NextGenScience

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Authentic Science Experiences:

Designing High School Science Learning to Reach all Students

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Foreword

Meaningful Science Education in 2021

Reflecting on Opportunities and Challenges for Science Learning During COVID–19

After school closures in spring 2020 due to the COVID–19 pandemic, science educators faced both challenges and opportunities related to designing high-quality science experiences. Many teachers reported that reduced instructional time and lack of adequate tools and resources for remote teaching negatively impacted students' use of science practices, student collaboration and discourse, and student engagement. But opportunities also arose to increase student engagement and learning:

- Some teachers reported increased flexibility for teaching and grading after the cancellation of state tests.
- Educators and curriculum developers found ways to address the science of a pandemic and in-the-moment lessons from a growing awareness of racial inequities.
- The shift to at-home learning for our nation's students became a powerful reminder of the critical assets of families as learning partners and communities as spaces for relevant phenomena and problems.[1]

Whether learning at home or in-person, several key design features can ensure high school students engage in science learning that is both meaningful and useful. This approach is based on a growing body of research about how students learn science best, which is reflected in *A Framework for K–12 Science Education* and state academic content standards inspired by its vision. These standards set a high bar for what students should know and be able to do by the end of high school to be prepared for college, careers, and citizenship. To achieve the ambitious goals set by these standards, students need access to meaningful, high-quality learning experiences.

This resource aims to articulate a vision that will help the field continue to identify and move away from barriers to meaningful science education and move toward what matters most for students.

1. Iveland, A., Rego, M. Sarna, J., and Wolbrink, V. (2020). Science Learning During COVID–19 and Beyond [Webinar]. Retrieved from: www.wested.org/resources/science-learning-during-COVID–19/

Introduction

Giselle's fifth period class is Science Research Methods, one of her school's college prep electives for high school seniors. For the past few weeks, the class has been learning about cancer. Giselle is particularly excited about today's class because her teacher has invited a professor from the local university to present his research on cell signaling pathways. During the lecture, Giselle's attention drifts between trying to make sense of the professor's unfamiliar words and wondering how this connects to her life:

> *I wonder if this guy always talks like a professor, even at home.*
>
> *He's making it sound like cancer is determined inside the cells, but I've always wondered if the reason my dad has cancer is because of the pollution in our neighborhood.*
>
> *Am I the only person who's going to have trouble remembering this? Will this be useful for anything besides the test?*
>
> *If I am having a hard time understanding this professor, will I actually be able to make it as a pre-med student?*
>
> *I thought I wanted to become a science researcher, but this isn't what I had in mind. Maybe thinking I could study science as a way to help people like my dad was a big mistake.*

Giselle's teacher has carefully planned a series of activities to help her students better understand an important topic like cancer, even inviting a researcher to interact with the class. Despite all best intentions to design engaging and effective high school science experiences, students like Giselle may still perceive science as disconnected from their lives, struggling to see real-world applications for the knowledge or skills or understand what actual scientists and engineers do in their work.

Through the adoption of the Next Generation Science Standards (NGSS) and other standards based on the *Framework*, many states have set a high bar for what we want students to know and be able to do by the end of high school. One challenge is that districts, schools, and often individual educators are left to figure out how to actually prepare students to meet these ambitious science learning goals.

Also, the lack of alignment between state or district-adopted learning goals, graduation requirements, and assessments often creates competing priorities for educators who are determining what to teach and how. Ensuring these system components work together is critical for changing what is measured to determine success and what is taught.

Of equal importance is the design and implementation of learning experiences. Many high school experiences, even those that cover specific science content or skills outlined in today's science standards, fail to prepare students like Giselle for what she hopes to become because they fail to incorporate prior learning experiences, student identity and interests, approaches to integrating science skills and knowledge, meaningful interactions with both adults and peers, or assessments that provide meaningful feedback to students and educators.

To prepare all students for success beyond high school, today's science experiences (e.g., daily classroom task, capstone project, apprenticeship, independent study, etc.) need to develop students' disciplinary knowledge and skills along with social, emotional, and career readiness competencies like motivation and academic tenacity for a range of postsecondary options. Decades of research have shown that, to acquire the essential knowledge and skills for doing science, students need deep and rich experiences that go way beyond memorization and demonstration laboratories.

Designing science learning experiences is complicated. In the NextGenScience team's analyses of science units and lessons, we have come to appreciate the great attention and care that developers invest in curricular design. Effective and evidence-based science experiences share five key characteristics, which prioritize ways of teaching science that are both meaningful and engaging for students:

Students integrate skills with core knowledge of science and engineering professions.

Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.

Students use science to explain the world around them and solve problems that matter to society.

Students learn by engaging with both peers and adults.

Students engage in a variety of assessment processes that showcase ongoing learning and promote confidence.

