student needs. This time is also useful for community building, dialog, and celebrating learning. In addition, synchronous learning can happen offline when students are expected to work independently at the same time, much like independent work in a classroom, and then come back together to share their work.

Asynchronous learning, in contrast, provides a great deal of flexibility and differentiation for students: those who need more time can take it, and those who are ready for more challenges can extend their learning. In the classroom, it can be difficult to let students work at their own pace, whereas remote asynchronous work can be designed to maximize autonomy for learners. During this time, students can watch videos and read texts to gather information, conduct investigations, design solutions to problems, leave feedback on their peers' work, write to communicate their thinking, review feedback received, and reflect on their learning. Including a large amount of asynchronous time in the class schedule can also be helpful to support learners who do not have continuous access to devices or broadband, who have other obligations for their time, or who benefit from more time to process ideas. It is important to note that there are grade band considerations for planning synchronous and asynchronous time: students in middle and high school are likely to be better at self-regulating their remote schoolwork than are elementary school students, who are more likely to need adult support for remote learning.

It will not be feasible to replace seat time, minute per minute, with screen time. There are limitations on the time students can spend in synchronous remote learning, trying to concentrate and remain engaged during online sessions. In addition, even where schools are beginning the school year with in-person instructional models, the time in class is often reduced in comparison with previous years. It is therefore important to think strategically about which activities to do in a whole class setting and which ones can be done independently, with students working remotely on their own or in small groups. Asynchronous work gives students time to thoughtfully develop their models, designs, and explanations, to think of new questions based on their prior experiences, and to gather information and ideas from people around them. Synchronous whole-class time is a great opportunity for student discussion and exchange of ideas and feedback, and for sharing student models, designs, and explanations. This kind of sharing is particularly important for science and engineering, as discussions often serve as the core component of student learning. However, some students will need more scheduling flexibility or may not have reliable internet access and should be provided opportunities to fully engage with instruction asynchronously, for example, by accessing recordings.

How are instructional norms and expectations being established?

In a time of stress, it is important to give students as much of a sense of predictability as possible.[2] Expectations for learning goals and instructional routines need to be established and communicated very clearly to both students and families at the beginning of each course and, ideally, for each activity. Even for those classes that are currently conducted in person, there is a risk that school could close at any time. It is therefore important to plan ahead for instructional routines that can be used in remote environments and get students accustomed to the tools that will be used.[3]

Students also need to see clear pathways to achieving success. They need to understand when and how they are expected to participate and what good participation looks like. Similarly, for each class assignment, rubrics that define what success looks like and video-recorded instructions that can be replayed as needed can be very helpful. Table 4-1 presents some general ideas for ways that expectations can be set for student participation and ways student learning can be supported whether learning is synchronous or asynchronous, and with or without access to computers and high-speed internet.

---

[2]See Tetrick, L. E., & LaRocco, J. M. (1987). Understanding, prediction, and control as moderators of the relationships between perceived stress, satisfaction, and psychological well-being. *Journal of Applied Psychology, 72*(4), 538–543.

[3]See https://chiefsforchange.org/wp-content/uploads/2020/05/CFC-TheReturn_5-13-20.pdf.

TABLE 4-1 Options for Setting Expectations and Supporting Student Learning

Synchronous Online Learning	Asynchronous Learning Aided by Computers and Broadband	Remote Learning with Limited Access to Computers and Broadband
• Set expectations for contributing during class discussions for each activity. • Use strategies to manage speaking such as each person nominating another to speak, until all have spoken. • Encourage sharing of ideas through chat. • Use and rotate breakout groups to increase participation and sharing of ideas. • Establish structures for quick teacher-student and peer-peer feedback. • Provide recordings of lessons for students who miss synchronous interactions.	• Set expectations for contributing and responding to asynchronous discussions for each activity. • Provide opportunities for students to share in different ways, such as videos or written responses or images. • Engage in discussion board conversations. • Establish a buddy system and encourage students to agree on times to meet online to collaborate on activities. • Develop respectful comment/feedback starters (e.g., "How about . . ."). • Provide students with feedback, such as comments on their documents.	• Set expectations for participating in class collaborative work for each activity. • Invite students to participate in class discussions by telephone. • Ask students to send questions by text message. • Use group text threads with groups of students. • Establish a buddy system and encourage students to agree on times for phone calls to collaborate on activities. • Send feedback for students in writing.

SOURCE: Adapted from *Staying Grounded When Teaching Remote.*[4]

How can remote instruction support student sense-making and problem solving?

With a shift to remote learning in many places, it can be tempting to focus on finding technological tools that can make class time fun for students. However, the focus needs to stay on the vision for teaching and learning and not on the particular tool used to help achieve that vision. Even in remote environments, student learning in science and engineering needs to center on engaging in the three dimensions—science and engineering practices, crosscutting concepts, and disciplinary core ideas)—to explain phenomena and solve problems. Finding ways to maintain this three-dimensional focus during the pandemic is critical to students' learning.

Whether in person or remotely, when learning is centered on student engagement in sense-making or problem solving, the teacher is not expected to provide the targeted information directly to students or to be the one primarily responsible for asking questions.[5] Instead, it should be the students who ask the questions and who pull together data and evidence to try to make sense of phenomena or solve

[4]See https://www.openscied.org/remote-teaching/.

[5]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/6#84.

problems.[6] The teacher takes on the role of scaffolding and facilitating this process, which requires more planning when done asynchronously than when done synchronously.[7]

Figure 4-1 shows an initial student work page intended for use with a remote, asynchronous class. The prompts were developed to help students ask questions that were used to drive instruction during the class, working toward sense-making of the phenomenon of increased forest fires in California.[8] Traditionally, the teacher would have led the students through each one of these conversations in person, but in an asynchronous environment, these kinds of work pages were provided to encourage students to engage in thinking and wondering independently before sharing their ideas with the rest of the class.

Changing the roles of teacher and student to ensure that students can initiate and drive sense-making is not trivial and takes time. It is easier to just present information to students than to undertake student-driven learning. However, students need to feel ownership over the learning process. They need to clearly see the connections between their curiosity and the next instructional activity. When students know that the activity one day is helping them figure out what they wondered about the previous day, instruction becomes coherent from their perspective, even though the order of lessons and questions addressed may look different from if they were laid out by a disciplinary expert who already knew all of the answers from the beginning.[9] When students perceive that instruction seems to follow their curiosity, they feel more associated with the process of learning and therefore are more likely to participate and be engaged. This engagement, while always important, is particularly relevant in the context of remote learning.

Helping students have these kinds of coherent experiences does not mean that instruction should go in whatever direction students are curious about:[10]

[6]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/6#95.

[7]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/6.

[8]It is important for educators to be sensitive to student stress or trauma when focusing on phenomena such as forest fires that may have large negative effects on students' lives, families, or communities.

[9]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#142.

[10]For more information, see *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/4#27.

Initial Wildfire Ideas One of the issues that is locally important to us is that wildfires have been more frequent and more severe in California in recent years. In this unit, we are going to figure out why that is and use chemistry to help explain it. Let's start with our experiences, what we already know about wildfires and construct our best starting explanation.	
	Part 1: Wildfire Ideas
1) Watch THIS VIDEO. What do you Notice, Wonder, or Think about the video? (List at least 3 things) See https://www.youtube.com/watch?v=_QbgM3hkW3A.	1. 2. 3.
2) What experience(s) have you had with wildfires? (have you or anyone you know been affected by wildfires)	
3) What do you think might be some of the causes of recent wildfires? (2–3 ideas)	
4) What questions do you have about wildfires? (at least 3 open-ended questions)	1. 2. 3.

FIGURE 4-1 Sense-making sheet that is a part of the Rate of Chemical Reaction unit curriculum materials.
SOURCE: Fay, L., Zinsser, A., Tschida, P., Fortier, A., and Kang, H.; Tustin High School, University of California Irvine; personal communication.

> "[T]he goal is to help students develop useable knowledge, so turning over complete control to students could take the investigations too far afield. Moreover, it can leave gaps in understanding that prevent students from developing reasonable explanations of phenomena." (*Science and Engineering for Grades 6–12: Investigation and Design at the Center*, p. 142)

The teacher instead facilitates student conversations to support students in figuring out what kinds of investigations would be most helpful to answer their questions.

How can educators support student collaboration and discussion in remote environments?

In order to support coherent instruction that is focused on sense-making and problem solving, students need opportunities to work together: brainstorming about possible ways to solve problems, collaborating to develop investigation plans, discussing data interpretations, and engaging in argument about how well the evidence supports an explanation for a phenomenon.[11] The exchange of ideas helps students reflect on their own thinking and builds connections between their different ideas.[12] This kind of dialog among students is a central mechanism for student learning,[13] whether students are working remotely or in person, but it presents additional challenges for remote learning. Educators can adapt facilitation techniques and technological tools to support students' remote exchange of ideas.

Box 4-1 details how one teacher adapted her classroom norms for student collaboration and discourse for use in a remote environment when her district shifted to remote instruction in spring 2020. Included in this story are glimpses of ways remote environments can positively affect how students participate in learning. Some students showed more agency, taking the initiative to write their ideas to share with the class, and one student participated more verbally than they had previously in person. The story also highlights that productive class routines and norms may take some time to become established and consistently used. Both students and teachers will need time to adjust.

---

[11] For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#218.

[12] For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/5#59.

[13] For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#30.

BOX 4-1 ENGAGING STUDENTS IN SCIENCE REMOTELY

Miriam is an experienced 5th-grade teacher in a large, urban, public school district, with 29 students, 60 percent of whom are from a household of low socioeconomic status. She is motivated by problem-based learning (PBL) because of the increased engagement of her students in collaboration, discourse, and modeling. She believes that students learn when they collaborate on a problem and that PBL addresses that need. Technology and distance learning presented a challenge, but the benefits of PBL motivated Miriam to meet the challenge.

In the online lessons, Miriam's students were enthusiastically trying to speak with one another, share stories, and simultaneously use the technology applications for scientific practices. Getting the students to participate in meaningful practice and dialogue was important to Miriam, and over the course of a month, using the online format, she iterated the PBL collaborative practice until it became valuable learning.

Miriam started the online star unit, like the in-class version, with photos of an unknown location and the acting out of a scenario. In this scenario, students are in a foreign place they do not recognize (as in a popular TV show).

Miriam introduced the scenario dramatically: "Look around you. Does anything look familiar? You have an assignment to travel 1,000 miles north, and then wait for your next message."

She flipped through slides, photos of buildings and mountains, as well as a photo of a woman facing north with a shadow jutting to one side, and the time 12:00 p.m. on the slide. Also, there was a slide with an image of the stars in the sky in the unknown location.

Miriam said: "Jot down any ideas. What do you know about how to figure out where you are and how to get around? Anything. Jot down anything that comes to your mind. One, two, three, go!" The students began writing in their notebooks.

One student could be seen furiously writing, another was thinking. Interestingly, Miriam had a clear view of students' work habits within the distance learning format.

continued

BOX 4-1 CONTINUED

After a few minutes Miriam said: "OK, you can share what you observed. Share your thinking about what your observation tells you about where you are. One at a time. If you have your hand up, tell me what you have for an idea, that you wrote down."

There were many hands raised.

She called on Chris. He said, "You can use the North Star."

Miriam wrote down his idea on the virtual white board. She asked him to explain.

He said, "The North Star can tell you where you are heading."

Chris had also started writing his reason for this on the class's virtual T-Chart. This is a contrast between in-class and virtual use of materials. In the classroom, students tell Miriam their ideas, and she records them on the whiteboard. Chris and others demonstrated interest and agency when they used the virtual whiteboard without being given permission.

Miriam thanked Chris, "This is great!" She added, "While Chris is writing, can someone share another idea? Liam, what do you have?"

In the first lesson of the unit, Miriam found the collaboration between participants was challenging, but not impossible. After the lesson, Miriam stated that she thought the sticky note and chat box moves worked, but they did not take the place of the turn-and-talks in the classroom. She wondered aloud how she could get the students to collaborate better. During each lesson, Miriam tried a new technique to get the students talking and figuring out part of the answer. Some of the attempts did not work, such as having all the students drawing on the same white board at the same time.

By the fourth lesson, Miriam figured out one way to bring together modeling and the figuring-out activity and still retain the attention of the students. As the two students led the drawing, the class took turns talking through how a shadow of a person changes over a day and how they could use that pattern as evidence, a crosscutting concept they had learned previously. Different pairs of students were in charge of drawing the 9:00 a.m., 12:00 noon, and 3:00 p.m. shadows. Miriam asked the two students to use the class's ideas and consult with one another while making decisions about what to draw. She reminded other students to jump in with helpful ideas.

Deryelle first used the virtual pencil, and she drew the sun and the sunlight in a straight line. She was tentative and awkward in this format, but the drawing was recognizable. Even though Brian was Deryelle's partner, he did not object.

BOX 4-1 CONTINUED

Miriam said, "Wow, Deryelle, can you explain what you did?"

Deryelle described the first picture, "Well I drew her, and I drew the sun, and it is right behind her to the right."

Alexa, often silent in class when it was held in person, made a suggestion, "Could you draw the shadow in the picture? Even just a line in a shadow?"

Brian said, "My turn, OK?" He used the pencil tool to outline a shadow and filled it in, in the right place, opposite the sun.

When the next pair, Adrianna and Luis, modeled the shadow at noon, the image from the unknown location was analyzed again, and Miriam addressed the class, "Do you think it's strange that it's noon and the sun is not above her?"

One student said, "Yah, it's kind of strange." Another student said, "The sun should be right above her at noon."

Miriam said, "Do you think the sun is always directly above us at noon here, like here in Wisconsin, or the USA?"

There was general agreement, "Yeah." (And some chats asked, "What season is it?" and "Is it noon in the place or here?")

Miriam had taught this unit before; she was expecting the answer. She did not see the chats. "OK. How about we get evidence? Is there someone here who can look at the clock tomorrow and look and see where the sun is at noon tomorrow?"

Many voices called "OK I will. I will. I can do it!"

Miriam said, "Don't forget!" ("I won't forget!" called out a voice). Miriam said, "Draw a picture or take a photo of the sun and your shadow at noon. Tomorrow."

A handful of students decided to call each other to remind each other and to work together.

Before the pandemic, science was the most engaging time of the day, and Miriam was determined to maintain familiar and important routines during this stressful time. She said she believed that students appreciated that she used science to extend responsibility for collaborative learning and maintain high expectations for learning. The online context

continued

BOX 4-1 CONTINUED

was challenging, some students could not figure out the technology, the students missed one another and their teacher, and, as students were given more agency, there were disruptions to the scheduled discussions and activities. The online units were also challenging because students used the format to indicate their needs: socializing, self-disclosure, humor, movement, empathy, and understanding. They also needed to keep their minds engaged. Hence, focusing on student engagement through science and responding to their needs may not ultimately be a problem, but a solution.

SOURCE: Teachers are enacting an adaptation of ML-PBL at Michigan State, grant RC104702 from the Lucas Education Research Foundation. Adapted from Miller, E.C., Berland, L., and Krajcik, J. (In Review). *Opportunities for Project-based Learning during Social Distancing of the COVID-19 Pandemic*.

When sharing ideas with others, students need to feel that their ideas and perspectives are valued. Creating and maintaining group norms of participation, respect, and openness to new ideas and to changing previous ideas is an important aspect of this kind of instruction.[14] Teachers will need to ensure that student ideas are shared and considered equitably.[15] Students may vary widely in how they share their ideas with each other, whether verbally, through gesture, or in writing. The teacher, and the class as a whole, may need to learn how to recognize and support diverse patterns of discourse.[16]

These kinds of shifts in class norms and procedures—especially in remote environments where it may be more difficult to gauge all students' involvement—will require ongoing professional learning for teachers and opportunities to try strategies little by little over time.[17] This might include strategies for facilitating student-to-student discourse through digital platforms using video, audio, text, and drawings. Teachers may need support for finding new ways to encourage students to share ideas in pairs, small groups, or with the whole class, as well as

[14]For more information, see *How People Learn II: Learners, Contexts, and Cultures*. Available: https://www.nap.edu/read/24783/chapter/9#141.

[15]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#110.

[16]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#130.

[17]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#30.

ways to capture student ideas for engagement in argument, reflection, and revision. High-quality curriculum materials can also play a large role in supporting teachers to lead these kinds of conversations, providing suggested discussion starters, strategies for facilitating student discussion,[18] and examples of student questions related to sense-making or problem solving.

All of these recommendations do not need to be implemented on day one of the new school year.[19] They should be scaffolded and introduced over time. Teachers are not failing if everything is not implemented immediately. A shift to teaching and learning that mirrors the vision of the *Framework* was still new to many teachers even in an in-person classroom environment, and they will need additional effort to determine how best to continue this transition in new learning and teaching environments.

How is student agency being fostered?

In any remote or nontraditional learning environment, students will be required to be more independent in their learning. They need to learn how to set goals, monitor their progress toward those goals, and follow through on accomplishing them.[20] In addition to supporting their academic achievement in all disciplines, these are valuable life lessons. While establishing deeper relationships and new instructional routines, educators have an opportunity to support students in building agency and self-reflection skills that will help set them up for success in later schooling, careers, and their daily lives.