The vision for today's science standards includes the design of experiences that help students meet ambitious learning goals in ways that engage, honor, motivate, and inspire them.

One of the most common definitions of authenticity in science education centers on helping students understand what it means to think and work like a scientist. While this is an important goal for science education, it cannot be achieved without considering both students' identities and the social and historical contexts of science. What is now authentic to scientists and the scientific community might be unfamiliar to or even at odds with how high school students view themselves and their communities, particularly students from cultural backgrounds that have been underrepresented in science and engineering professions.

If high school science experiences intend to prepare students for college and careers in science, they must consider how scientific knowledge and skills are most relevant and useful to students in the context of their communities and lives. Thoughtfully designed authentic experiences can enable students to make meaningful connections with science, support feelings that science is "for me," and help students see how science can be useful and relevant to their everyday lives. Doing so will give students the ability to use scientific knowledge and skills in their everyday lives.[2]

2. Aschbacher, P. R., Li, E., and Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *J. Res. Sci. Teach.*, 47: 564-582. https://doi.org/10.1002/tea.20353

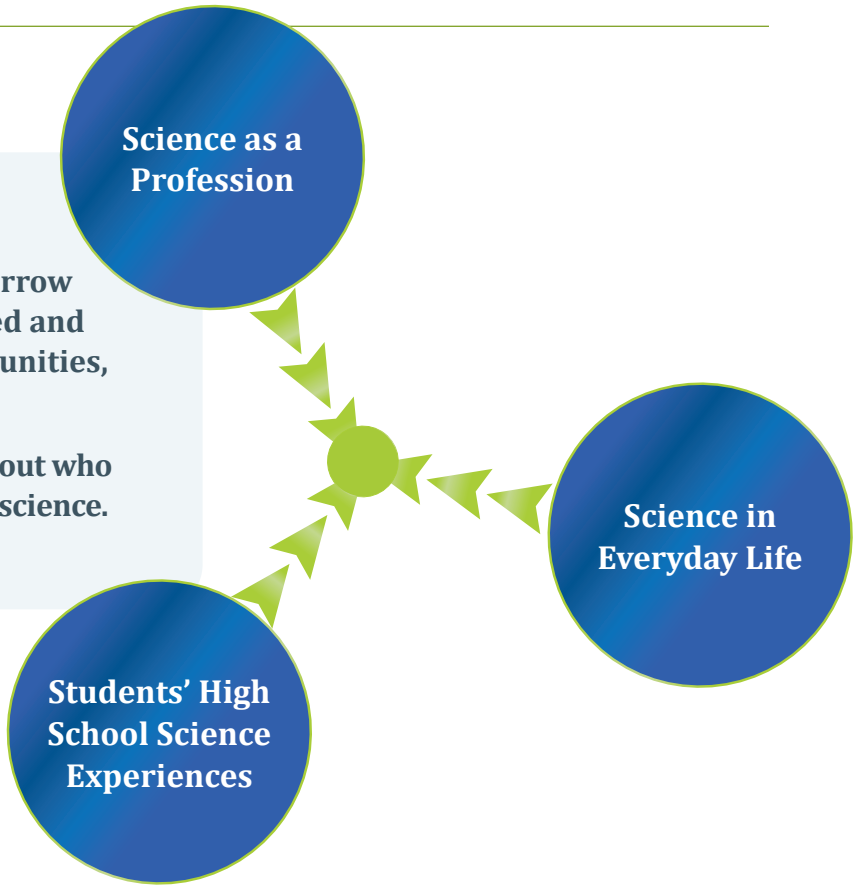
Our Approach

To develop this resource, NextGenScience reviewed existing literature on the role of authenticity in K–12 classroom science learning and considered how these findings connect to existing goals related to academic, social-emotional, and career-readiness knowledge and skills. This analysis included connections to *A Framework for K–12 Science Education (Framework)* and the Next Generation Science Standards (NGSS) as well as existing tools for evaluating the design of science instructional materials, like the EQuIP Rubric for Science and the NGSS Lesson Screener. Then, we surveyed educators, curriculum developers, district leaders, and researchers to understand which features of authenticity were valued by the field and why. Finally, we gathered several leaders in the field with expertise in science teaching and learning, career readiness, social emotional learning, assessment, and equity to form an advisory board to review and provide feedback on this resource.

In this resource, we identify and discuss five key features of authentic science experiences, which can support educators with meeting the vision of the *Framework* and NGSS. For each feature, we highlight the research that supports why this feature is important for students. Then, we share a series of vignettes that illustrate what these features look like in a variety of high school science experiences across the nation. We conclude with a discussion of important considerations for those seeking to design and implement more authentic high school science experiences.

Authentic Science experiences can narrow the gap between how science is viewed and experienced by K–12 students, communities, and STEM professionals.