As discussed in the foundational principles in Chapter 1, instructional routines that focus on student sense-making of phenomena or problem solving help build student agency by engaging them in thinking through and planning instructional sequences. Similarly, giving students as many choices as possible—including the schedule for completion of work, the selection of research topics, the ordering of investigations when different orderings could each work coherently, and the modality of their assessment responses—helps them take ownership and stay engaged in their learning process. Providing students with flexibility of expression may mean that students need to be supported to access and use additional

[18]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#130.

[19]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/9#197.

[20]See Shepard, L.A., Diaz-Bilello, E., Penuel, W.R., and Marion, S.F. (2020). *Classroom Assessment Principles to Support Teaching and Learning*. Boulder, CO: Center for Assessment, Design, Research and Evaluation, University of Colorado Boulder.

technological tools. For example, some students may not have access to video cameras[21] that would be needed to record their gestures, which can communicate students' scientific understanding even when they do not know all of the scientific vocabulary or grammar that would be needed to communicate orally or in writing.[22]

Box 4-2 presents the story of a teacher who found ways to provide more autonomy for her students in their learning, through both scheduling and choices for how to engage in investigations.

BOX 4-2 GIVING STUDENTS CHOICES IN THEIR WORK

Alex was a first-year teacher in a rural school district in the 2019–2020 school year. She had learned in her pre-service program how important it is to support students' sense of agency to help motivate them, and she therefore tried as much as possible to give students choices, such as letting them decide what sources of energy they were going to research.

When the class moved to remote learning in the spring, some of her students from low-income families were struggling in different ways. Some had to work because their parents had been laid off. Some needed flexibility in scheduling in order to participate. Several students also didn't have access to devices or internet.

A social worker in the school began working with students who needed devices and internet access to help find the resources for them. The school began to offer Chromebooks to students who didn't have a device. However, that meant that Alex had to ensure that everything she wanted to do with the students would work with a Chromebook. She decided to have the class participate through Google apps so that students would have the option of completing all their work online, and she checked all online simulations to be used to make sure they were compatible.

In order to help her Earth science students figure out why wind affects ocean currents, she gave students a choice: they could either explore and investigate the phenomenon through online simulations, or they could set up an investigation to see the phenomenon

---

[21]Note that it is important to ensure that the privacy rights of both students and educators are protected when cameras are used. In addition, many students may feel uncomfortable if peers and the teacher can see or hear what is occurring in their home environments.

[22]See Suarez, E. (2020). "Estoy Explorando Science": Emergent bilingual students problematizing electrical phenomena through translanguaging. *Science Education*, 104(5), 791–826. doi: https://doi/org/10.1002/sce.21588.

BOX 4-2 CONTINUED

in their own house and to test different ideas. To help as many students as possible do the investigation at home, Alex made sure the required materials (e.g., bowls, water, black pepper), though common, were available to the students. In addition, with the option of doing the investigation through a simulation, any students who might not have the necessary materials were able to participate without any perceived embarrassment. When Alex collected students' feedback about the unit, she saw student comments about appreciating the choices and wishing they got them more often.

In summer 2020, Alex did not know whether her fall classes would be remote, in person, or a mix of the two, but she planned to continue trying to give her students as many options as possible no matter the format. For example, for in-person classes, because she would need to minimize the contact students have with materials and each other, she planned to split them into small groups that all focus on different aspects of a problem or phenomenon, and give students choices about which part they want to study.

SOURCE: Interview with Alex Chernouski, July 28, 2020.

The students in this story recognized and valued the choices they offered and expressed a desire to be offered such opportunities more often. This highlights students' perceptiveness about whether they are viewed as full and competent partners in their learning.

To ensure that students develop a sense of competence, they need enough support so that they never feel completely lost. Students need support as they work to understand directions and assignments and to realize that they have the tools and capability to complete the assigned work. Students, themselves, can assist in this process by doing such things as helping to brainstorm ways their class peers can learn to use new tools and procedures. They can also become partners in troubleshooting when something goes wrong—if the technology is not working as expected, if a classmate is disruptive, if they do not understand something someone said, or if their remote environment makes it difficult to engage.

How can investigations and design be done in remote environments?

Investigations are a central part of how students learn science and engineering.[23] In some classrooms, investigations have been traditionally used to allow students to physically engage with materials and confirm what was taught in the textbooks, but it is now well understood that investigations can be more fundamental to the learning process.

> "Students learn by doing. Science investigation and engineering design provide an opportunity for students to do. When students engage in science investigation and engineering design, they are able to engage deeply with phenomena as they ask questions, collect and analyze data, generate and utilize evidence, and develop models to support explanations and solutions. Research studies demonstrate that deeper engagement leads to stronger conceptual understandings of science content than what is demonstrated through more traditional, memorization-intensive approaches. Investigations provide the evidence that students need to construct explanations for the causes of phenomena. Constructing understanding by actively engaging in investigation and design also creates meaningful and memorable learning experiences for all students. These experiences pique students' curiosity and lead to greater interest and identity in science." (*Science and Engineering for Grades 6–12: Investigation and Design at the Center*, p. vii)

This process is still central when learning takes place remotely. Many science and engineering investigations do not need to be confined to classrooms or use of specialized equipment. Students can explore phenomena in their homes and communities, and they can engage in the science and engineering practices—such as asking questions, collecting and analyzing data, and arguing about evidence—to learn about the world and solve problems without being in a traditional laboratory.[24] Some investigations are purely based on students' observations, such as recording information about the weather over time, and teachers are already accustomed to helping students make these observations in their home environments. Some investigations that have typically been done in class could easily be supported with objects commonly found around the home, such as designing a

[23]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/4#33.

[24]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/4#32.

Rube Goldberg device to test energy transfer. Some districts are considering providing inexpensive materials that might not be available in all homes, such as magnets, to each student.

Box 4-3 describes how educators collaborated with families and caretakers to creatively figure out what kinds of materials could be used to support students in their engineering investigations.

BOX 4-3 IDENTIFYING MATERIALS FOR INVESTIGATIONS

The American Society for Engineering Education (ASEE) wanted to support students, educators, and families affected by schooling disruptions. They set up a Facebook page* where a new engineering design challenge is posted every day. They also started a remote summer engineering camp. For all of the Zoom-based learning programs, the course leads gave caretakers a list of supply needs a week ahead of time so that they would have time to think about gathering or substituting materials. The ASEE team emphasized that the lists of materials used in students' designs could be extremely flexible. For example, for one project that involved transferring energy from wind to a wind sail, the students and caretakers were given the following supply guidance:

- **Legos, K'Nex, axles, wheels, paper, cardboard, tape, string, Ziploc bags**
- **Don't have wheels? Carrots cut into round shapes? Cardboard wheels? Plastic bottle caps?**
- **Don't have axles? Toothpicks? Straws? Pencils? Barbecue skewers?**
- **Fan to provide the wind (or go outside if it's a windy day)**

When families did not have any of the suggested substitutions at home, they could ask the course leads for other ideas. Discussions about available materials were also great opportunities to talk with the students about constraints in engineering design. One of the leads on this project made sure that her whole instructional team was sensitive about language when talking about constraints to make sure their language was inclusive and did not marginalize students who may not have certain materials at home—to be clear from the beginning that anyone could run out of anything on any given day, and that the point is about figuring out solutions.

*https://www.facebook.com/groups/687366151802693/.

SOURCE: Interview with Stacy Klein-Gardner, July 27, 2020.

This story illustrates the role families can play in helping to think through how to provide materials necessary to engage in investigations. To participate effectively in this planning process, however, the families in the story needed time in advance to save materials or think of alternatives, and they needed access to the course educators for troubleshooting discussions.

In general, many types of investigations can be managed effectively in remote settings. However, without access to measurement equipment often used in classrooms, such as digital scales, graduated cylinders, or scientific thermometers, students might not be fully prepared to engage in some discussions about data accuracy until they return to a classroom. Students would still be able to engage in robust collaborative discussions of the details of an investigative plan, but the quality of data collected at home might not be as high as that collected at school. Alternately, if there are data students cannot collect, the teacher could remotely demonstrate some data collection and measurement issues, or students may be able to analyze data from existing databases,[25] such as those provided by the United States Geological Survey[26] or the National Oceanic and Atmospheric Administration.[27] When using data sets, there could be implications for how students engage in analyzing and interpreting data and developing evidence-based explanations if they cannot use data from their own investigations. Students may need extra support to see how the data fit together with the phenomenon or problem being addressed when they are not able to collect their own data.[28]

Most importantly, activities that involve handling any potentially toxic chemicals or dangerous maneuvers should not be used in remote environments, so this constraint will limit the scope of some investigations. When instructional units rely on student engagement in such activities, it could be helpful to move these instructional units to later in the school year or to a different school year, or to set up laboratory access for rotating small groups of students in a classroom or community partner location, such as a museum. However, even when classes take place in person, there are extensive safety issues to consider in light of the pandemic.[29] For example, students and teachers should frequently wash their hands, and materials and equipment need to be cleaned after each person uses them. The

[25]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#160.

[26]See https://www.usgs.gov/products/data-and-tools/overview.

[27]See https://www.ncdc.noaa.gov/data-access/quick-links.

[28]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#168.

[29]For more information, see *Reopening K–12 Schools During the COVID-19 Pandemic: Prioritizing Health, Equity, and Communities*. Available: https://www.nap.edu/read/25858/chapter/7#57.

National Science Teaching Association Safety blog has compiled detailed recommendations for safe investigations in both remote and classroom environments.[30] It could also be helpful to make use of outdoor learning spaces because they have many benefits to learning and might facilitate social distancing and reduce the number of common materials handled by students.[31] All of the established safety considerations related to outdoor learning spaces will still be applicable, though, in addition to the safety considerations related to COVID-19.[32]

Due to the difficulties of engaging in some investigations safely during the pandemic, many teachers are exploring the use of simulations for student investigations. Simulations can be especially effective for allowing students to visualize and explore phenomena that are not normally visible, such as the movement of particles.[33] Use of simulations also provides an opportunity to support students in the science and engineering practice of using computational thinking, using and developing computer models of phenomena to collect data or test engineering designs,[34] and seeing the effect of new parameters or data on simulation outcomes. Ideally, simulations could be paired with comparisons to other investigations that students conduct themselves. Some sources of simulations are free online, such as those created by Phet[35] and the Concord Consortium.[36] To use these tools effectively, teachers will need support for incorporating them into instruction and helping students interpret the results.[37] In particular, younger students may need more scaffolding to make appropriate connections and distinctions between a simulation and the real world.

The challenges related to conducting investigations in remote environments may provide educators with a new opportunity to reconsider the purpose of each investigation used in instructional units. If an investigation had been previously included for the purpose of giving students "hands-on" experience with materials and helping them confirm conclusions, that investigation does not need to be incorporated into remote instruction. Educators can instead focus on

---

[30]See https://www.nsta.org/topics/safety#lab-safety-blog.

[31]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#220.

[32]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#227.

[33]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/8#172.

[34]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available https://www.nap.edu/read/18802/chapter/5#28.

[35]See https://phet.colorado.edu/.

[36]See https://concord.org/our-work/focus-areas/stem-models-simulations/.

[37]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/9#194.

investigations that are used as a central part of students' work to figure out science and engineering ideas and build proficiencies such as thinking through investigation design considerations.[38] Because secondary school teachers typically have had more experience teaching traditional lab classes, they might need extra support to shift away from confirmatory labs.

How can technological tools be incorporated effectively?

Once educators have chosen their approach to effective remote instruction—including how students will be sense-making or problem solving, how the experience will be coherent and collaborative, and how student agency will be supported—technological tools to support this approach can be chosen. A wide variety of apps are available to support research-based science and engineering learning and teaching, including using discourse-driven sense-making of phenomena.[39] Some districts and states are sharing lists of suggested tools with teachers.[40] When choosing tools to support instructional routines, it is important to keep instructional goals in mind and to select tools and uses that will best support students even if those tools are not the newest or flashiest available. High-quality learning and teaching need to remain the central focus.[41]

Students may be excited, at least initially, to have the opportunity to use some new types of software and hardware for their learning.[42] However, student engagement is not the only goal. Productive engagement means that students are motivated to figure out a phenomenon or solve a problem, and many types of technological tools can support and even extend this kind of engagement.[43] Programs such as Jamboard,[44] Padlet,[45] or Pinup[46] could support student exchange of ideas in a similar way to how a driving question board could be used in a physical classroom, but also provide the option for discussions to continue

---

[38]See http://ambitiousscienceteaching.org/wp-content/uploads/2014/08/Primer-Supporting-Changes-in-Thinking.pdf.

[39]See https://docs.google.com/spreadsheets/d/1uqPSgLG8THMu77uGq2A_uW8Tmu0JVx-_3CR6JobfEKk/edit#gid=296808603.

[40]See, for example: https://drive.google.com/file/d/1oJ8j8K7iWx7up3krPt63iGispFtqxsna/view?fbclid=IwAR3pvbNyO0LeL25O2MuHY9C7DnxZJO9tjwXVCNq77BaBjIYTyvl9wdJ8tro.

[41]See https://aect.org/docs/SurveyofInstructionalDesignModels.pdf?pdf=SurveyofInstructionalDesignModels.

[42]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/9#194.

[43]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#170.

[44]See https://gsuite.google.com/products/jamboard/.

[45]See https://padlet.com/.

[46]See https://pinup.com/.

asynchronously at students' own pace. Similarly, online modeling tools can augment students' ability to visualize their own thinking and communicate their learning.[47] Models drawn on paper and then photographed can serve many of these purposes, but digital models can be more easily revised as students' learning progresses, and some can even be used to test ideas.[48,49] The Google Science Journal app[50] can support students' work with investigations, allowing students to both collect and write about data. Many of these tools used for online and remote learning could also be useful and valuable for in-person classroom engagement.

For example, Figure 4-2 shows a 6th-grade student's initial model on Jamboard as an attempt to make sense of one part of a phenomenon—how heartworms got into a dog's bloodstream. This was used in class as a steppingstone to building an understanding about how different parts of an ecosystem interact with one another and are affected by environmental changes. The student pasted images, labels, and a description to develop their model. Their classmates were then able to add questions or feedback to the page, and students were encouraged to reflect on this feedback to determine whether they wanted to make changes to their models.

A heavier reliance on screen time for teaching and learning may introduce new difficulties with communications, but it may also augment communications in many other ways. For example, many devices and applications do not support use of closed captioning or sign language. However, technology makes it easy for students to rewatch videos as many times as they need to, view transcripts and translations of the audio, and submit ideas and questions through various modalities, including text, audio and video recordings, and photos. For example, students could take pictures of their engineering designs to communicate their initial ideas about how to solve a problem and share those pictures with the class and the teacher. The use of video cameras could also improve remote communication during both synchronous and asynchronous exchanges because they allow students and teachers to attend to nonverbal cues such as gestures and facial expressions.[51]

---

[47]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#239; also see https://sagemodeler.concord.org/.

[48]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/6#97; also see https://www.edsurge.com/news/2018-02-01-how-samr-and-tech-can-help-teachers-truly-transform-assessment.

[49]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/6#97.

[50]See https://sciencejournal.withgoogle.com/.

[51]Note that it is important to ensure that the privacy rights of both students and educators are protected when cameras are used. In addition, many students may feel uncomfortable if peers and the teacher can see or hear what is occurring in their home environments.

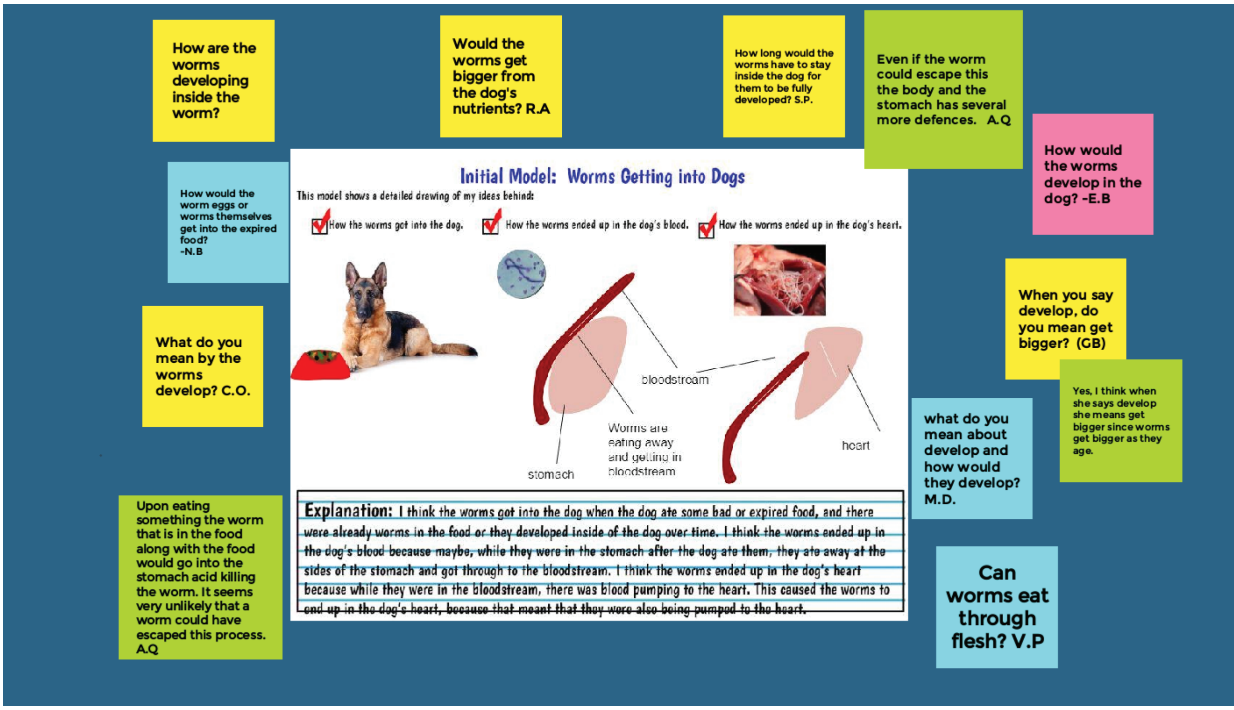


FIGURE 4-2 A 6th-grade student's model of how heartworms get into a dog's bloodstream.
SOURCE: Interview with Gretchen Brinza, July 29, 2020.

Asynchronous sections of a class can allow students time to think and reflect before contributing ideas or to work in small groups in their native language before translating to English. Working in breakout rooms can allow students to share their ideas in small groups in a low-pressure situation before sharing them with the whole class.[52]

Similarly, some accommodations for students with visual and mobility impairments,[53] such as using a camera to capture and then broadcast what a teacher sees through a microscope, are supportive of all students' learning in remote environments as well. Whether in remote or in-person environments, following the principles of universal design for learning can maximize students' opportunities to engage in scientific and engineering investigations.[54] This can

[52]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#130. Also see *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives*. Available: https://www.nap.edu/read/25182/chapter/5#60.
[53]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#234.
[54]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#233.

include using assistive technology, providing materials in multiple formats, and allowing students to participate through multiple modalities.[55] The International Society for Technology in Education has resources to help educators think through accessibility issues with online learning.[56]

There have never been as many choices of tools available for instructional support as there are now. However, when students are asked to learn to use new programs or applications for each activity or for each class, they may be distracted from their learning and could become frustrated. To help ensure that students are supported to believe that they can succeed, it might be helpful to provide step-by-step use videos for each new program required and to reduce the number of new programs introduced. It may also be helpful to support coordination between teachers to decide about whether the same programs can be used in multiple classes. Such coordination is particularly important for middle and high schools, where students typically have different teachers for classes.

In addition, many students may not have access to a computer or broadband internet or may not be able to access them at the same time as the rest of the class due to multiple siblings sharing one device or family members working from home. It is therefore important to plan for ways to provide access to learning for all students and to consider equity of access when selecting learning activities, such as simulations. Providing offline or low-bandwidth materials may be essential.[57] As noted in Chapter 3, some teachers are taking advantage of students' access to a parent's or caretaker's cell phone to support participation, although cell phones do not provide students with the same type of experience as they would have on a computer.

As the tools and routines selected may be new to many teachers, professional learning opportunities could be provided to enable teachers to have first-hand experience with the tools and routines as a learner, allowing them to develop new strategies for use with their students and to plan for remote classroom management.[58] Such opportunities could support innovation, allowing educators the flexibility to think creatively and apply what they learn to effectively support the individual needs of their students.

---

[55]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#163.

[56]See https://www.iste.org/learn/online-learning.

[57]See http://documents1.worldbank.org/curated/en/531681585957264427/pdf/Guidance-Note-on-Remote-Learning-and-COVID-19.pdf.

[58]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#173.

More information about educational resources and organizations that can be helpful partners in supporting teaching and learning remotely have been compiled by SETDA.[59] In addition, the National Science Teaching Association is hosting an ongoing series of webinars supporting remote learning.[60]

NEXT STEPS TO CONSIDER

- Provide supports to ensure equitable access for all students to instruction, whether providing technology access or ensuring that low bandwidth tools are available.
- Provide guidance to teachers about:
    - how best to divide synchronous and asynchronous time;
    - the importance of establishing equitable norms for participation and discussion;
    - ways to help build student agency in the learning process, including providing students with choices in their learning; and
    - whether online breakout rooms are allowed and, if not, what alternate methods could be used to facilitate small group remote discussions.
- Provide examples and templates to teachers for using student curiosity about sense-making and problem solving to drive instruction.
- Find ways to reduce the number of different technological tools students have to use for their different classes, for example, by providing common tools or encouraging teachers to share resources with each other.
- Ensure that students, families, and teachers are all aware of and commit to safe practices for engaging in investigations whether remotely or in classrooms.

[59]See https://www.setda.org/main-coalitions/elearning/partner-resources/.
[60]See https://common.nsta.org/search/default?action=browse&type=webseminararchive&sort=4.

5

Managing and Modifying the Scope of Content and Curriculum

It takes time for students and teachers to build relationships and then to begin exploring and building the science and engineering ideas necessary for explaining phenomena and solving problems. However, teaching and learning during a pandemic very likely comes with challenges related to instructional time. As a result, educators may feel that they need to find ways to reduce the amount of material they "cover." It might be tempting to choose a set of "priority standards" to address this issue for science and engineering, as was done for mathematics and English language arts, but priorities in science and engineering are framed differently. This chapter describes the priorities of science and engineering education and describes ways to optimize instructional time.

In addition to challenges related to instructional time, the current and ongoing changes in the education landscape likely also require that instructional materials be modified to account for technology constraints and student needs. These modifications may need to be made to every lesson, whether an open educational resource, a commercially produced resource, or materials developed at the district level. Some developers are making some adjustments to their materials, but many others are not. For science, very few multigrade coherent instructional programs are currently available that have been adapted to support instruction in multiple learning environments. As a result, many districts and teachers feel pressure to either quickly modify materials on their own or find new online programs as a stop-gap measure.

Although the work to make the necessary modifications to instructional materials is happening at breakneck speed, it is important to ensure that the resulting materials retain and even increase their focus on good teaching and learning principles—on how students can learn science and engineering effectively. High expectations for all students need to be maintained, supporting high-quality educational experiences that empower students. Whether learning and teaching take place in person or remotely, synchronously or asynchronously, a focus on the vision of science and engineering education remains the same: all students making sense of phenomena or solving real-world problems by learning and applying grade-appropriate disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs).

It is challenging to figure out how to save instructional time and still be consistent with the vision of the *Framework*. However, if the scope and sequence of materials need to be modified to account for resource disparities in remote environments, it is critical that students not be disadvantaged by receiving less engaging and rigorous instruction as a result of the modifications. When educators review materials that have already been adjusted, they will need to look carefully at where changes have been made to make sure the changes will not negatively affect students or increase inequities in opportunities to learn.

The guiding questions in this chapter are intended to help education practitioners consider how this volume's four foundational principles—in particular, Principle 1—can be applied to modifying the scope and sequence of materials and to reviewing materials that have been modified—whether locally or by the original developers—to ensure they support learning in the current changing environment and adhere to the vision of the *Framework*:

How can instructional time be used most effectively?

How can instruction be organized to focus on the most conceptually meaningful student work?

The focus of curricula will need to be on conceptually meaningful student work. When the schedule and mode for instruction shifts and time in the classroom is reduced, there is an opportunity to look beyond the concept of seat time and focus on what students really need to take away from their learning experiences. There is no time for busy work—work that does not build deep and flexible knowledge and skill—and it might be necessary to leave out some favorite instructional activities that are fun, but do not link to meaningful content, or that focus mainly on memorizing specific facts or details.

Practitioners modifying or reviewing instructional materials can look for evidence that all parts of instruction are deeply meaningful, providing support for either building relationships between peers and the teacher or carefully building enduring student proficiencies in all three dimensions.

However, building these student proficiencies in science and engineering is a time-intensive process. Although there are many ways to maximize instructional time, it might not be feasible for students to reach all of the previously targeted learning goals during a period of ongoing system disruptions. In this situation, the focus needs to shift from trying to "cover" all of the targeted content to staying true to the vision of the *Framework* and the NGSS with rich three-dimensional learning experiences. Covering content in relation to science and engineering education is often enacted as the delivery of information about the DCIs to students. In such a scenario, none of the *Framework* or NGSS learning goals would be met.

The *Framework* includes descriptions of the progressive deepening of a limited number of DCIs over time. Even without the constraints of technology and time imposed by a pandemic, the focus was already on depth over breadth. For example, rather than including details of concepts such as stoichiometry, the DCIs focus on broadly applicable ideas, such as the conservation of atoms during chemical reactions. In addition, by emphasizing the need for students to integrate such ideas with science and engineering practices and crosscutting concepts, the *Framework* called out the value of having students build useful knowledge and skills in an authentic way. Instead of having students memorize ideas related to DCIs and then reflect those ideas back on assessments, students engage in such practices as analyzing data or arguing from evidence to develop DCIs and CCCs, and then show that they have developed these thinking tools by making sense of a phenomenon or solving a problem. In this way, students learn deeply enough that they are able to transfer their knowledge and skills to new situations.

Box 5-1 details how one teacher implements the idea that understanding the underlying principles of science in a deep way can prepare students to see connections between different areas of science, helping them ask the right questions and more easily solve problems when they encounter new situations, and transfer their knowledge and skills to explain new phenomena.

BOX 5-1 FOCUSING ON MEANINGFUL WORK

Gretchen is a 5th- and 6th-grade science teacher in Chicago. She uses a student-driven story lines approach with her students in which all lessons build on each other progressively to answer questions the students asked and work toward explaining phenomena. The students started the 2019–2020 school year by trying to figure out why cold drinks warm up faster in some cups than in other cups. In the first instructional unit, they eventually built an understanding of kinetic energy and molecular collisions. Then in the second unit, students tried to figure out how and why Mount Everest moves so drastically each year and even more so during earthquakes. The students started to see patterns between the concepts they had to use to figure out the two very different phenomena.

Students asked Gretchen: "Is this earthquake thing like the cups? Like the energy in a hot drink transferring to the cup's walls is like the energy of the Earth's core needing somewhere to go?" They were beginning to build the understanding of how much in the world can be explained by the kinetic energy of molecules.

When the class moved to remote learning in the spring, the class was in the middle of explaining another set of phenomena—beginning with trying to figure out what was wrong with a sick dog—and Gretchen knew it would be in the students' best interest to continue their current storyline, allowing students to continue to work collaboratively through jamboards and class discussions toward answering their own questions. Students discovered that the dog had heartworms* and learned that heartworm incidence rates have been on the rise due to environmental factors, such as precipitation and temperature increases. The students once again had the epiphany on their own that if temperature is involved, then something about heartworm transmission must be affected by the kinetic energy of molecules. This connection is not made in the materials because it is very advanced, but could easily lead students to ask very astute questions about how the development of heartworm larvae is affected by the kinetic energy of molecules.

*An interim student model from this process is shown in Figure 4-2, in Chapter 4.

SOURCE: Interview with Gretchen Brinza, July 30, 2020.

To make the best use of limited time, student learning experiences can aim to build and make use of the kinds of deep understandings that were seen in the story. These experiences equip students to make sense of the world around them.

The process to begin narrowly focusing instruction on deep and meaningful three-dimensional learning might look different in different grade bands because middle and high school students might have already had more experiences using the three dimensions during instruction than elementary students. The secondary students might therefore have more comfort with this kind of learning, potentially providing a smoother transition to its use in a different learning environment.

How can students build toward more than one science or engineering learning goal at one time?

Educators can also maximize instructional time by connecting different science and engineering domains and ideas. For example, if students are trying to figure out how a tree grows, they will need to build ideas from both the life and physical sciences. When ideas from both domains are supported simultaneously, it takes less instructional time than if there is a focus in one unit only on life science ideas about photosynthesis and then a focus in another unit only on the regrouping of atoms in chemical reactions. In the same way, it would take more time to focus on helping students learn how to conduct investigations in one unit and then to begin learning how to analyze data in a separate unit.

One of the benefits of using real-world phenomena and problems as instructional drivers is their tendency to require both learning from multiple domains and from multiple practices. This tendency supports the use of "bundling," or building toward multiple standards, performance expectations, or unit-level learning goals at one time. Instructional materials can take advantage of natural connections between multiple SEPs, DCIs, and CCCs to help students make sense of phenomena or solve problems.

These bundles can form the basis for instructional units. For example, in a 9-week 5th-grade unit from the Science and Integrated Language (SAIL) team at New York University, students explore a series of phenomena related to how garbage smells and why it changes over time. The students engage in instruction that builds their proficiency toward ideas related to decomposers in an ecosystem, the particle model of matter, different properties of matter, conservation of matter, and chemical reactions. Students also build toward several aspects of five different

SEPs as well as building understanding of how parts of five different CCCs can be used to help make sense of phenomena. In addition, the unit promotes language learning for all students, including English learners. By bundling these ideas together, students' experiences were both more coherent and shorter than they would have been if all learning goals were addressed independently.

Some elementary instructional units and middle school courses already integrate science disciplines in this way; in contrast, high school courses very rarely integrate more than one discipline. Therefore, for bundling discussions at the high school level, educators might begin within each science discipline independently.

How can learning be coordinated within and between grade levels?

> The sequence of core ideas that are introduced throughout the year, and the connections made between them are important in helping students develop an understanding of the most important ideas in science and how they are connected or related through crosscutting concepts. (*Guide to Implementing the Next Generation Science Standards*, Chapter 5, p. 29)

In addition to coherence within instructional units, as described in the previous chapter, it is important to plan for coherence within and between years. Although ideas in science and engineering do not build in as much of a linear, grade-by-grade fashion as do those in mathematics,[1] scientific ideas, concepts, and practices exist as progressions that build over time. The ideas, concepts, and practices students build in their early years support their future learning. If these foundational ideas and practices are completely omitted in an attempt to save instructional time in one year, student learning in future years will be affected.

These science and engineering progressions are important factors when adjusting or evaluating curricula. If high-quality, year-long instructional programs are available that have been adjusted to accommodate student needs for remote or hybrid environments, they will likely be the most coherent option for students because connections are often made between one instructional unit and the next. However, when these options are not available, it is important to consider the progressions between ideas to decide whether some content will be skipped this year, what content can be built in for future years after students are back in school in person, and what content order will be most conducive to student learning in remote, hybrid, or blended learning environments.

[1]See https://issuu.com/achieveinc/docs/achieve-learningprogressionsincbp.

When modifying or evaluating curriculum for early parts of the school year—times when establishing relationships and instructional routines in remote or hybrid environments is essential—it could be helpful to focus on phenomena or problems that do not directly build on core ideas from the previous year or grade level so that all students can start with a common, shared experience. For example, a phenomenon about hair being attracted to a balloon would help students build toward a 3rd-grade level of understanding of electric and magnetic forces and does not directly rely on understanding of related DCIs from 2nd grade.

Later in the school year, after relationships and instructional routines have already been established, educators can consider choosing phenomena or problems that can help diagnose what students may be missing from previous instruction. For example, a problem about weather-related hazards used in 3rd grade might require students' background knowledge from 2nd grade about how water can change the land and how it can exist in both solid and liquid form. This problem could therefore be used later in the 3rd-grade year, after students and the teacher have become comfortable with one another and with the instructional model. This approach would allow the teacher more time to focus on closely monitoring student learning, uncovering students' underlying ideas about water, and working with students individually to ensure they have the support they need to solve the problem about weather-related hazards. Below is a schematic of this approach (Table 5-1).

TABLE 5-1 Considerations for Units Across the School Year

Early in the School Year	Later in the School Year
Not relying on understanding of related DCIs from the previous grade	Requiring understanding of related DCIs from the previous grade
Providing common, shared experiences	Diagnosing what might be missing from previous instruction

To use this kind of approach, it is important to understand how DCIs, SEPs, and CCCs build on students' prior understanding, including within a grade band. Although the *Framework* describes DCIs as end-of-grade-band expectations, they are often used as learning goals in individual courses. Appendix K of the NGSS describes some examples of the ways middle and high school courses that use these DCIs can be sequenced conceptually over time within the grade band.[2] These

[2]See Appendix K. Available: https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20K_Revised%208.30.13.pdf.

types of examples may be helpful in thinking about the conceptual foundations students will draw upon for learning in each course.[3] In middle and high schools, districts (even within the same state) are likely to be using different course models, so coherence within progressions will need to be determined based on the course model used.

Figure 5-1 below is an image from NGSS Appendix K. In this course model, educators put the DCIs they considered to be foundational in course 1 and showed with arrows how the ones introduced in course 2 build on those in course 1, and how the ones included in course 3 build on those in course 2. Connections such as these are present throughout the K–12 content of the *Framework*.

In the NGSS, a section on each page of performance expectations lists "Articulation of DCIs across grade bands." They include many, but not necessarily all, connections students might be building on as they progress in their learning. Appendices E,[4] F,[5] and G[6] of the NGSS describe progressions of the three dimensions across grade bands K–12. Appendix E summarizes the core ideas in each grade band so the differences across time are clear, and Appendices F and G list the specific elements of the SEPs and CCCs, respectively, that students are expected to know by the end of each grade band (i.e., by the end of grades 2, 5, 8, and 12). For example, Figure 5-2 shows the progression for one CCC, Stability and Change. In addition, examples of K–12 connections and progressions for all three dimensions of the *Framework* are listed and described in the National Science Teaching Association (NSTA) Atlas of the Three-Dimensions.[7] Using these resources can help educators identify knowledge and skills that will be used as the foundation for future learning.