Doing so will broaden student ideas about who is a doer of science and what counts as science.



Features of Authentic Science Experiences

Five core features of authentic science experiences can support the design and implementation of meaningful and enriching science learning for today's high school students:

1. **Students integrate skills with core knowledge of science and engineering professions.**
2. **Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.**
3. **Students use science to explain the world around them and solve problems that matter to society.**
4. **Students learn by engaging with both peers and adults.**
5. **Students engage in a variety of assessment processes that showcase ongoing learning and promote confidence.**

For each feature, we provide:

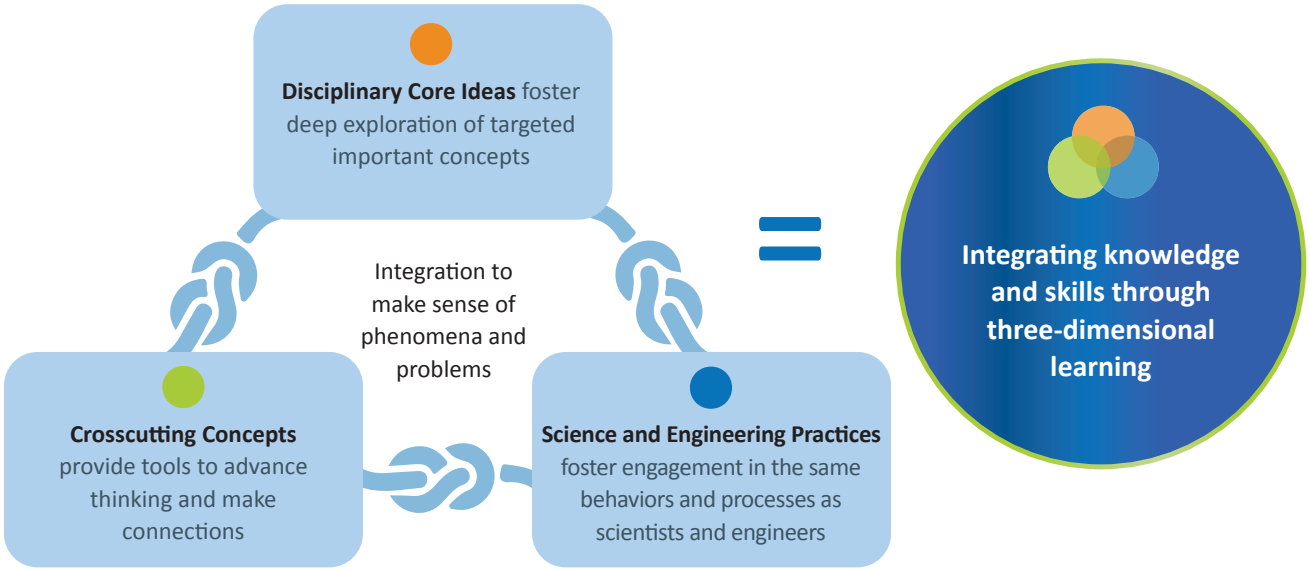
- descriptive elements;
- connections to research on why this approach is critical for student success;
- key social/emotional learning and career readiness competencies[3,4,5] that are closely related to development of the feature;
- other frameworks to inform or support its use; and
- questions for developers and educators to ask while considering instructional materials and supports.

In the vignettes that follow, we also highlight examples of what each feature might look like in practice.

3. ConnectEd. (2012). College and Career Readiness: What do we mean? https://ccrscenter.org/sites/default/files/CACRFramework_V1-1_2012_0126.pdf
4. Collaborative for Academic, Social, and Emotional Learning (CASEL). (2015). Effective Social and Emotional Learning Programs — Middle and High School Edition. Chicago, IL.
5. Sovde, D., James, K., Waters, J., Green, G. Q., Krengel, K., Moore, E., ... & Farrington, C. (2019). *Integrating Social, Emotional and Academic Development: An Action Guide for School Leadership Teams.* Aspen Institute.

1 Students integrate skills with core knowledge of science and engineering professions.

Students integrate skills and core knowledge of science and engineering professionals through three-dimensional learning.



A key feature of authentic science experiences is that students investigate and answer fundamental questions about the natural and designed world by engaging in approaches used by scientists and engineers. In three-dimensional learning, students learn core ideas in the various science disciplines while also learning concepts that cut across — and connect — ideas in different disciplines. They learn and apply these ideas and concepts together with the practices of science and engineering, such as analyzing data, to help make sense of the world and solve problems. Authentic science experiences can also help build a foundational understanding of how to use engineering design practices and principles to solve important problems. This integrated approach differs from previous approaches to science education, which have emphasized just one dimension of science or focused on teaching the dimensions separately.