Not all the foundational building blocks for students' learning are necessarily found within the same science discipline. For example, students' understanding of the particulate nature of matter developed in late elementary school directly supports their learning related to photosynthesis and water cycles in middle school. As these connections are not always immediately apparent, it is important to communicate and plan across grade levels so that students' learning over time

[3]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available https://www.nap.edu/read/18802/chapter/7#56.

[4]See https://www.nextgenscience.org/sites/default/files/resource/files/AppendixE-ProgressionswithinNGSS-061617.pdf.

[5]See https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf.

[6]See https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf.

[7]See https://old.nsta.org/store/product_detail.aspx?id=10.2505/97819389466080.

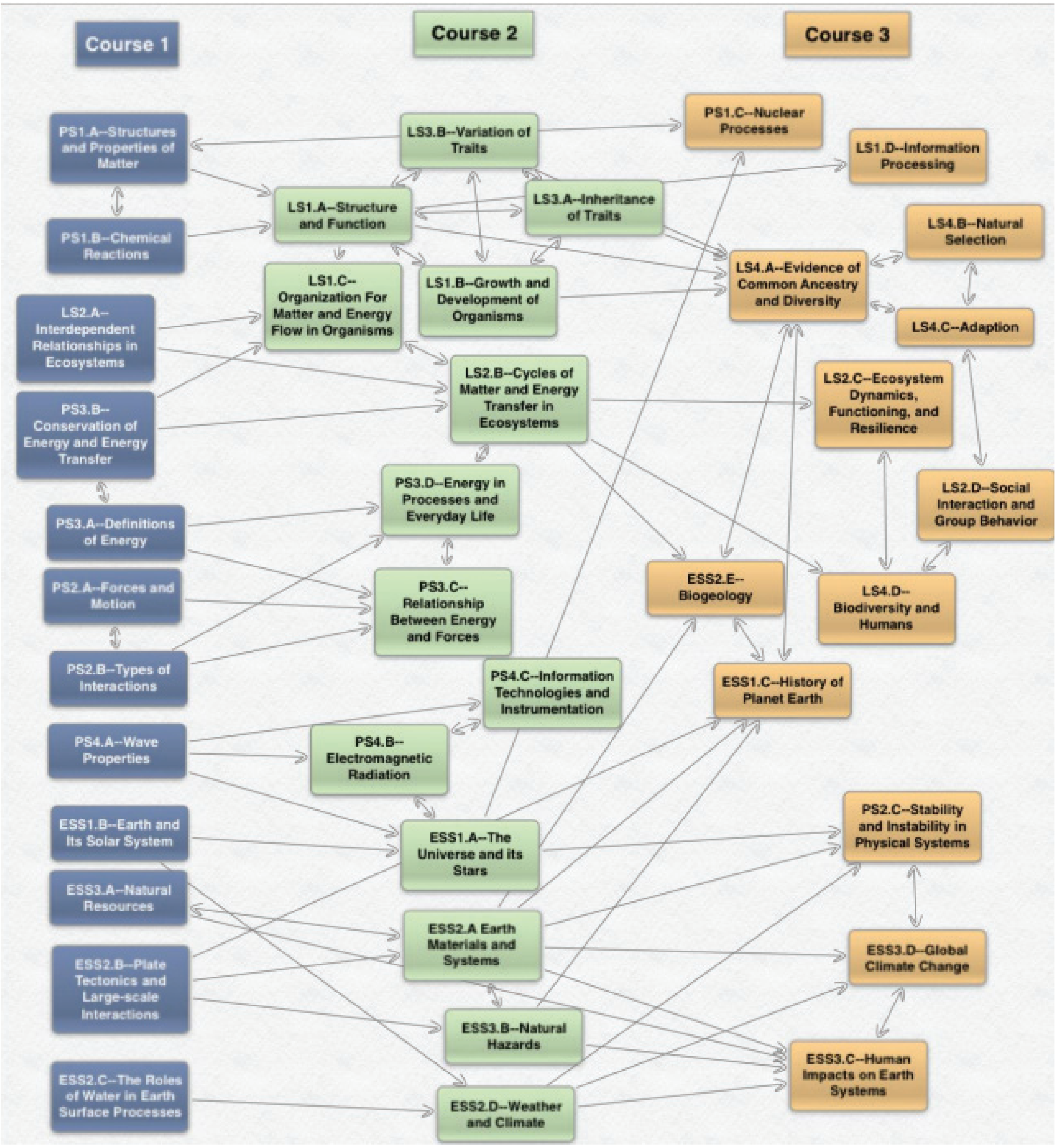


FIGURE 5-1 Educators' mapping of performance expectations.
SOURCE: NGSS Appendix K. See https://www.nextgenscience.org/sites/default/files/Appendix%20K_Revised%20 8.30.13.pdf.

Primary School (K–2)
• Things may change slowly or rapidly.
• Some things stay the same while other things change.
Elementary School (3–5)
• Change is measured in terms of differences over time and may occur at different rates.
• Some systems appear stable, but over long periods of time will eventually change.
Middle School (6–8)
• Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.
• Small changes in one part of a system might cause large changes in another part.
• Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.
High School (9–12)
• Much of science deals with constructing explanations of how things change and how they remain stable.
• Systems can be designed for greater or lesser stability.
• Feedback (negative or positive) can stabilize or destabilize a system.
• Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

FIGURE 5-2 Learning progression for Stability and Change.
SOURCE: Adapted from NGSS Appendix G and used in Furtak, E., Badrinarayan, A., Penuel, W., Duwe, S., and Patrick-Stuart, R. (Forthcoming). Assessment of Crosscutting Concepts: Creating Opportunities for Sense-Making. In J. Nordine and O. Lee (Eds)., *Crosscutting Concepts: Strengthening Science and Engineering Learning.* Arlington, VA: NSTA Press.

can be coherent after any adjustments are made to curricular progressions. This is particularly critical if foundational content is moved from this year to a subsequent year because of the COVID-19 pandemic.[8]

Challenging students to continually progress in their learning over all three dimensions can also help maximize instructional time. If instruction this year shifts to include new ideas that are easy to learn and teach in a remote environment but do not help to build toward learning progressions, students' time will not be used most efficiently. When students are "introduced" to cell structures, modeling,

[8]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#143; also see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/7#53.

or the idea of cause and effect multiple times over several years of school, they may begin to feel bored or that their prior understanding and ideas are not being considered and honored. Students are unlikely to feel engaged if instruction is repetitive. Finding out what students have already learned can help educators and curriculum designers position new content as an extension of previous content without spending valuable time on repetition.

The call for less repetition, however, does not mean that SEPs and CCCs should not be used more than once. To build deep understanding of and engagement with these dimensions and be able to use them in new situations, students need to experience them with multiple different DCIs in the context of multiple phenomena or problems. In many state standards, including the NGSS, SEPs and CCCs build throughout each grade band, allowing students the opportunity to explore them in multiple contexts over time. Students therefore have more than 1 year to build toward proficiency on the different aspects of each SEP and CCC.

This approach allows a large amount of flexibility during educational transitions. Instruction could begin in fall 2020 by allowing students to apply SEPs and CCCs they have previously developed to new phenomena or problems instead of trying to develop new SEP and CCC proficiencies right away. For example, while students are adjusting to a new instructional schedule, they could begin the year using their previously developed SEP proficiency in using models to predict a new phenomenon rather than beginning the year trying to learn how to choose which type of computer model will make the most accurate predictions about a phenomenon. Similarly, students faced with figuring out the phenomenon that "some parts of the world get a lot of rain and other parts get very little rain" could use their prior CCC knowledge that "systems may be part of larger complex systems" to think differently about how to approach the phenomenon. Using this concept, they could ask "are there larger global systems that affect the precipitation rate in the different areas?" rather than immediately being required to learn how to use new CCCs as thinking tools. This kind of repeated use of particular SEPs and CCCs can also be beneficial in shifting learning environments by helping to build consistency and familiarity across lessons.

Just as there is some flexibility with building SEPs and CCCs across grade levels, it may be helpful to think differently about building student understanding of DCIs over the next 2–3 years as the education system slowly recovers. DCIs are divided only by grade band throughout K–12 in the *Framework*. With the reduced emphasis of high stakes testing in many states, educators may have more flexibility to support students to build toward DCIs in a way that works well in the current learning environment. For example, if classes are not able to support students to build toward the 3rd-grade idea "Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years" this year, it could be bundled together next year in instruction that builds toward the 4th-grade idea "Rainfall helps to shape the land and affects the types of living things found in a region." In this way, students would still be able to deeply build understanding in the DCIs by the end of the grade band even if the scope of instruction each year is shifted.

How can phenomena or solutions to problems be investigated in students' homes or communities?

When modifying or reviewing instructional materials for blended, hybrid, or remote environments, the driving phenomena or problems need to be carefully selected.[9] Consider choosing as the focus of instruction phenomena or problems that:

- make clear connections to students' interests and backgrounds,
- require students to build toward grade-appropriate learning goals, and
- can be investigated safely in remote environments or with materials that are widely and inexpensively available.

As discussed in Chapter 4, even when classes are expected to be fully in person for all students, situations may change quickly, and back-up plans will be needed.

As one of the foundational principles of this document, the idea of using phenomena and problems to drive all science and engineering instruction has already been discussed. In particular, Chapter 3 introduced the importance of choosing phenomena or problems that are truly engaging to students and connected to their homes and communities. Students have a better chance to succeed if their learning is contextualized with relatable and personally meaningful phenomena. Although the idea of using phenomena and problems to drive instruction is not unique to pandemic-related system disruptions, it has become more critical than ever. Educators reported widespread lack of student interest and engagement

[9]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#27.

in learning in spring 2020 after their classes moved to remote settings.[10] Allowing students to engage with phenomena and problems that are closely connected to their lives or the lives of their families and others in the community is one of the best ways to maintain student interest in their own learning.

The phenomena used do not need to be extraordinary occurrences, such as explosions or a two-headed fish. Interesting science phenomena, such as color, are all around children every day. Teachers can help students become curious about these phenomena, helping them realize that they are not already able to explain why their pencil looks red.[11] The same is true for focusing instruction on problems to solve: selecting small, everyday problems that are relevant to students and their communities, such as the fence on a hill becoming loose after a heavy rain, can encourage students to find other similar, related phenomena and problems in their own neighborhoods.

Box 5-2 presents the story of a group of young children engaged in trying to help their teacher solve a simple, everyday problem. Finding the solution allowed them to build toward their learning goals, including beginning to build a foundation for planning investigations and making claims from data. The students were able to work both collaboratively toward sense-making and independently to record their ideas, creating formal writing artifacts.

BOX 5-2 PROBLEM SOLVING WITH SEEDS

The first time they met with the 5- and 6-year-old students in their classes via video conference after switching to remote instruction in Spring 2020, the teacher team from the Early Learning Center was not sure who would attend and how they would adjust to the unfamiliar set-up. As the children trickled into the virtual meeting room, they squealed with joy to see their teachers and one another. They naturally began sharing what they had been doing during quarantine, and showing each other drawings, toys, and pets. After about 10 minutes, the teachers welcomed them more formally and introduced some simple norms for remote participation (e.g., put your finger on your nose if you want to ask a question). Teachers and student teachers took turns "driving" the technology (e.g., muting and unmuting microphones) and leading instruction.

continued

[10]See https://wested.ent.box.com/s/bs3aezjcj9s6daowr4z9fwp7lfbjm0ia.

[11]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/7#113.

BOX 5-2 CONTINUED

Before the pandemic, the children had been investigating what plants and animals need to survive. When classes changed to remote instruction, teachers were aware that they needed a compelling question and multiple relevant opportunities to collect and make sense of data. They launched a unit virtually using a favorite approach with young students—whoopsie daisy!—in which the lead teacher, walking outside, tripped and dropped a container of seeds that she was planning to plant in her garden. The fallen seeds presented a problem because they were now mixed with pebbles and other small objects as she scooped them up.

The question driving initial instruction based on this problem was "Which ones are seeds?"

Students were immediately eager to assist with the task, and intuitively suggested sorting the objects by size, shape, and color. Once objects were sorted, though video conversations, the teachers asked students to make predictions about which ones were seeds and recorded their ideas on a chart the students could see on the screen. Participation was structured such that children were able to agree and disagree with one another about the variety of small objects before brainstorming how to figure out which objects were seeds.

The class was unified on its plan to plant what might be the seeds in dirt in separated cups, add water, and place them in the window to get sun. Teachers patiently followed children's directions, seizing the opportunity to engage in the science practice of designing a simple and fair test of which objects were seeds and which were not. Over the next few weeks the class observed through daily pictures that baby plants appeared in some of the cups and not in others, as shown in the picture:

BOX 5-2 CONTINUED

Because teachers had grouped like objects in columns, germination patterns emerged as a histogram that was easily transferrable to a simple data table. Children could negotiate basic claims (part of a science practice) about which objects were seeds based on evidence of sprouting, using their idea that some things change and some things stay the same (part of a crosscutting concept). Once seeds were identified, the class designed a series of investigations to determine what plants need to survive (e.g., light or dark, soil or no soil, water or no water).

SOURCE: Adapted from a case developed by Carla Zembal Saul for use in this book (personal communication).

The driving problem to solve in the story maintained students' engagement over many weeks of instruction, allowing students to drive more of the learning themselves and to build a sense of agency in the learning process. When phenomena and problems are used in this way, they can anchor units of instruction and help students learn to handle setbacks and wrong turns along the path to an explanation or solution.[12] During this process, supporting students to make close connections to the lives of their families and others in their communities can motivate them to persist in their learning.

Box 5-3 describes how a teacher engaged students in figuring out a compelling phenomenon and used a survey assignment to ensure that students could clearly see how what they were doing in class related to the lives of people they know. Using the survey also gave students more opportunities to talk about their learning with their friends and family, providing much needed "face time" for when in-person classroom instruction is not available. Although the instructional unit in the story was used in an in-person environment, the idea of a digital survey prompting family and community conversations could be used in remote environments and adapted for many phenomena, providing students with opportunities to make connections between their schoolwork and their communities.

In this story, students were initially engaged by trying to answer their own questions through surveying people they knew. However, students became even more motivated and excited to continue learning after they saw trends in real data come in

[12]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/7#112.

BOX 5-3 COMMUNITY ENGAGEMENT THROUGH SURVEYS

Holly was a field test teacher for the high school unit from Next Generation Science Storylines, "Why don't antibiotics work like they used to?" The unit focuses on a real-life case study of a girl who scraped her knee, got a serious infection, and had to work through a series of different antibiotics as one after the other eventually stopped working. The girl in the case study, Addie, is about the same age as students who used this unit, so the students immediately get engaged, wanting to figure out what is happening and why.

During the unit, students tried to figure out what antibiotics are and why they stop working. They begin to wonder whether people they know take antibiotics. Once they learned that there are guidelines from the Centers for Disease Control and Prevention (CDC) about how to take antibiotics, students also wondered whether their friends and family members knew about and followed the CDC guidelines.

At this point, Holly charged the students with collecting data from their families, friends, and neighbors about their antibiotic use and whether they keep taking antibiotics after they start feeling better. The students used a survey to collect the data, which went directly to a Google form, and the students usually recorded the information on their phones while talking to their interviewees. Students were very engaged in this assignment and loved seeing the results come in online from their classmates' surveys. They got so excited that they continued conversations with friends and family members about antibiotics and adding new survey responses to the form long after the class had moved on. Parents would tell Holly that their kids, who normally never talk about school and especially not about science, would begin talking at length about Addie, such that the parents themselves felt like they knew just as much as their students.

Holly taught the unit for a few years in a very diverse inner-ring suburb of Detroit until leaving the classroom recently to help develop more units similar to this. Using this kind of engaging phenomenon-based teaching resulted in an increase in students who decided to sign up for the school's advanced placement biology course after taking this introductory biology course. One student said to Holly: "I never would have taken AP biology if I didn't have you for biology last year. I didn't even know I liked science—why aren't all teachers teaching science like this?"

SOURCE: Interview with Holly Hereau, July 27, 2020.

from the community members surveyed by the whole class. This allowed students to see that their school learning was meaningful and relevant in the real world.

To help introduce both teachers and families to phenomena-based learning, NSTA has been developing a series of short "Daily Dos"[13]—tasks that embed sense-making and can be completed remotely. For example, in the task "Why don't the dishes move?"[14] students try to figure out how dishes stay on a table when someone yanks the tablecloth out from under them. Students are supported with short and safe home-based investigations to explore this idea. Similarly, the creators of the NGSS Phenomena webpage have begun developing resources for teachers and families to use for remote phenomenon-based investigations.[15]

Additional support for selecting engaging and authentic phenomena and problems is available from several different organizations:

- Next Generation Science Standards: www.nextgenscience.org/phenomena
- *Qualities of a Good Anchor Phenomenon for a Coherent Sequence of Science Lessons*, from the Institute for Science + Math Education: http://stemteachingtools.org/brief/28
- *Using Phenomena in NGSS-Designed Lessons and Units*, from the Institute for Science + Math Education: http://stemteachingtools.org/brief/42
- *Criteria for Evaluating Phenomena*, from NSTA and NGSS: http://static.nsta.org/ngss/docs/Criteria%20for%20Evaluating%20a%20Phenomenon.pdf
- *Tools for Ambitious Science Teaching—Anchoring Events*: *Modeling presentations*, from the College of Education of the University of Washington: https://ambitiousscienceteaching.org/presentations-on-anchoring-events-and-modeling/
- *Appendix I: Engineering Design in the Next Generation Science Standards*: https://www.nap.edu/read/18290/chapter/15

How can students build toward more than one academic discipline at one time in elementary school?

In addition to maximizing instructional time by making connections between different science domains, meaningful connections can also be made between

[13]See https://www.nsta.org/daily-do.
[14]See https://www.nsta.org/lesson-plan/why-dont-dishes-move.
[15]See https://www.ngssphenomena.com/virtual-science-education.

different academic disciplines, such as integrating science and literacy instruction. Although making these kinds of connections is very beneficial to students at all grade levels, it is likely to be easiest to begin this work at the elementary level.[16] Students in elementary school often have only one teacher or a small group of teachers who work closely together, and elementary teachers are more likely to have close relationships with families and therefore more knowledge about students' backgrounds and interests. In addition, elementary students are most at risk of missing out on science and engineering instruction.[17]

When schools have reduced time or resources, there is often a tendency to focus primarily on literacy and mathematics—especially in the early grades.[18] However, science and engineering education are essential for all students, including at the elementary level.[19] Reducing students' access to science and engineering instruction affects not only their preparedness for coursework in all subjects in later grades, but also their development of critical thinking and problem-solving skills.[20] Ensuring that all students have access to this critical preparation at the elementary level is an equity issue.[21]

In addition, science and engineering learning does not detract from literacy and mathematics learning. It supports and promotes learning in other disciplines by providing the rich and engaging contexts necessary for deep learning throughout the curriculum.[22] Children are naturally curious and gravitate to real-world experiences, and they can explore these real-world experiences in high-quality science and engineering instruction. Curriculum developers can harness these experiences to also teach students mathematics and literacy concepts in a natural and engaging way.

Box 5-4 tells the story of an upper-elementary language arts teacher who decided on her own that a great way to teach her students reading and writing

---

[16]For more information, see *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/3#8.

[17]See https://www.sreb.org/sites/main/files/file-attachments/sciencebrief_may2020.pdf?1591981783.

[18]For more information, see *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Available: https://www.nap.edu/read/13158/chapter/5#22.

[19]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/10#80.

[20]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/10#230.

[21]For more information, see *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Available: https://www.nap.edu/read/13158/chapter/7; also see *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/read/13165/chapter/16#282.

[22]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#140.

BOX 5-4 LEARNING ENGINEERING AND LANGUAGE ARTS TOGETHER

Jennessa is a 5th-grade language arts teacher in an urban school district. Roughly 60 percent of her students qualify for free or reduced-price lunches, and 10–15 percent of her students each year have special needs. Jennessa previously taught in a school where everything was taught in isolation, so the elementary teachers had to jump from math to social studies to science whenever the time for each subject was over. In a school that gives her flexibility, she frequently integrates science investigations and engineering design into her literacy lessons because they excite her students—even though science and engineering are not part of her curriculum. These kinds of cross-curricular connections were even more important to Jennessa after the class moved to remote instruction in spring 2020, as time with students became extremely limited. She wanted to maximize instruction and student engagement.

In her class, she likes to pair novels with informational texts and to align topics with investigation and design work that can motivate students. For example, the class read *The Boy Who Harnessed the Wind* using close reading strategies to help students understand different ways authors can convey meaning from text features. This book was paired with nonfiction articles about engineering, and students compared and contrasted reading strategies between the different kinds of texts. Students also engaged in design work to solve problems related to the texts. In the virtual environment, students often are able to model their designs using Tinkercad. Other times they use scrap materials they have around the house, and Jennessa plans ahead so students can have plenty of time to save up supplies. Throughout their work on engineering designs, Jennessa's students are asked to reflect on what worked and what did not work. These student reflection pieces are used to strengthen their writing skills, requiring use of certain vocabulary or grammar structures.

To begin the fall 2020 semester, Jennessa plans to start with a natural disaster unit, focusing on nonfiction texts. She says that the ELA curriculum typically has students start the year by writing personal narratives and reading fiction, but that she thinks kids are bored of that routine and want to start with something real and current. It will be hurricane season on the East Coast where the students live, so they can discuss what is happening, connecting it to what they have learned about forces and energy. She plans to show students a video

continued

BOX 5-4 CONTINUED

of a bridge twisting in a storm to get them curious, asking questions, writing about their observations and thoughts, and engaging in investigation and design to explore the effects of forces and energy transfer on objects. As they discuss and read, students will encounter (see) words they do not know, which will be an opportunity for the class to figure out how to find the meaning of new words and what to do when words have multiple meanings.

Jennessa believes that literacy education is very flexible, and she likes finding new connections to help engage students. In the future, she plans to incorporate coding in her lessons through Tinkercad. She frequently finds herself learning along with the students and is grateful to have administrators who allow teachers to take risks, fail, and try again.

SOURCE: Interview with Jennessa Libby-Reynolds, July 25, 2020.

skills was through an engineering context. Making the kinds of connections described in this story between two or more disciplines not only maximizes instructional time, but also increases coherence for students and allows them to understand the content from each discipline more deeply than if they had to become familiar with a different context for their learning in each discipline.[23] Many state science standards make explicit connections to literacy and mathematics content standards that could be taught simultaneously, such as reading informational texts or organizing data into graphs.[24] In addition, many current state science, literacy, and mathematics standards have overlaps in the practices they expect students to learn and use, such as placing an emphasis on student reasoning and arguing from evidence.[25] At the secondary level, many state ELA standards include an emphasis on "science and technical subjects" that could be used as an area of collaboration.

These connections exist not only with mathematics and ELA. With an increased reliance on computers, simulations, and computational modeling in

[23]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/5#57; also see Gasparinatou, A., and Grigoriadou, M. (2013). Exploring the effect of background knowledge and text cohesion on learning from texts in computer science. Educational Psychology, 33(6), 645–670.

[24]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#31.

[25]See Cheuk, T. (2013). *Relationships and Convergences among the Mathematics, Science, and ELA Practices*. Refined version of diagram created by the Understanding Language Initiative for ELP Standards. Palo Alto, CA: Stanford University.

remote environments, there is a new opportunity to more naturally add in connections between science and engineering and learning related to computer science, technology, and technology literacy (including privacy and cyberbullying concerns online).[26] These kinds of connections would also contribute to the computational thinking sections of the science and engineering practices.

It is important to stress that although there are significant points of connection between disciplines, that does not imply that simply using science and engineering contexts to teach literacy, mathematics, and computer science would provide all of the science and engineering learning students need.

> For example, reading a science-themed informational text as part of ELA instruction is not sufficient for science instruction, just as reading to obtain information in science class is not sufficient for literacy instruction.

The processes and appropriate pedagogy from each discipline need to be used in instruction. For science and engineering, this means that students still need focused sense-making and problem-solving opportunities that allow them to deeply build an understanding of fundamental science and engineering ideas, practices, and ways of thinking, as well as discipline-specific forms of literacy.

Even when schools are open and fully operational, many students often do not have access to science and engineering instruction at the elementary level—especially English learners, students with special needs, and students deemed to be academically at risk. These students are often pulled out of science class time to focus on literacy and mathematics because of assumptions that they need to focus on "basics" or that before they can engage in science and engineering they need higher levels of skills in literacy and mathematics.[27] With the shifts to hybrid or remote learning, these students are at even higher risk of missing out on the engaging science and engineering experiences and rich context building that can support their literacy and mathematics education.[28] For example, one of the best ways for English learners to build their language skills is to have meaningful

[26]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/7#53.

[27]For more information, see *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives*. Available: https://www.nap.edu/read/25182/chapter/5#102.

[28]For more information, see *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available: https://www.nap.edu/read/13165/chapter/16#282. Also see *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives*. Available: https://www.nap.edu/read/25182/chapter/5#60.

reasons to need to communicate. Rich science and engineering investigations provide those meaningful reasons.[29]

Box 5-5 describes a program designed to make use of science contexts and practices to strengthen English language skills for English learners.

BOX 5-5 SCIENCE SUPPORTING LITERACY FOR YOUNG CHILDREN

The Early Learning Center is a pre-K–2 public school in the northeastern United States. The students largely live in multigenerational families whose home language is Spanish. When the school moved to a remote instructional model in mid-March, teachers quickly shifted their attention to the well-being of their young students. Two kindergarten teachers whose classes were already working together closely decided to collaborate with their student teachers on ways to stay connected with children and their families. The teachers and students in these classes are part of a national professional development grant aimed at supporting teachers of emergent bilingual students to facilitate language learning through science practices. The teachers combined their classes and held online meetings twice per week. Each teacher–student teacher pair took responsibility for one session weekly, and they focused on extending their ongoing science investigations in this new format.

Although the classroom teachers were monolingual English speakers, the two student teachers were bilingual in Spanish and English, and they translated in real time. The teachers' selection of science as the focus of their online sessions was based on their classroom experiences: they had observed that students were more likely to ask questions, participate in discussion, write in their science journals, and talk to their families about what they were learning when science was at the center of instruction. For example, students were motivated to help brainstorm solutions to problems and to agree or disagree with their classmates' ideas. This extra student-driven and authentic engagement with language promoted the development of students' literacy skills.

SOURCE: Adapted from a case developed by Carla Zembal Saul for this book (personal communication).

This story highlights the benefits of allowing students to engage in sense-making discussions in their home language. By providing translation, the student teachers in the story gave the students the supports they needed to feel comfortable sharing their initial ideas and to feel that they were part of the learning

[29]For more information, see *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/4#28.

community. With this foundation, students were able to begin engaging in science learning, motivating them to build the language skills necessary to expand their understanding and participation.

Many models exist for integrating science learning with other disciplines and show promising results for students' educational outcomes.[30] School time does not have to be divided into completely separate disciplines, such as one block for ELA, one block for mathematics, and one block for science. It is possible to maintain fidelity to each discipline while making connections among different disciplines. Students may even learn more effectively if they learn more than one discipline at one time. There is a current opportunity while reimagining school schedules and curricula to better integrate disciplines that only rarely exist independently in the real world.[31]

To modify schedules for remote, hybrid, or blended learning, some districts are telling teachers that science instruction should be included during class time for other disciplines, such as mathematics. However, without specific supports for what integration of multiple disciplines looks like in instruction, teachers are likely to simply follow their specified mathematics curriculum. If some teachers receive clear guidance about what integration could look like and other teachers do not receive this guidance, gaps may widen between which students have opportunities for science and engineering and which do not.[32,33] Because integration or coordination of subject matter is more likely to take place at the elementary level than at the secondary level, elementary teachers will need support for integration or coordination of subject matter. To help provide this kind of guidance, the Oklahoma State Department of Education included disciplinary integration notes in its Return to Learn Guidance,[34] and several Education Service Districts in Washington state worked together to develop resources that support elementary-level students in building toward standards from multiple disciplines together. For example, the kindergarten resources focus on "tackling trash" and include a virtual field trip and remote learning assignment; they help students build toward learning goals from science, ELA, mathematics, and computer science at the same

[30]See Self, J. (in press). *Using Science to Bolster Literacy Skills in Elementary.* Council of Chief State School Officers; also see Drake, S.M., and Burns, R.C. (2004). *Meeting Standards through Integrated Curriculum.* Alexandria, VA: Association for Supervision and Curriculum Development.

[31]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/4#18.

[32]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available https://www.nap.edu/read/18802/chapter/10#81

[33]For more information, see *Developing Assessments for the Next Generation Science Standards*. Available https://www.nap.edu/read/18409/chapter/4#27.

[34]See https://sde.ok.gov/sites/default/files/documents/files/R2L Launching Instruction in Grades 3-5.pdf.

time.[35] The resources are housed at OER Commons, an online library of resources that can be freely used and repurposed by others.

Who is involved in planning for and supporting curriculum modifications?

The instructional resources used with students can significantly affect their learning; it is important that these resources be of high quality.[36] However, developing high-quality instructional materials is a complex, iterative process that involves teams of well-trained curriculum developers working in concert with expert teachers. The teams need to have a deep understanding of the *Framework*, along with expertise in supporting students with a wide range of needs, such as English learners and students with disabilities.[37] Curricular programs resulting from these kinds of development processes may be more effective in supporting student learning than curricula that are developed quickly by just one or two individuals.[38] In addition, more than one teacher typically uses the same resource, so it is more efficient and effective for teams of educators or developers to work together to modify instructional materials and then to provide them to individual teachers than to expect each teacher to make all of the modifications on their own.[39] For example, supplementary online resources could be provided along with context for how they fit into preexisting units. Individual teachers should not be required to create and modify their materials entirely on their own.[40]

In addition, because many of the ways to reduce instructional time described above involve coordination between more than one discipline or year of instruction, science and engineering teachers, science curriculum coordinators, and even science curriculum developers may not be able to implement these ideas alone. School- and district-level leadership can provide guidance about the importance of multiple disciplines and multiple years working together. For fall 2020 and

[35]See https://www.oercommons.org/courseware/lesson/68130/overview.

[36]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/12#271.

[37]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/7#55.

[38]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/7#55; also see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#172.

[39]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available https://www.nap.edu/read/25216/chapter/8#154.

[40]See Schwartz, H.L., McCombs, J.S., Augustine, C.H., and Leschitz, J.T. *Getting to Work on Summer Learning: Recommended Practices for Success, 2nd Ed.* Available: https://www.rand.org/pubs/research_reports/RR366-1.html also see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#35.

subsequent years, they can also provide support structures to help teachers connect with their students' teachers from the spring to find out what adjustments were made to the curriculum during the initial months of the pandemic and how students handled the transition.

Schools throughout the country are experiencing ongoing educational disruptions at the same time, and many of these schools have science standards influenced by the *Framework*. There is therefore an opportunity to collaborate across schools and districts to help modify high-quality materials. In addition, schools in the same district could get advice from community sources about local resources and phenomena that relate to students' homes and cultures.

These collaborations can also extend across state lines. For example, the state of Louisiana initiated work to adapt iHub and OpenSciEd instructional units[41] for remote use, supporting teams of administrators and teachers experienced using the curricula to make the necessary adjustments. Then Louisiana sought help from other states to find teachers who could help continue this work. Now, Massachusetts educators are working together with a team from Louisiana to adapt the rest of the OpenSciEd materials. The results from this work will be freely available to all districts in the country as each unit adaption is completed.[42]

These kinds of collaborations are also happening through informal educational institutions and scientific and engineering societies. For example, the National Association of Geoscience Teachers supported hundreds of geosciences educators from across the country to work together to figure out what the community could do to offer online field camps for their students.[43] Although these virtual experiences were initially created with college undergraduate students in mind, many of them may support high school Earth sciences learning. The growing collection of ideas and resources is now freely available online.[44]

Once modifications are made to the instructional materials, either by local teams or by the original curriculum developers, the materials will need to be reviewed to make sure they have not shifted away from the vision of the *Framework* due to the modifications and that they can be effectively implemented in high- and low-resource areas.[45] Like curriculum development, review processes

---

[41]See iHub and OpenSciEd develop free and publicly available instructional materials. See https://www.colorado.edu/program/inquiryhub/; also see https://www.openscied.org/.

[42]See https://www.openscied.org/remote-learning-adaptations/.

[43]See https://nagt.org/nagt/teaching_resources/field/designing_remote_field_experie.html.

[44]See https://serc.carleton.edu/NAGTWorkshops/online_field/activities.html.

[45]For more information, see *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/4#37.

are ideally rigorous processes that involve teams working together to carefully consider criteria for quality and can even include pilot testing.[46] This kind of process is supported by the NGSS EQuIP rubric[47] and the NextGen TIME tools and processes.[48] However, with the current need for materials to support students right away, it can be helpful for trained educators to use tools such as the NGSS Lesson Screener[49] to get initial information about quality.

The table below summarizes how curricula can be changed to better serve student learning during and after the COVID-19 pandemic (Table 5-2).

Table 5-2 Shifting Curricula During a Crisis

Moving From	Moving To
Maximizing Instructional Time	
Teaching academic disciplines in isolation	Teaching academic disciplines in a coordinated way, taking advantage of overlaps
Building toward one or two standards at a time	Building toward a bundle of learning goals that all work together to help students explain a phenomenon or solve a problem
Including busy work or discrete content that is only useful in one field of work	Focusing only on deep proficiencies that are broadly applicable
Introducing content several times over the years to make sure students understand it	Building on prior knowledge to help students grow
Modifying Materials	
Expecting every teacher to adjust their own curriculum	Providing teachers with the modifications necessary
Working alone as a district to modify materials	Collaborating with educators across the country to modify common materials
Ensuring Quality of Materials	
Driving learning with phenomena or problems that are interesting to curriculum developers	Driving learning with phenomena or problems that engage and motivate students and connect to their culture and background
Leaving gaps in student understanding due to time shortages	Coordinating the scope and sequence of content carefully to ensure student learning builds coherently

[46]For more information, see *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/4#23.