If we want students' classroom science experiences to allow them to practice science and engineering, these experiences must integrate knowledge and skills. This approach to designing science experiences can improve students' scientific literacy and critical thinking skills, create an appreciation for science, and improve interest and motivation for science learning.[6] These outcomes are valuable for all high school students, not just those planning to pursue science careers and studies beyond high school.

Designing science experiences that integrate both knowledge and skills begins with identifying clear learning goals for the experience. The NGSS and similar standards are composed of performance expectations that integrate both knowledge and skills for assessment purposes. Integrated learning experiences that help students build toward these expectations likewise need integrated learning goals. This approach differs from previous ways of defining science learning goals and more authentically reflects how knowledge and skills are used in the discipline. For example:

- **The "messy" use of science and engineering practices**. In their work, scientists and engineers use disciplinary practices in a variety of ways rather than using a set scientific method, an oversimplified and inaccurate depiction of doing science that has been reinforced by previous approaches to teaching science.

6. National Research Council (2012). A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

- **The cross-disciplinary nature of the real-world**. When scientists use science and engineering ideas to explain phenomena and solve problems, these ideas are not neatly organized and accessed as different disciplines as the separate biology, chemistry, and physics high school courses might indicate. The science ideas that students will need to access and make sense of in authentic science experiences may benefit from spanning disciplines rather than being constrained by artificial barriers of course maps.

When students integrate science and engineering core content with practices and use crosscutting concepts as tools for thinking, learning is more effective. The *Framework* emphasizes the integration of scientific knowledge and skills because it "allows for deep exploration of important science concepts as well as time for students to develop meaningful understanding, to *actually* [emphasis added] practice science and engineering, and to reflect on their nature."[7]

Key Connections to SEL and CCR:

- Critical thinking
- Cognitive flexibility
- Systems thinking

When students are expected to make connections between progressively more complex ideas over time and required to incorporate their reasoning skills throughout the learning process in order to obtain and process information, they have opportunities to build these and other competencies.

Attention to approaches that integrate both knowledge and skills can support a more rigorous and logical progression of science knowledge and skills developed from kindergarten to high school, promoting development of student executive functions such as cognitive flexibility.[8] Over the past several years, many districts and states have started to rethink their high school course pathways, considering where science ideas logically connect to one another in a certain learning progression rather than which ideas traditionally should be learned in a given year based on the name of the course. These shifts have the potential to improve the design of high school science coursework by supporting an approach that considers how novice learners construct complex ideas and practices over time, deepening the complexity of what students know and can do.[9]

STUDENTS INTEGRATE SKILLS WITH CORE KNOWLEDGE OF SCIENCE AND ENGINEERING PROFESSIONS

Questions to Consider

Is the experience defined by clear learning goals that integrate science and engineering practices with science content?

Will the learning result in an artifact that demonstrates the integration of both science knowledge and practice?

Does the learning require students to connect ideas across disciplines, reflecting the cross-disciplinary nature of the real world?

Does the learning require students to use and develop a variety of science practices, rather than focusing on a pre-determined "scientific method" or "engineering design process"?

7. Ibid.
8. Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. New York: Science., 333(6045), 959–964. https://doi.org/10.1126/science.1204529
9. National Research Council. (1999). How People Learn: Brain, Mind, Experience, and School. Committee on Developments in the Science of Learning. *J. D. Bransford, A. L. Brown, and R. R. Cocking* (Eds.). Washington, DC: National Academy Press.

2 Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.

Authentic science experiences place learners at the heart of the design, considering students' prior learning experiences, interests, values, and motivations. These student assets inform both the content (what is taught) and the delivery (how it is taught). When learning experiences make connections to what students bring to the classroom as well as where they may need additional support, students' engagement, confidence, and motivation for learning increase.[10] The design of these "personally authentic" experiences[11] requires careful consideration of two factors: (1) student experiences and interests and (2) student culture and language.

> "Learning environments that only see learners' alternative conceptions as wrong can produce conflicts between learners' cultural, ethnic, and academic identities and this approach can also leave narrow the possibilities of generative engagements between community ways of knowing and scientific ways of knowing"
>
> National Academies Press, Learning Through Citizen Science

1. Student Experiences and Interests. High-quality science experiences consider how the learning connects to students' lives. Making these connections improves learning by increasing student engagement and motivation and leveraging prior knowledge and experiences.