[47]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/8#172; also see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/7#57.

[48]See https://nextgentime.org/.

[49]See https://www.nextgenscience.org/screener.

NEXT STEPS TO CONSIDER

- Review materials to ensure that all parts of instruction are meaningful: either building relationships or building deep student proficiencies that are broadly applicable.
- Choose phenomena or problems that allow students to build toward a "bundle" of learning goals at one time.
- Review materials to ensure they avoid building toward repetitive learning goals, both this year and in future years.
- Coordinate planning conversations across grade levels to ensure students' learning builds coherently over time, in all three dimensions.
- Select phenomena and problems that can be explored virtually and that connect to students' homes and communities.
- Review materials to ensure phenomena or problems used to drive learning will authentically engage and motivate students.
- Provide guidance about how to coordinate and integrate different academic disciplines, especially in elementary school.
- Adopt a team approach to planning for and supporting curriculum modifications.
- Provide teachers with the modifications necessary for using instructional materials in their new teaching environment.

6

Monitoring Learning for Continuous Improvement

A critical aspect of education is assessment, providing feedback on student learning to all parts of the education ecosystem. However, in this time of transition and blended learning environments, assessment used for the purpose of accountability is likely to be less useful and less equitable. For example, disparities in the resources available for student learning are likely to have increased.[1] In addition, for many purposes and uses, such as to monitor students' achievement of state learning standards, assessments need to be administered under standardized conditions and cover the same content and skills, which is not currently feasible. In this situation, it is more helpful to students to focus on continuous improvement through ongoing formative assessment and feedback. When student learning experience centers on explaining phenomena and designing solutions, embedded formative assessment becomes a natural way to support learning progress.[2]

Focusing on continuous improvement is also important for the entire education system at this time: educators are not expected to immediately implement all changes to instruction and assessment needed to adjust for the ongoing changes to learning environments in response to the COVID-19 pandemic. The process of implementation during the pandemic will be iterative and will require careful monitoring so that adjustments can be made along the way, in a manner very similar to that used to support ongoing student learning.

The guiding questions in this chapter are intended to help education practitioners consider how this volume's four foundational principles—in particular, Principles 1 and 4—can be applied to planning for equitable and supportive formative assessment for students and continual improvements to education systems.

---

[1]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/8#67.

[2]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/12#270.

How should any unfinished learning from spring 2020 be addressed?

Although students may not have had opportunities to learn all of the material planned for spring 2020 due to disruptions to the school schedule, education experts throughout the country are recommending that the focus not be on diagnostic assessments in the beginning of the 2020–2021 school year.[3] Instead, instruction can focus on grade-level-appropriate content along with ongoing monitoring of each student's real-time needs for accessing the current content. As students engage in learning activities, teachers can look for evidence that students have the background knowledge and skills they need to engage with the grade-level material. Using effective formative assessment, they can determine students' individual, immediate needs in each lesson and instructional unit to help them continue to build along learning progressions[4] toward the targeted learning in each of the three dimensions of learning: disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs).

These kinds of determinations are not new; they are standard practice for effective teaching and learning. Students come to the classroom every year with different levels of understanding from the previous year's instruction for a variety of reasons. This year, unfinished learning is likely the focus of more school conversations as educators try to ensure students do not have "gaps" in their knowledge from any missing instructional time in spring 2020. However, it may not be necessary to try to address all unfinished learning right away when missing concepts and practices are not immediately needed for grade-level content this year. As detailed in Chapter 5, educators can plan together over the next one or more years to ensure that students have opportunities to build all of the necessary foundational knowledge and skills to support their future learning. In addition, a focus on gaps—on what students lack—is less supportive of student learning than a focus on what understandings students bring to class. All students bring to the learning environment a unique set of skills and understandings. As teachers get to know their students, they can more clearly see how to build on each student's foundational knowledge and skills to support their continued learning.

---

[3]See Council of Chief State School Officers, *Restart & Recovery: Assessment Considerations for Fall 2020*. Available: https://ccsso.org/sites/default/files/2020-07/Assessment%20Considerations%20for%20Fall%202020.pdf; also see Lake, R., and Olson, L., *Learning as We Go: Principles for Effective Assessment During the COVID-19 Pandemic*. Available: https://www.crpe.org/sites/default/files/final_diagnostics_brief_2020.pdf.

[4]See Shepard, L.A., Diaz-Bilello, E., Penuel, W.R., and Marion, S.F. (2020). *Classroom Assessment Principles to Support Teaching and Learning*. Boulder, CO: Center for Assessment, Design, Research and Evaluation, University of Colorado.

How can remote or online classroom assessment be adjusted to support student learning?

Assessment is often thought of as a process that educators use to obtain a snapshot of student proficiencies at a given point in time. Currently, however, the focus can be on a high-quality classroom assessment system (whether the class is remote or in person) that prioritizes formative assessment to support continuous improvement. As defined by the Council of Chief State School Officers:[5]

> [Formative assessment is] "a planned, ongoing process used by all students and teachers during learning and teaching to elicit and use evidence of student learning to improve student understanding of intended disciplinary learning outcomes and support students to become self-directed learners."

Although formative assessment processes are foundational components of research-based teaching and learning, using them explicitly is still new to many teachers and requires deep pedagogical and assessment skills. In addition, when formative assessment is discussed, it is generally with a focus on information for teacher use rather than on ways both teachers and students can use that information to adjust teaching and learning. Ideally, student artifacts can be used to help both teachers and students identify where the students currently are along a continuum of understanding and proficiency for each of the three dimensions—SEPs, CCCs, and DCIs—and how well they are able to integrate them, and therefore help clarify the next steps each student needs to progress along those continua for each dimension.[6] Used in this way, formative assessment can be a significant driver for student learning.[7]

To monitor and support student learning, especially in remote learning environments, it is important to collect evidence of student thinking, not just whether students know the right answer or have memorized the correct words. To focus only on the answer or the words is to focus primarily on outcomes related

---

[5]See https://ccsso.org/resource-library/revising-definition-formative-assessment.

[6]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#32; also see Shepard, L.A., Diaz-Bilello, E., Penuel, W.R., and Marion, S F. (2020). *Classroom Assessment Principles to Support Teaching and Learning*. Boulder, CO: Center for Assessment, Design, Research and Evaluation, University of Colorado.

[7]For more information, see *Design, Selection, and Implementation of Instructional Materials for the Next Generation Science Standards: Proceedings of a Workshop*. Available: https://www.nap.edu/read/25001/chapter/4#30.

to DCIs rather than on all three dimensions.[8] One beneficial outcome of remote instruction is the potential for increased recognition of the value to student learning of using the three dimensions for assessment purposes. For example, in one district before the pandemic, teachers had been using assessments based on memorization of factual content, but with remote instruction they became concerned with academic integrity issues, realizing that it was too easy for students to find the answers online to their usual assessments. The teachers became motivated to try new ways to monitor students' learning, and they realized the benefits of shifting to new, three-dimensional instructional materials that would support students to learn in deep ways that could be assessed authentically.

Performance tasks, research projects, multimedia portfolio curation, and other student-generated artifacts can (1) offer students a range of ways to demonstrate their thinking; (2) provide information about student thinking that teachers can use to inform instructional decisions, including the potential need for individualized supports;[9] and (3) give students concrete ways to reflect on and track their own learning over time.[10] When student artifacts are collected remotely rather than through classroom performances, it may even be easier to document student progress and for students, families, and teachers to all monitor the progress together.

Some tools, such as the OpenSciEd exit tickets,[11] collect information on students' affective responses, allowing teachers to monitor how students are feeling and to help identify students who might need extra emotional support. Student writing and discourse can also provide evidence about student thinking, and real-time discourse can provide opportunities for teachers to probe more deeply to get more information or to gently add guiding questions that help students challenge their own thinking.[12] As discussed in Chapter 4, to ensure this process is equitable and culturally responsive, classes will need to create explicit norms and guidelines for maintaining respect and understanding different students' perspectives and patterns of participation.[13]

[8]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available https://www.nap.edu/read/18802/chapter/5#34.

[9]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/9#196.

[10]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/6#98.

[11]See https://docs.google.com/forms/d/e/1FAIpQLSeqUgoiUhY9PkJobJ1Ijs9iLgoXzLWea4E9rx0-nlqndX-mqXg/viewform.

[12]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#125.

[13]See http://stemteachingtools.org/brief/25; also see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/12#270.

To support formative assessment processes, teachers need to first ensure that their students can share their thinking in equitable ways. Box 6-1 describes some techniques a teacher used with her students to help them share their learning artifacts after their class transitioned to remote instruction in spring 2020.

BOX 6-1 SHARING STUDENT ARTIFACTS

Michelle teaches early elementary school special education students. The Individualized Education Plan needed for Michelle's special education students does not have a place for science, but because of the students' high interest in science, Michelle was able to leverage this content area to assess speaking, writing, and behavioral objectives.

When looking for a way to monitor the learning progress of her younger students, she found that it was easy to have students draw on paper and hold their work up to the screen so it could be assessed and shared. The mouse pad was often not user friendly for many young hands; it was easier for students to write or draw on paper and then hold it up to the screen for the class to see. There were a few kindergarteners that required family members' help to share their work, but most primary-grade students were able to complete and share their work without a great deal of family member support. Students and, if needed, family members would also take photos with phones or screen shots for documentation. Then Michelle would add the student's work to slides that were shared with the class. The students loved sharing their work and telling everyone about it, especially when they had the opportunity to explore and experience science.

To support special education students in writing, Michelle often used word banks that included key terms related to the students' investigations, such as speaker, tuning fork, siren, and sound. In the virtual classroom, she placed word banks on Google slides and displayed them on a shared screen during Zoom sessions to support students when they were engaged in talking or writing about their ideas. There were also times when asynchronous activities provided additional opportunities for students to talk about their ideas. Michelle asked her students to record their ideas using Flipgrid and send her the videos, or they would talk to Michelle on a Zoom call and she would type out what they said in real time to record the student artifacts.

SOURCE: Adapted from a case developed by Susan Gomez-Zwiep for this book (personal communication).

This story illustrates that teachers still have many options to monitor student progress in remote environments. Some of the ways the class adapted to remote learning, such as sharing some thinking over recorded videos, produced artifacts of student learning that would allow more detailed information to be tracked over time compared to teacher notes from students' class discussions.

Whichever technological tool is used to gather student artifacts, it is important that the modalities used for student responses (e.g., writing, speaking, drawing) be flexible and adapted to student needs.[14] For example, when the goal is to monitor student understanding of ideas and not the actual form of expression, students could be given the choice of different modalities to describe their thinking, including orally, through gestures in a video, or by taking pictures of their drawings. In particular, tasks can be designed with scaffolds to support students from bi- and multilingual backgrounds, including reducing linguistic complexity, making evaluation criteria explicit, and providing alternative ways for students to express their ideas.[15] In addition, teachers can make sure all students are supported to feel included in class discussions.

Teachers and others designing assessments need to be clear about the three-dimensional learning targets they want to assess, the types of evidence that would help provide insight into students' progress toward these targets, and the types of student work or observations that would provide that evidence. As evidence is collected, teachers can appraise progress and identify any areas of difficulties for students, such as being able to apply a particular crosscutting concept to make sense of a phenomenon or effectively argue from evidence. Teachers can use this information to plan for how to support the students in building those proficiencies.[16]

As discussed in Chapter 4 in the context of instructional routines, it is especially important that students understand what is expected of them and what success looks like when they are working more independently in remote, blended, or hybrid environments. Rubrics are important tools to help students assess and monitor their own learning along a progression of performance and therefore help build their agency in learning. For this reason, it can be beneficial to use student-friendly rubric language to describe levels of proficiency for DCIs, SEPs, and CCCs expected in any performance and for the three dimensions integrated. It is also important that the rubric be tailored for the specific lesson context. For

[14]For more information, see *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives*. Available: https://www.nap.edu/read/25182/chapter/9.

[15]See Fine, C., and Furtak, E. (2020). The SAEBL checklist: Science classroom assessments that work for emergent bilingual learners. *Science Teacher* (Normal, Ill.), 87, 38–48.

[16]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#129.

example, generic rubrics about modeling are less helpful than grade-level-specific indicators of student modeling of one particular phenomenon.

If students become partners in helping to create the rubrics, they can get a clearer picture of what success looks like and how it is attainable.[17] Checklists can also help students understand what to include in their responses. For example, checklists could show students that they are expected to include both visible and invisible elements in their models (where appropriate to the grade level), thereby supporting students' developing ability to create these models on their own and to think about parts of systems that are not visible. It is to be expected that elementary school students will need more support for monitoring their own learning than middle school or high school students. More details about formative assessment that supports the goals of three-dimensional science and engineering learning are described in *Developing Assessments for the Next Generation Science Standards* and *Seeing Students Learn Science*.[18]

How can students be supported to give and receive constructive feedback from both their peers and their teachers?

Receiving meaningful feedback is a powerful way for students to progress in their learning, and it is an essential part of integrating effective formative assessment practices into teaching and learning.[19] Incorporating peer feedback into lessons has the added benefit of reducing the sense of isolation that students may feel in remote learning situations. Giving and receiving ongoing constructive feedback can help encourage students to persist in their learning in all settings. In addition, reflecting on their performance and the feedback they receive and then deciding how to incorporate it helps promote student agency.

Giving feedback is not the same as determining grades. While students and teachers are adjusting to new learning environments, building relationships and developing a sense of comfort with the growth opportunities available with formative assessment, it is important to help students feel safe sharing their evolving thinking and their questions along the way. They need to know that they will not

[17] For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#32.

[18] For more information, see *Developing Assessments for the Next Generation Science Standards*. Available: https://www.nap.edu/catalog/18409/developing-assessments-for-the-next-generation-science-standards; also see *Seeing Students Learn Science: Integrating Assessment and Instruction in the Classroom*. Available: https://www.nap.edu/catalog/23548/seeing-students-learn-science-integrating-assessment-and-instruction-in-the.

[19] For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#32.

be penalized for not getting the "correct" answers right away or for sharing ideas they later revise. In addition, when students are learning remotely with disparate access to resources, grading may be less equitable.[20] At least early in the 2020–2021 school year, it may be helpful to focus on the following types of actionable feedback suggested by the Council of State Science Supervisors in collaboration with the National Science Teaching Association and the National Science Education Leadership Association:[21]

- one-on-one conversations or written feedback with a mechanism for students to reflect and respond that highlights positive aspects of student performance;
- goal-oriented reflections on possible next steps;
- opportunities to discuss challenges students are facing and ways to move forward; and
- constructive identification and suggestions for areas of growth, perhaps focusing on one actionable area at a time.

Box 6-2 describes how a teacher made her feedback to students more personal and approachable through the use of videos.

BOX 6-2 USING VIDEO FOR FEEDBACK

Kathy, a middle school science teacher, learned on a Friday evening in spring 2020 that her school was going digital, and by Monday morning the switch had already taken place. She was happy that her students were already well versed in Google Classroom so the switch was not as difficult for her as it was for many of her colleagues. However, she still needed to find a way to capture students' attention, authentically assess their learning, and meet the state's standards. To engage with her students and offer a way for them to participate asynchronously, one of the first things she tried was "screencasting"—a way to capture audio and video while sharing your screen. This allowed her image to be on screen as she narrated her Google slides and gave directions for activities. Her students loved it. They

[20]See https://drive.google.com/file/d/1t5UjlFtHzR-Efl1eRodfHD_CExEje0e5/view.
[21]See https://drive.google.com/file/d/1t5UjlFtHzR-Efl1eRodfHD_CExEje0e5/view.

BOX 6-2 CONTINUED

wanted to see her face and feel connected. She did these videos unscripted, just as she would talk in the classroom, to make sure she sounded informal and approachable. She already had established relationships with her students' families, so she was comfortable being herself on camera, including being a bit goofy, and was not worried that a parent or caregiver would find it unprofessional.

Kathy also used screencasting to personalize feedback for her students. She made individual videos for each student by opening up the student's work document, turning on Screencastify, and then just talking about the work as if she were talking directly to the student in a short personal conversation. The videos added context and a personal tone to the feedback, avoiding the risk of sometimes cold and remote-sounding emails. Students responded very positively to these videos, seeming to understand and incorporate more of the feedback than they had done before when they received it in written formats. Kathy heard reports that some parents listened in to her feedback videos—including parents who had not read the written feedback previously given to the student. The parents told her they appreciated hearing directly from the teacher, with the nuances and expressions possible through a video.

Students in Kathy's class also used video to communicate their understanding of key science ideas to her. For example, they videotaped themselves explaining and demonstrating Newton's laws, narrating a roller coaster project while identifying potential and kinetic energy, and creating weather reports. Kathy was able to use these student artifacts as formative assessments that helped clarify what the students understood about the concepts and how they were using science and engineering practices, which helped her differentiate supports for ongoing instruction. Students also had opportunities to watch each other's videos and give critiques, practicing what they had been learning about giving good feedback.

SOURCE: Interview with Kathy Biernat, July 28, 2020.

The students in the story appreciated and benefitted from the technical medium of videos, which can seem more personal than written communications. This story also highlights the importance of communicating feedback in a caring and humanized way such that students feel personally valued and supported.