Engagement and motivation. Students' experiences and cultures mediate how they make sense of new ideas.[12] Eliciting students' prior knowledge while considering what students might find interesting or ask questions about creates meaningful links between students' lives and what they are learning. Cultural Formative Assessments gather data about students' cultural contexts, interests, and identities help teachers incorporate and build on those aspects throughout their science and engineering instruction. These assessments can also help students to build social and emotional self-awareness skills, such as identifying personal and cultural assets. As cited in the *Framework*, a large body of research supports a connection between designing around student interest and identities and improved interest in STEM careers:

> *"Research suggests that personal interest, experience, and enthusiasm—critical to children's learning of science at school or in other settings—may also be linked to later educational and career choices. Thus, in order for students to develop a sustained attraction to science and for them to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences." (p. 28).*[13]

Leveraging prior knowledge. Because some scientific ideas may conflict with students' existing ideas or experiences, gathering evidence from and encountering various phenomena firsthand can lead to major shifts in student thinking. Supporting these shifts is most effective when learning is positioned on a long-term continuum, requiring connections between students' prior knowledge and experiences, current learning experiences, and future learning goals. The K–12 progressions for the disciplinary core ideas, crosscutting concepts, and science and engineering practices in today's science standards can support educators with:

- considering what background knowledge is required of learners;
- understanding how science knowledge and skills typically develop; and
- appreciating where learners might need additional guidance to allow them to build deep and enduring understandings.

10. National Academies of Sciences, Engineering, and Medicine. (2018). Learning Through Citizen Science: Enhancing Opportunities by Design. Washington, DC: The National Academies Press. https://doi.org/10.17226/25183
11. National Academies of Sciences, Engineering, and Medicine. (2021). Cultivating Interest and Competencies in Computing: Authentic Experiences and Design Factors. Washington, DC: The National Academies Press. https://doi.org/10.17226/25912
12. Bell, P., Stromholt, S., Neill, T., & Shaw, S. (2017). Making Science Instruction Compelling for All Students: Using Cultural Formative Assessment to Build on Learner Interest and Experience. [OER Professional Development Session from the ACESSE Project] Retrieved from http://stemteachingtools.org/sp/self-doc
13. National Research Council. (2012). A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

2. Student Culture and Language. Science requires students to make use of complex language in all forms: speaking, reading, listening, and writing. The design of learning experiences must attend to language development and use, particularly for emerging multilingual students. Authentic learning experiences leverage the linguistic assets of learners by encouraging students to use familiar language and modes of expression as they make sense of and communicate new ideas.[14] In addition, these learning experiences highlight valuable perspectives of students' family members and communities, engaging them as resources and partners in the learning process.

Designing experiences in this way is important for creating more inclusive, equitable learning environments. By grounding learning in the world of students, authentic science experiences expand students' perception of how science gets done and by whom,[15] allowing students to identify more with science and scientific practices. Failing to consciously attend to student identities and experiences in the classroom deepens institutional inequities, creating "invisible obstructions to learning, and students from minority groups remain in danger of experiencing school as unfamiliar, uncomfortable, and alienating."[16] This is especially important in the teaching of science where students, particularly those whose cultural backgrounds differ from the culture of school, may already view science as disconnected from their lives or hold negative beliefs about themselves as science learners.

Key Connections to SEL and CCR:

- Self-knowledge
- Self-esteem
- Productive self-concept

Designing science learning experiences that connect to and make use of students' diverse and rich assets can help students begin to see themselves as positive contributors to the scientific enterprise, and they can begin to understand and value their unique contributions to the learning process.

STUDENTS' INTERESTS, CULTURE, IDENTITIES, AND EXPERIENCES ARE POSITIONED AS FUNDAMENTAL ASSETS IN THE LEARNING PROCESS.

Questions to Consider

What background knowledge and skills are learners bringing to the experience?

Does the experience require students to make connections between the targeted science ideas and students' lives and interests?

Will students see the phenomenon, problem, or situation as meaningful to their own lives?

Will students be able to use the skills they are developing through the experience outside of the classroom?

Are students able to communicate and demonstrate their ideas in ways that are most comfortable to them?

Are there students who won't be able to fully engage in the experience, because of disabilities or English language proficiency?

Which communities did the design team engage with in designing this learning experience?

Did the design team consider the interaction between cultural ways of knowing and the targeted science ideas?

Will students be able to use their expertise from outside the classroom to engage with this learning experience?

14. National Academies of Sciences, Engineering, and Medicine. (2018). English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives. Washington, DC: The National Academies Press. https://doi.org/10.17226/25182
15. Rivera Maulucci, M. S., Brown, B. A., Grey, S. T., & Sullivan, S. (2014). Urban middle school students' reflections on authentic science inquiry. *Journal of Research in Science Teaching*, *51*(9), 11191149. http://onlinelibrary.wiley.com/doi/10.1002/tea.21167/full
16. Hogg, L. (2011). Funds of Knowledge: An investigation of coherence within the literature. *Teaching and Teacher Education*, 27, 666–677. https://doi.org/10.1016/j.tate.2010.11.005

3 Students use science to explain the world around them and solve problems that matter to society.

A key feature in the design of authentic high school experiences is the central role of phenomena (observable events that occur in the universe and that we can use our science knowledge to explain or predict) and problems (situations somebody wants to change). Creating the need to explain observable events and solve meaningful problems enables connections to students' lives and builds a meaningful context for learning. Requiring students to apply science knowledge and skills to real-world situations leads to deeper learning.[17]