Teachers need continued professional learning experiences and ongoing support to increase their facility with using and scaffolding different types of feedback to support student learning across different instructional environments, and to identify tools that can help this process. For example, teachers can support peer feedback processes that promote critical thinking, colearning, and student growth, which might take the form of small breakout room discussions or use of tools such as Jamboard (see Figure 4.2) to allow students to provide feedback to each other and promote student reflection and changes in thinking. Peer feedback can be a strong source of motivation for students and may help build a sense of collaborative learning among everyone in a class.[22]

Box 6-3 describes how a teacher made use of peer conversations to help push students' thinking, allowing students to clarify their ideas without needing direct intervention from the teacher. Although this activity took place before the pandemic, the tools and ideas can be applied to the 2020–2021 school year.

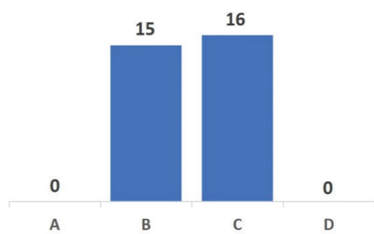
BOX 6-3 PEER FEEDBACK FOR IMPROVING STUDENTS' UNDERSTANDING

A new high school chemistry teacher was looking for a way to gather "on the spot" data about students' understanding. She decided to use Plickers* and to add in a space for students to provide reasoning to go along with their answers.

She collected several forms of data with this tool. For some of her classes, she had the students answer on their own and explain their reasoning. She displayed the students' answers so that everyone could see them and told the students to talk in breakout rooms and discuss their reasoning. If they wanted to change their answers at that point, they were welcome to do so. On one of the questions, many students correctly identified the right answer, but many other students did not. See the graph below:

[22]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/7#123.

BOX 6-3 CONTINUED



Julia knew that 1 mole of chlorine reacts with hydrogen to produce 1 mole of HCl. She therefore mixed 36g of chlorine with hydrogen and expected to get 36g of HCl.

1) What did she get instead? (choose a response below)
2) Why didn't she get what she expected? Use your calculations as evidence to explain in the response box what Julia saw and why.

A. 1.02 grams
B. 18.51 grams
C. 37.01 grams
D. 234.6 grams

Once the students answered, the teacher had them discuss their answers in their breakout groups. This allowed the students to check with their group members to see how their reasoning differed from others. As the discussion ensued, students gained clarity about this chemistry concept, and they could then change their responses if they wanted to do so. There was then a shift in student responses with almost every student choosing the accurate answer.

Plickers gives instant feedback, so the teacher was able to immediately see how students were changing their responses after they talked in breakout groups. Additionally, having the students write their explanations allowed her to later go back and determine what and how they were originally thinking when they picked their first answer, helping to gauge their proficiency in integrating calculations, scientific principles, and prior CCC knowledge about conservation of atoms in chemical reactions as evidence in explanations. Ultimately, the data were feedback for the teacher about which concepts students understood and could demonstrate the first time and which were not clear to them without discussion. She used the feedback to determine which ideas and proficiencies needed to be revisited in the next class.

*Plickers is an assessment tool that provides a visual graph to show how many students are answering each answer for a multiple-choice question; see plickers.com.

SOURCE: Adapted from Furtak, E.M., Glasser, H.M., and Wolfe, Z.M. (2016). *The Feedback Loop: Using Formative Assessment Data for Science Teaching and Learning.* Arlington, VA: National Science Teachers Association.

As shown in the story, peer feedback and discussion can quickly prompt student learning. Small group conversations, in this case through video conference breakout rooms, allowed each student's ideas to be considered by peers in more detail than would be possible in a full class discussion and therefore allowed each student time to talk through and reconsider their own ideas.

How can feedback from families and other stakeholders be gathered and used to inform ongoing improvements?

As understanding evolves about how to keep students and educators safe through the COVID-19 pandemic, decisions about instructional models and schedules will likely change. Ongoing modifications will need to be made to instructional plans. These modifications directly affect teachers' practice and will affect families, so school district decisions about changes need to be made in partnership with teachers, students, families, and community partners. Feedback from these different stakeholder groups, who have a vested interest in the outcomes of student education, will improve decision-making processes and help ensure that they address the specific needs of the community, as well as of students.[23]

In addition, all education stakeholders, including teachers, students, and families, benefit from staying informed about how new curriculum, instruction, and assessment decisions are being implemented and the anticipated effects.[24] Feedback from students, teachers, parents or guardians, and education leaders can be collected and used to make ongoing adjustments to the curricular program and education services as needed.[25] This feedback can include both needs and assets related to academics, physical and mental health, and socioeconomic conditions. One example comes from the Oklahoma State Department of Education, which held virtual information gathering meetings with educators from across the state in spring 2020 to find out how things were going soon after school closures. Another example comes from the Colorado Department of Education, which did a needs assessment to determine the best ways to support educators and students.[26] In addition, short periodic surveys could be used to gather ongoing information

[23]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/11#88.

[24]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/2#8.

[25]See https://www.carnegiefoundation.org/our-ideas/six-core-principles-improvement/.

[26]See https://www.cde.state.co.us/communications/needsinventory-results.

from a wide variety of stakeholders, including teachers, students, families, caregivers, and community partners.[27]

As with feedback for student learning purposes, feedback gathered about the education system is more helpful when it is ongoing, actionable, and timely—not lagging by 1 year or more.[28] This means that regularly collecting data on a small number of priority metrics and having plans for how to make changes based on those data is much more useful than collecting data on hundreds of metrics with no plans for how to use the results. In order to be useful for identifying system needs and addressing longstanding educational inequities, whenever possible, enough data need to be collected such that they can be disaggregated by race, ethnicity, socioeconomic status, gender identity, sexual orientation, English learner status, immigration status, and different ability status.[29] In addition, because the needs for elementary, middle, and high school students, families, and teachers are different, feedback should be gathered from each grade band.

When collecting the data, it is important to consider what metrics are being used, because the issues measured will likely be those that receive attention. For example, monitoring the number of families engaged in planning processes could lead to an emphasis on engaging families. Monitoring the number of students with special needs who do not have access to high-quality science and engineering instruction could lead to an emphasis on reducing this number.[30] Monitoring the time spent on science and engineering in elementary school classes could lead to an increase in this time. For some of these metrics, such as the quality of science and engineering instruction accessible to all students, it may be necessary to observe virtual classes and review teachers' lesson plans and student work.[31] Additional ideas for setting up systems of ongoing monitoring and feedback can be found in *Developing Assessments for the Next Generation Science Standards*[32]

As data are collected, they need to be used similarly to formative assessment—in support of the continuous growth and improvement of students,

---

[27]For more information, see *Developing Assessments for the Next Generation Science Standards*. Available: https://www.nap.edu/read/18409/chapter/8#204.

[28]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/8#67.

[29]See https://docs.google.com/document/d/163ZNDs7sZ0FWOT7-1JFxQ9Lbo6zbQNJhaHSs0LbljCE/edit.

[30]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/4#21.

[31]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/8#64.

[32]For more information, see *Developing Assessments for the Next Generation Science Standards*. Available: https://www.nap.edu/read/18409/chapter/8#205.

educators, and systems.[33] Implementation throughout the pandemic period is expected to be slow, and improvements are expected to be iterative with each round of implementation and feedback.[34] Maintaining communications with families and educators about a realistic timeline of expectations and ongoing progress toward goals will be important.[35]

NEXT STEPS TO CONSIDER

- Continuously monitor student needs for engaging in grade-level learning rather than conducting diagnostic assessments at the beginning of the year.
- Use formative assessment to look for evidence that students have the background knowledge and skills they need to engage with the current grade-level learning.
- Use “classroom”-level assessment to support continuous improvement in student learning and provide supports for students to give and receive feedback from both peers and teachers.
- Support teachers in collecting ongoing evidence of student progression in all three dimensions—SEPs, CCCs, and DCIs—and in their use together.
- Encourage teachers to focus on formative assessment practices, including providing actionable feedback, that highlight continuous improvement rather than summative grading.
- Develop mechanisms for monitoring and communicating to families about whole-class, grade-level, and school-level progress.
- Carefully choose and communicate the priority metrics that will be used for monitoring systemwide progress of science and engineering education
- Collect ongoing feedback from students, families, teachers, and community partners on their needs and how implementation is going during the pandemic.

---

[33]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/11#249.
[34]See https://www.nap.edu/read/25216/chapter/11#261.
[35]See https://www.nap.edu/read/18802/chapter/4#20.

7

Supporting Collaborations and Leveraging Partnerships

Educators at all levels of the school system are working hard to address the current challenges of the COVID-19 pandemic, trying to keep students and staff safe while also supporting student learning. They do not need to work alone. Partnerships of all kinds are available to support these efforts.

The guiding questions in this chapter are intended to help education practitioners consider how this volume's four foundational principles—in particular, Principle 3—can be applied to supporting collaborations and partnerships among educators and among school systems and other community members.

How can teachers be given the time and resources to collaborate and support each other?

Teachers, like students, need opportunities to learn over time and to get feedback that helps them grow professionally.[1] In spring 2020, very few school systems had the time to set up ways for administrators to support teachers by observing their virtual classes or providing feedback on their lesson plans, but more schools and districts are making plans to incorporate these kinds of opportunities in the coming months, with a focus on teacher learning rather than teacher evaluation. In addition, joint planning time[2] and professional learning communities (PLCs) can be an invaluable resource for educators when they are given time and space—even remotely—to learn from one another, facilitated by teacher

[1]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/2#7.

[2]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/9#190.

leaders or instructional coaches.[3] Participating in PLCs can be a way for teachers to share their learning about students' cultural backgrounds and phenomena that connect closely to community interests and to collaboratively look at student work to help figure out how to help students progress toward three-dimensional learning goals.

Box 7-1 describes how teachers who met remotely in a PLC were able to share feedback to help each other strengthen their understanding of science and engineering practices.

BOX 7-1 A VIRTUAL TEACHER LEARNING COMMUNITY

Seven new and experienced secondary science teachers participated in an online teacher learning community called the virtual teacher learning community (or vTLC) to support their codesign of formative assessment activities around modeling. All participants had affiliations with the same university-based teacher certification program, either as graduates, mentor teachers, or affiliates of the program. University faculty and graduate students served as member-facilitators in the community. Building on the research base around effective professional learning experiences—setting clear agendas, connecting with problems of practice, and working together long-term—the group gathered online monthly, using Google tools, after school hours, to learn about modeling, to design learning experiences to engage their students in modeling, and to reflect on what the students had learned.

Facilitators set the agenda for each meeting, including setting goals for student learning related to the science and engineering practices of modeling. The discussion then focused on how models and modeling support the development of student understanding within their different content areas, which ranged from middle school Earth science to high school biology and chemistry. The teachers shared ideas using links placed in the chat box, holding up student-created work to the screen, and through screen shares.

Over the course of the regular monthly meetings, the community created unique modeling activities that support student learning in their respective classrooms. At the same time, the cross-disciplinary space and diverse experience and expertise of the

[3]See https://docs.google.com/presentation/d/1OZQJuiYxvB8Hi_a3zfjNftiZ-bQ9_MqO15nxXPwf04k/edit#slide=id.g78195a4180_1_42; also see *Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts*. Available: https://www.nap.edu/catalog/21836/science-teachers-learning-enhancing-opportunities-creating-supportive-contexts; and *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/6#40.

BOX 7-1 CONTINUED

participants enabled the teachers to deepen their own understanding of the science and engineering practice of modeling. For example, Brooke, a beginning teacher, had been focused almost exclusively on having her biology students build physical models, such as cell structures or a candy representation of the musculoskeletal system of an arm. However, in the fifth meeting of the virtual community, the group had an interesting conversation that pushed Brooke's understanding and encouraged her to engage her students with a mathematical model to represent viral and bacterial growth. This shift, prompted by gentle questions asked by a middle school teacher, Shawn, helped her shift her design from physical models that did not have a clear connection to explaining phenomena toward mathematical models that represented relationships among the variables involved in viral and bacterial growth.

The teachers also considered, over the course of many meetings, the relationship between testing and refining models with evidence collected during investigations. For example, one teacher, Cody, wrestled with how to engage his students in using evidence to interrogate a model on plate tectonics in his middle school Earth science class. Over the course of the virtual meetings, the teachers were able to talk through these issues, discuss examples of Cody's students' work, and identify with some ideas to try.

SOURCE: Adapted from Swanson, R.D., Buell, J.Y., and Furtak, E.M. (Manuscript submitted for publication). *Virtual Teacher Learning Community: An Online Community of Practice for Science Teachers.*

This story highlights not only the benefits of collaborative learning, but also the time required for building understanding of new ways of teaching and learning—which is true for both students and teachers. The teachers in the vTLC did not transform their teaching after just one meeting. They spent time over many weeks deepening their understanding and working together to figure out what application of high-quality learning and teaching principles could look like in their remote classrooms.

In addition to PLCs, teachers will need multiple, ongoing opportunities for professional learning to help them support an effective transition to the new demands of changing instructional models for remote, hybrid, and other new school models. As mentioned throughout this volume, those opportunities need to include strategies for:

- incorporating students' background, culture, and perspectives in meaningful ways in instruction;
- identifying students who are struggling with trauma;
- adopting self-care techniques for health and well-being;
- providing explicit instruction to students on social and emotional skills, habits, and mindsets;
- using new technological tools for instruction;
- facilitating student discourse to help the students feel that they are driving learning toward sense-making or problem solving;
- integrating content from multiple disciplines; and
- providing constructive feedback to students in remote settings.

When locally provided professional development opportunities in all these topics is not available, it can be helpful to make use of resources from organizations, such as the National Science Teaching Association (NSTA), to help bolster teacher learning. It is important to note that the professional learning needs of teachers in different grade bands are likely to be different. For example, teachers in elementary grades are more likely to need more time to engage in professional learning related to several different academic disciplines than middle and high school teachers.

Teacher professional learning in the near future will be conducted remotely, giving teachers the opportunity to experience instruction in the ways their students have been experiencing it.[4] WestEd's K–12 Alliance[5] did virtual professional learning for teachers in summer 2020 and found that many of the same principles about how to engage students virtually (see Chapter 4) also apply to adult learners. For example, the K–12 Alliance found that it is important to be strategic in divvying up synchronous versus asynchronous activities. Professional learning providers found that the time one can expect to have productive synchronous participation in an online environment is much more limited than during face-to-face professional learning. However, they also noticed a benefit associated with

[4]For more information, see *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Available: https://www.nap.edu/read/25216/chapter/9#200.
[5]See https://k12alliance.org/.

community building. When their teachers already had close working relationships, their online meetings could be productive for a much longer stretch of time than when people were working together for the first time. The group worked to further build communities between the teachers by keeping the same participants in breakout groups for several sessions, although they also found that eventually it was helpful to change breakout groups to ensure equitable participation.

How are supportive networks being leveraged?

As noted in Chapter 5, the COVID-19 pandemic is a national challenge that is clarifying opportunities for communities to work together across schools, districts, and states.[6] In addition to collaborating on modifying instructional materials, communities are also finding many ways to collaborate to support science and engineering education through joint development and collection of strategies for effective online, virtual learning.[7] For example, the New Jersey Science Education Leadership Association (NJSELA)[8] recently held a virtual session that brought together district leaders from throughout the state, allowing them to share their strategies for supporting science education in the upcoming school year. In Colorado, the Colorado Science Education Network, the Colorado Association of Science Teachers, and the Colorado Department of Education Science Specialist convened to develop a common set of tools for use for remote science education across the state. Across states, members of the Council for State Science Supervisors (CSSS) worked with NSTA and NSELA to produce a series of brief guidance documents to aid science education practitioners in their planning.[9]

Similarly, teachers throughout the country have been connecting regularly to share ideas and resources related to teaching science and engineering during the pandemic environment through both synchronous and asynchronous Twitter chats at #NGSSchat and #NGSSslowchat. A recent study of the #NGSSchat activity

---

[6]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/2#7.

[7]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/9#70.

[8]See https://www.njsela.org.

[9]See http://stemteachingtools.org/news/2020/guidance-for-supporting-science-learning-during-covid-19; also see http://cosss.org/projects.

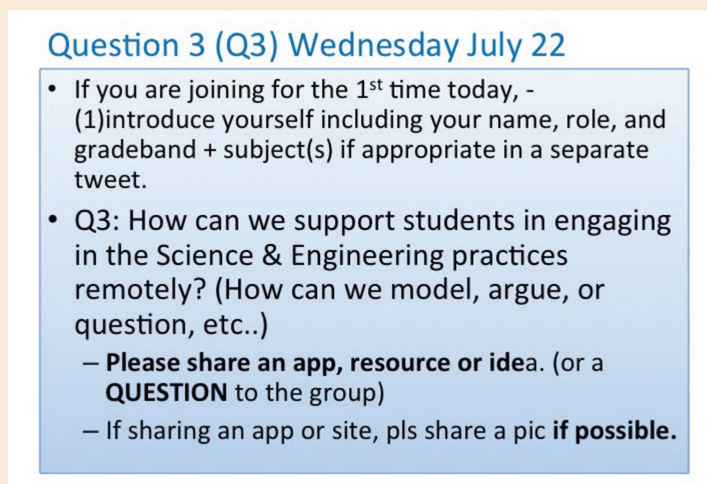
found that participants had opportunities to transform their professional practice through the online conversations.[10]

Box 7-2 shows examples of tweets that include types of ideas exchanged in the community through these chats.