Although explaining the world and solving problems is central to the practice of professional scientists and engineers, traditional science learning experiences and previous ways of teaching science have frequently overlooked or underemphasized the role of phenomena and problems, instead using them as a hook or organizing learning by general science concepts, such as learning about balanced and unbalanced forces. This strategy might help some students remember important facts, but it often leads to knowledge that is neither useful long term nor meaningful beyond passing an exam. In contrast, anchoring the science learning experience in investigations of phenomena, such as a tug of war match that ends in a tie, helps students build more usable knowledge anchored in what the student already knows.

Key Connections to SEL and CCR:

- Curiosity
- Creativity and innovation
- Problem solving

When student curiosity is used to drive learning with the goal of figuring out something meaningful to the students, students can strengthen the link between their curiosity and the real world. As they solve problems based on these real world phenomena, they can be supported to practice creativity and innovation as a way to find more effective solutions.

Building student motivation and engagement. This approach fosters curiosity about why the phenomenon occurs or how to solve the problem and motivates students to ask questions and find answers that help them learn the targeted concepts. When students are motivated to ask questions and see that their questions lead to learning, their engagement in or ownership of their own learning increases. These types of successful learning experiences often take place over a sustained period of time, so engaging in coherent progressions of learning can also help to sustain students' motivation and focus, building skills for academic tenacity and resilience, which will be useful beyond the high school classroom.

Connecting to the lives of all students. Phenomena and problems are effective learning tools when they connect content to students' everyday lives as well as require students to use scientific practices and knowledge in realistic ways. Phenomena and problems offer a real-world context for students to use science to make sense of the natural and designed world and use engineering to solve problems, helping students see the importance of science and engineering to everyday life. Science experiences become more authentic for students when phenomena are culturally or personally relevant and problems matter to students and their community. This approach may include opportunities for students to share their learning in ways that are useful to audiences beyond the classroom, including community members, peers, or even science professionals.

17. National Research Council. (2012). A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

Designing learning experiences around phenomena and problems also provides more equitable access to meaningful learning, particularly for English language learners and students who have been traditionally underserved by science learning. Because students can directly experience or observe phenomena and problems, science ideas are constructed from concrete experiences rather than more abstract symbols or terminology.[18] All students have an access point to enter the conversation — not just students who are more comfortable with the academic language of science and general science topics.

STUDENTS USE SCIENCE TO EXPLAIN THE WORLD AROUND THEM AND SOLVE PROBLEMS THAT MATTER TO SOCIETY

Questions to Consider

Are students explaining a real-world phenomenon or solving a problem that matters to society?

If a problem: Do students use both science and engineering design ideas to generate a solution to the problem?

If a phenomenon: Do students have opportunities to construct, critique, and revise scientific models and explanations of the phenomenon?

Is the learning experience driven by student questions that relate both to science and to students' interests and curiosities about the world?

Will the artifact created through the learning experience be useful to an audience outside of the classroom?

18. Rosebery, A. S., & Warren, B. (Eds.). (2008). Teaching science to English language learners: Building on students' strengths. Arlington, VA: National Science Teachers Association. http://www.worldcat.org/oclc/180081139

4 Students learn by engaging with both peers and adults.

Learning is a social enterprise, whether taking place in a classroom or a professional scientific community. Designing effective and meaningful learning experiences requires consideration of the norms and social systems of both networks of scientists and communities of high school students, leveraging connections between the two worlds. Authentic science experiences provide guidance to instructors to facilitate these complex but critical interactions in the learning space.

Supporting discourse and communication skills. Student-to-student discourse is critical for helping students share ideas and make sense of ideas.[19] Scientists also engage in discourse, though the language may differ. These experiences bridge students' ways of knowing with more specialized forms of scientific discourse. Considering when to introduce academic vocabulary and provide support for writing and discussion can provide multiple access points to the experience, ensuring more learners can meaningfully engage. A major way of supporting scientific discourse is to help students learn to listen carefully and respond to one another's ideas, being respectful of cultural differences in communication. This leads to the negotiation of the meaning of ideas and claims that are supported by evidence,[20] and also allows students opportunities to develop aspects of social and emotional learning like working with diversity and adopting others' perspectives.

Preparing students to read, write, and communicate like scientists can support student success in college and beyond. However, without adequate support, unfamiliar academic language creates unnecessary barriers to participation, decreasing motivation and opportunity to learn. Experiences that include meaningful contexts for science learning along with support for language development have been shown to improve both science and language learning.[21]

Fostering interactions with STEM professionals. STEM professionals can serve as valuable mentors to students, providing students opportunities to ask questions, get feedback, and build relationships that extend beyond the learning experience. Scientists and engineers from different backgrounds can serve as role models for students who might not otherwise see themselves reflected in this community. Such interactions can also build confidence, which not only encourages persistence in science but spills over into other subjects and aspects of the students' lives. Meaningful interactions with STEM professionals have been shown to increase students' interests in STEM careers, build positive student science identities, and build supportive environments for learners. The opportunity to learn from and alongside science professionals, particularly individuals who share the same gender or ethnicity, can improve students' sense of belonging and promote positive science identities.[22]

Key Connections to SEL and CCR:

- Communication
- Teamwork and collaboration
- Working with diversity

Science experiences can be designed to allow students to realize and utilize the benefits of collaborating in teams, including while gathering data, exploring diverse ideas, and solving problems together.

19. National Academies of Sciences, Engineering, and Medicine. (2019). *Science and Engineering for Grades 6–12: Investigation and Design at the Center*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25216
20. Ibid.
21. Lee, O., & Buxton, C. A. (2013). Integrating science learning and English language development for English language learners. *Theory Into Practice, 52*(1), 36–42. https://doi.org/10.1080/07351690.2013.743772
22. Kricorian, K., Seu, M., Lopez, D., et al. Factors influencing participation of underrepresented students in STEM fields: matched mentors and mindsets. *IJ STEM Ed* 7, 16 (2020). https://doi.org/10.1186/s40594-020-00219-2

Providing feedback and monitoring learning. Authentic science experiences encourage students to monitor their own learning and to provide and receive feedback from both peers and their instructor. The instructor plays a critical role, guiding students in next steps to support productive thinking and reflection. The quality of classroom learning experiences is significantly influenced by the classroom culture and learning community that teachers and students co-create.[23]

STUDENTS LEARN BY ENGAGING WITH BOTH PEERS AND ADULTS

Questions to Consider

Do students have opportunities to receive and respond to meaningful feedback from both peers and their instructor?

Do students provide feedback to both peers and their instructor to improve learning and the design of the experience?

Is meaningful collaboration and discourse with peers fundamental to the learning design?

Do students have the opportunity to interact and build relationships with STEM professionals?

Does the experience connect students to STEM professionals whom students can identify with or who work or reside within their communities?

23. Watkins, Chris. (2005). Classrooms as Learning Communities: What's in it for Schools?. London: Routledge. https://doi.org/10.4324/9780203390719

5 Students engage in a variety of assessment processes that showcase ongoing learning and promote confidence.

An important feature of authentic science learning experiences is the inclusion of meaningful and equitable assessment opportunities. In particular, authentic learning includes formative assessments — assessments embedded throughout the learning process to provide both students and teachers with information they can use to make adjustments and to enable students to improve their performance. This kind of assessment informs the learning process and is therefore somewhat distinct from summative measures that might only provide information about how well students performed in a particular area after that area of learning is finished.

Formative assessment that plays an essential role in authentic learning experiences takes many different forms as it adapts to address the needs of many different students and directly measures learning from multiple and various learning experiences. It shares two practices described in Joe Feldman's book *Grading for Equity*:

Supporting Hope and a Growth Mindset

The idea of encouraging mistakes as part of the learning process (e.g., allowing revisions) reflects the real-world work of scientists and engineers, building ideas over time by connecting one experience to the next. This practice also supports the idea that students are continuously learning by engaging in discourse with and receiving feedback from both peers and adults. Equitable formative assessments are an effective way to promote this growth mindset in students,[24] as well as an opportunity to build other aspects of social and emotional skills, such as self-awareness and direction. If the goal is to incorporate equitable science experiences into students' high school coursework, monitoring student performance with the goal of providing individualized feedback to enable adjustments to learning along the way is critical. In addition, a strict focus on right and wrong answers can "produce conflicts between learners' cultural, ethnic, and academic identities" and contribute to inequity in science classrooms.[25]

Building "Soft Skills" and Motivating Students Without Grading Them

Giving students opportunities to actively participate in and develop ownership of their learning can be a more effective and meaningful motivator than a grade. One way to increase students' ownership is to position their interests, culture, identities, and experiences as fundamental assets in the learning process and empower them to engage in self-assessment and reflection throughout the learning experience. Formative assessments, which focus on adjusting learning and instruction rather than awarding grades, can help foster this agency and intrinsic motivation.

In addition, authentic assessments, both formative throughout the learning experience and summative at the end of a learning experience, share the following additional two practices:

Key Connections to SEL and CCR:

- Knowing how to learn
- Goal Setting
- Self-direction

When students are made partners in the assessment process by taking part in developing performance rubrics, giving and receiving feedback, and deciding how to incorporate that feedback, they can be supported to develop these and other essential competencies.