BOX 7-2 TWITTER CONVERSATIONS FOR LEARNING

Tricia Shelton @TdiShelton

Welcome to Day 3 of #NGSSslowchat. Let's embrace the idea that "all creative work builds on what came before" (Austin Kleon) Pls share & then RT, like or engage in convo w/ another #NGSSchat



Debbie Andres @MsA_Physics Jul 22

Replying to @TdiShelton

A3: A lot of of the NGSS S&EPs are developed in the classroom through the peer-to-peer interactions. I think my strongest tool will be to have my students white board their ideas often. I think Google Jamboard might be the way to go due to the sharing features. #NGSSslowchat

---

[10]See Rosenberg, J., Reid, J., Dyer, E., Koehler, M., Fischer, C., and McKenna, T. *Idle Chatter or Compelling Conversation? The Potential of the Social Media-Based #ngsschat Network for Supporting Science Education Reform Efforts*. Available: https://doi.org/10.31219/osf.io/uwza6.

BOX 7-2 CONTINUED

Wanda Faye Bryant @wandabryant Jul 22

Another lesson for outside: draw what's in your backyard and ask questions about the drawing. Resource: https://m.alibris.com/booksearch?mtype=B&title=mapmaking+with+children and examine historical context of county! https://mnfi.anr.msu.edu/resources/vegetation-circa-1800. Thank @KelloggBioStn for these ideas!

#NGSSslowchat #ngsschat

Hannah Crowder @mshcrowder Jul 22

Replying to @TdiShelton

A3: I designed my first unit to be fully remote. Google forms used for collecting initial ideas & questions. Sts draw initial models and upload them to a discussion board. A video explains how to use the indicators & lab equipment. Sts make predictions on our LMS. #NGSSslowchat

Frank McGowan @frankmcgowa Jul 22

Replying to @TdiShelton

A3: A start-up goal for the year is to get Ss comfortable with discussing and sharing ideas. If remote, plan to ease in Zoom breakout rooms so that students feel good talking. Low entry point discussions and shift to science sense-making along the way.

In their twitter chats, educators gain access to ideas, strategies, and resources shared by other practitioners throughout the country. They also have the opportunity to be a part of a community that is larger than their own district or state, and to see that teachers like them are struggling with similar issues and figuring out solutions to common problems.

Most school systems throughout the country are currently working to implement *Framework*-based standards, so there are likely many shared goals and shared measures of success that can facilitate collaborations.[11] Sharing ideas

[11]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/4#19.

across district and state boundaries can be especially helpful when implementing science and engineering education, because there are often fewer school and district personnel with expertise in science- and engineering-specific pedagogy than with expertise in language arts and mathematics, and there may be less local infrastructure to support science and engineering.[12] State, district, and school leaders can support this kind of idea sharing, reducing the isolation[13] educators may feel during the pandemic in many ways, including[14]

- identifying opportunities for cross-district and cross-state collaborations, for example, by making connections between science educators in different small rural communities to share ideas about effective science and engineering learning in remote and virtual environments;
- acknowledging that educators and leaders need time to participate in these collaborations on an ongoing basis and then providing that time;
- celebrating educators and leaders who participate in collaborations, for example, by sharing their story in a newsletter;
- disseminating lessons learned from the collaborations; and
- modifying district pandemic response plans based on the lessons learned from collaborations.

How are informal learning environments and community partnerships being incorporated?

Education benefits the entire community. Many school systems have established partnerships over many years with community members and organizations, such as local employers, museums, science centers, and aquaria, and these relationships have resulted in curriculum materials, donations of supplies, scholarships, student internships, space, and advice. During the COVID-19 pandemic, various kinds of support opportunities are being provided across the country, and

[12]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/4#17.
[13]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/5#36.
[14]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/9#71.

the Association for Science and Technology Centers is collecting a list of many of the opportunities available.[15]

While schools and districts focus on managing the day-to-day work of adapting systems to function during the pandemic, it can be helpful to bring community partners into the conversation to help think about solutions and share resources. Although this takes time and effort, the results can more than compensate for the work involved. For example, Thorne Nature Experience[16] is providing child care and support for small groups of 1st- to 5th-grade students enrolled in Boulder Valley School District to help them with their remote learning activities. The site is working with the school district to identify low-income and high-needs students to participate, and the organization will provide access to wireless internet, food, and school support for students.

These types of partnerships can extend across the K–16 system. Many schools are facing teacher shortages in science and engineering at a time when students need one-on-one attention more than ever. At the same time, university students in preservice preparation programs may not have the same level of access to K–12 classrooms that they have had traditionally.

Box 7-3 describes how one university used a one-to-one pairing of its preservice teachers with K–12 students to support the young students and to provide valuable teaching experience for the preservice teachers.

BOX 7-3 CONNECTING PRESERVICE TEACHERS TO K–12 STUDENTS

Bionca, a third-year preservice teaching student at Old Dominion University, took part in spring 2020 in a program (supported by the National Science Foundation) to pair education and engineering undergraduate students with K–12 students to work on engineering. Bionca worked with Kevin, a 5th-grade student who was very gifted in communications but did not consider himself to be strong in STEM subjects. The pair worked together one-on-one on Zoom calls for 2 hours a week for 5 weeks to try to figure out how to design a robot that could help solve the problem of bee extinction, and to figure out how to market the device. The pair also coordinated with Bionca's engineering partner, who helped plan and execute the engineering components of the lessons. Bionca used Kevin's excitement related to communications and marketing to engage him in figuring out how to solve the engineering design problem more effectively.

continued

[15]See https://www.astc.org/coronavirus/educationalresources/.
[16]See https://thornenature.org/.

BOX 7-3 CONTINUED

Because Bionca did not have prior experience with engineering or robotics, she was learning along with Kevin. Kevin noticed this and seemed to feel that this made the problem solving authentic—for once, his teacher did not have all the answers. Bionca created lesson plans that included a lot of freedom and autonomy for Kevin. He was expected to do research on his own, and then the pair would work together to create a mind map and summarize what he had found in his research. Sometimes Kevin was discouraged because nobody was present in person to help him troubleshoot his robot, and he and Bionca had to rely on webcams through limited bandwidth to try to share information about a problem. However, he was encouraged enough to continue trying on his own, and he learned over time to persist in figuring out how to solve problems that arose.

By the end of the project, he was the one to push the learning forward, making sure that he had the information he needed. Besides becoming familiar with engineering design, Kevin was happy that he had created something himself and that he completely understood it. Bionca was excited that she was able to introduce Kevin to a type of education she had never experienced herself before this program, giving him the foundation to venture in any direction he wanted to in the future. Through the experience, she also gained confidence in her ability to teach remotely and to engage with engineering and coding. She plans to continue applying these lessons learned in her future teaching.

SOURCE: Interview with Bionca Bryant, July 29, 2020.

Both the 5th-grade student and the preservice teacher in this story made large learning gains after only five meetings together. This highlights the mutual benefits that can come from community partnerships when all parties have their needs met.

Another effective model is that of community schools,[17] which leverage community partnerships to organize relationships and resources between a school and its community, promoting equitable outcomes in health, education, and employment. During the pandemic, these kinds of partnerships have focused on opening channels of communications between families and schools, gathering data on family needs, helping connect families with food, broadband access, and

[17]See http://www.communityschools.org/.

computers, and positioning family members of traditionally underserved students as leaders in their local communities.

If schools and community members have not already created partnerships, it can be helpful to begin the long-term process of establishing these kinds of relationships, either formally or informally, fostering sustainability of education programs and student support structures.[18] There are many possible partners, including libraries, afterschool programs, public broadcast stations, museums, environmental education organizations, city government offices, higher education institutions, park associations, churches, and local businesses, many of whom are adversely affected by student mobility and have a stake in the long-term well-being of the community's students. In addition, many of these partners can contribute to instructional activities to help deepen student knowledge of science and engineering practices, crosscutting concepts, and disciplinary core ideas by connecting content to real-world phenomena and problems.[19]

Some families and community organizations might not immediately understand how they can be helpful to schools, and they may have been historically discounted by school systems. They might need targeted, personal communications and invitations to share their expertise. These partnerships need to be developed collaboratively, with each partner contributing to the discussions about existing challenges, opportunities, roles they could play, and ways they could all benefit. If schools drive these conversations alone, just asking for what they assume each partner can contribute—such as funding—the partners may not have a chance to contribute to the thinking and innovation necessary to address ongoing community challenges during the pandemic. Instead, if educators share their problems with the personnel from these different partnership institutions, they can help find solutions. For example, librarians might know where to locate a 3D printer or how to get books to all the students, and park rangers might know the best place to observe a particular phenomenon in the local area.

More detail about long-term sustainability and structure of partnerships is described in the *Guide to Implementing the Next Generation Science Standards*.[20]

---

[18]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/2#7.

[19]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/9#73.

[20]For more information, see *Guide to Implementing the Next Generation Science Standards*. Available: https://www.nap.edu/read/18802/chapter/9.

NEXT STEPS TO CONSIDER

- Create strategies and mechanisms for teachers to collaborate with and support each other.
- Plan for providing ongoing professional learning opportunities for teachers to support their changing instructional practices, including:
  - identifying productive ways teachers can receive feedback; and
  - identifying regional, state, or national science and engineering teacher networks that can provide professional learning resources or support.
- Leverage networks that connect schools, districts, and states.
- Share information with educators and other decision makers about ways they can collaborate across schools, districts, and states.
- Look for opportunities to partner with institutions and organizations in the community and beyond.
- Highlight examples of existing, successful partnerships to showcase examples for the field.
- Invite community partners to help brainstorm and implement solutions to challenges in the school system.

Appendix

Online Resources

This appendix provides in one place the links for the science and engineering-related online resources referred to in the body of the volume.

Resources for Working with Families

Council of State Science Supervisors—Resources for family science learning
http://cosss.org/projects

Learning in Places—Outdoor learning for grades K–3
http://learninginplaces.org/

Data Sets

United States Geological Survey
https://www.usgs.gov/products/data-and-tools/overview

National Oceanic and Atmospheric Administration
https://www.ncdc.noaa.gov/data-access/quick-links

Simulations of Science Phenomena

PhET Interactive Simulations
https://phet.colorado.edu/

Concord Consortium
https://concord.org/our-work/focus-areas/stem-models-simulations/

Instructional Materials and Resources for Learning

Washington State Elementary Frameworks for Science and Integrated Subjects
https://www.oercommons.org/courseware/lesson/68130/overview

OpenSciEd
https://www.openscied.org/remote-learning-adaptations/

Next Generation Science Storylines
https://www.nextgenstorylines.org

Unit from the Science and Integrated Language Project, New York University
https://www.nextgenscience.org/resources/grade-5-sail-garbage-unit

NSTA sample lesson, Why don't dishes move?
https://www.nsta.org/lesson-plan/why-dont-dishes-move

Resources for Selecting Phenomena and Problems

NGSS Phenomena webpage
https://www.ngssphenomena.com/virtual-science-education

NextGenScience examples of phenomena
https://www.nextgenscience.org/phenomena

Qualities of a Good Anchor Phenomenon for a Coherent Sequence of Science Lessons
http://stemteachingtools.org/brief/28

Using Phenomena in NGSS-Designed Lessons and Units
http://stemteachingtools.org/brief/42

NSTA Criteria for Evaluating Phenomena
http://static.nsta.org/ngss/docs/Criteria%20for%20Evaluating%20a%20Phenomenon.pdf

Ambitious Science Teaching: Anchoring events
https://ambitiousscienceteaching.org/presentations-on-anchoring-events-and-modeling/

NGSS Appendix I: Engineering Design in the NGSS
https://www.nap.edu/read/18290/chapter/15

Resources for Evaluating Instructional Materials

NextGen TIME
https://nextgentime.org/

NGSS EQuIP
https://www.nextgenscience.org/equip

NGSS Lesson Screener
https://www.nextgenscience.org/screener

Online Field Experiences for Geoscience

National Association of Geoscience Teachers
https://nagt.org/nagt/teaching_resources/field/designing_remote_field_experie.html

Resources Available through Museums, Parks, and Other Science Information Organizations

California State Parks Online
http://www.ports.parks.ca.gov/

Association of Science and Technology Centers, List of museums with online programs
https://www.astc.org/coronavirus/educationalresources/

About the Author

JENNIFER CHILDRESS SELF is a STEM education consultant and advisor focusing on supporting the implementation of the Next Generation Science Standards (NGSS) and similar *Framework*-based standards as well as identifying the essential components of high-quality STEM instructional materials. Additionally, she has been involved in many projects internationally, recently working with a partnership between UNESCO and school systems in Turkey to develop and implement new STEM curriculum standards and working in India and Malaysia to help establish professional learning communities for teachers, including those in refugee communities. Previously, she was the Director of Instructional Support for Science at Achieve, where she coordinated the development and implementation of the NGSS. Prior to joining Achieve in 2011, she was the Director of the Center for Building Awareness of Science Education (BASE) at the National Science Resources Center, now the Smithsonian Science Education Center (SSEC). She currently serves on the Advisory Board of the Global STEM Alliance and was previously a board member for the New York Academy of Sciences and an Advisor for the development of the *Framework for K–12 Computer Science Education*. She earned a bachelor's degree in Biochemistry from the University of Missouri-Columbia and a Ph.D. in Biomedical Science from the University of Texas-Houston.

Acknowledgments

This book was made possible by the sponsorship of The Carnegie Corporation of New York.

A group of expert practitioners and researchers in the field of science education served as consultants and provided ongoing input in the development of this book. Special thanks are due to them for their invaluable guidance throughout the process. This group included the following individuals:

Kevin Anderson is the science education consultant at the Wisconsin Department of Public Instruction, where he also helps coordinate state-level STEM initiatives. Previously, he worked as a public middle school teacher, regional education consultant, and education researcher.

Janet Carlson is an associate professor and the faculty director of the Center to Support Excellence in Teaching (CSET) at Stanford University. CSET works to improve the quality of instruction, keep equity at the center of the work, and develop leading educators

Erin Marie Furtak is a professor of STEM education and associate dean of faculty at the University of Colorado at Boulder. Frustrated while trying to realize educational reforms as a public high school biology teacher, she turned to studying how science teachers learn and improve their daily classroom practices through formative assessment.

Maya Garcia currently serves as the science content specialist at the Colorado Department of Education where she leads implementation efforts for the newly adopted 2020 Colorado Academic Standards for Science and supports the agency's STEM education portfolio. She serves on the Board of the Council of State Science Supervisors, as well as on the National Academies' Board on Science Education.

Susan Gomez-Zwiep was formerly a professor of science education at California State University Long Beach. She is currently a senior science educator at BSCS. She began her career in education as a middle school science teacher. One of her primary research interests is science and language development—using language to provide equitable access to science learning and to accelerate language development.

Scott Marion is the president of the National Center for the Improvement of Educational Assessment, where he supports state and district leaders in designing and implementing meaningful educational assessment and accountability systems. He began his career as a field biologist and high school science teacher and he later served as director of assessment and accountability for the Wyoming Department of Education.

Jenny Sarna is director of NextGenScience, a project at WestEd that supports the design of quality and coherent K–12 programs that align science standards, instructional materials, professional learning, and assessments. Previously, she served as director of district support at Achieve, a nonprofit, nonpartisan organization dedicated to improving science standards implementation and as both the high school science specialist and pK–12 science manager for the Chicago Public Schools.

Special thanks are also due to Heidi Schweingruber and Judy Koenig, staff of the National Academies, who coordinated the work of the consulting experts, worked with the author, and shepherded the book through the complex development and review process.

The author also wishes to thank the dozens of education researchers and practitioners who shared their work, experiences, ideas, and concerns related to science and engineering education during the COVID-19 pandemic. In addition, the author is grateful for the helpful feedback provided by the following district administrators who reviewed early partial drafts of the document: Cristian Carranza, Miami Dade, FL; Jenny Christian, Dallas, TX; Brian Cinnamon, Kingsport, TN; KD Davenport, Philadelphia, PA; Scott Goldthorp, Cherry Hill, NJ; and Amber McCulloch, Puget Sound Educational Service District, WA.

The final draft of this book was reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the Division of Behavioral and Social Sciences and Education of the National Academies. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published book as sound as possible and to ensure that the book meets institutional standards for objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank six individuals for their review of the final draft of this book: Michael Heinz, Science Coordinator, Office of Standards, New Jersey Department of Education; Matthew Krehbiel, Director of Outreach, OpenSciEd; Okhee Lee, Professor of Childhood Education, Teaching and Learning, New York University; Tiffany Neill, Deputy Superintendent of Curriculum and Instruction, Oklahoma Department of Education; Stephen L. Pruitt, President, Southern Regional Education Board, Atlanta, GA; and Nancy Butler Songer, Dean and Distinguished University Professor, School of Education, Drexel University.

Although the reviewers listed above provided many constructive comments and suggestions, they did not see the final draft of the book before its release. The review of this book was overseen by Patricia Morison of the National Academies. She was responsible for making certain that an independent examination of this book was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this book rests entirely with the author.