24. The ACESSE Project shares the ways formative assessment practices can support equitable science instruction in a series of resources. These assessments are embedded throughout instruction and serve as check in points to get feedback on how to adjust a learning experience to better support students on their journey to proficiency (slide 31). Ideally, formative assessments are not graded; rather, they are iterative processes that focus on (1) clarifying the intended learning to the student, (2) eliciting context-specific evidence of student learning during a learning experience, (3) interpreting that evidence and (4) adjusting the learning experience accordingly. This timely feedback to the student can promote self-reflection, student agency, and make learning more relevant.

25. National Academies of Sciences, Engineering, and Medicine. (2018). Learning Through Citizen Science: Enhancing Opportunities by Design. Washington, DC: The National Academies Press. https://doi.org/10.17226/25183

Valuing Knowledge, Not Compliance

This practice focuses on assessing and grading students based on their proficiency in the targeted integration of knowledge and skills rather than compliance or effort (e.g., whether students have completed homework). *Grading for Equity* emphasizes that certain approaches to grading are not only less effective to communicate the level of student proficiency, but some may also perpetuate biases and inequities. For example, the practice of combining both nonacademic and academic information into a grade (e.g., work turned in late vs. proficiency in a targeted knowledge or skill) is not only less effective to let students know how well they did, but it may place subjective value on certain nonacademic behaviors, perpetuating inequity.[3] As Feldman writes, equitable and effective assessment practices help to "improve learning, decrease failure rates and grade inflation, make classrooms more caring and less stressful, strengthen relationships between teachers and students, and build students' responsibility and character." When designed to accurately assess the learning goals of the experience in an equitable way, assessments have the potential to tell us much more about student proficiency because they can support more students with demonstrating their knowledge and skills. Used consistently, these kinds of assessment and grading practices also help ensure students receive fair and accurate feedback on their work.

Assessing Knowledge and Practice in an Integrated Manner

Science assessments have traditionally often focused on students answering questions using rote knowledge (e.g., memorization of definitions or procedures). The design of authentic experiences, however, will naturally require a different approach to both evaluating success of the experience and grading proficiency for participating students. While important, the field is still learning how to effectively design assessment opportunities that are meaningful, accessible, and effectively elicit student performance using targeted science knowledge and skills. Challenges might include (1) developing and using complex sets of scoring guidelines to evaluate open-ended or portfolio-based student work or (2) working within the school- or district-level reporting constraints and grading policies that may either oversimplify nuanced student performances or not allow for nontraditional assessments.

> "[Equitable grading practices] improve learning, decrease failure rates and grade inflation, make classrooms more caring and less stressful, strengthen relationships between teachers and students, and build students' responsibility and character."
>
> J. Feldman, Grading for Equity

The practices just outlined can support designers of science experiences to prioritize what's most important when developing assessment and grading strategies. What we value gets assessed, and what we assess gets valued in instructional experiences.

STUDENTS ENGAGE IN A VARIETY OF ASSESSMENT PROCESSES THAT SHOWCASE ONGOING LEARNING AND PROMOTE CONFIDENCE.

Questions to Consider

Do assessment and grading practices focus on student proficiency in targeted knowledge and skills rather than compliance or effort?

Do students have the opportunity to iteratively receive regular feedback on their progress toward targeted science knowledge and practice throughout the experience and demonstrate revised thinking?

Do assessments focus strictly on "right" and "wrong" answers?

Are students empowered to engage in self-assessment and reflection throughout the learning experience?

Are assessments asking students to answer with rote knowledge or use reasoning to explain, predict, or design a solution in a real-world context?

Vignettes

The following vignettes highlight some of the key authentic science experience design features, in a variety of contexts. While not all features may be present or highlighted in each vignette, the content was selected because it provides specific examples of designers attending to these principles.

Making Sense of COVID–19 in the High School Science Classroom 21
This vignette shares the design features of two high school experiences that connect science instruction to students' interests and experiences by framing learning around current events — in this case, the COVID–19 pandemic.

New Approaches to Teaching Physical Sciences 26
This vignette highlights the design features of two physical science units that reimagine the ways traditional physics and chemistry content was once taught with the goal of providing more rigorous, meaningful science experiences for high school students.

Summer Science Experiences..... 31
This vignette highlights an adaptation of a summer science research program designed to prepare students who identify as members of underrepresented communities for science learning beyond high school while carefully considering students' identities, interests, and prior learning experiences.

Engaging Tennessee High School Students through Educator-Designed Classroom Tasks..... 34
This vignette tells the story of a community of practice that sought to increase understanding of howthey can assess what truly matters in science education: a student's ability to make sense of the world around them. Their design process prioritized reaching all students — particularly those traditionally underserved by science programs — with more meaningful and relevant classroom science tasks.

Making Sense of COVID–19 in the High School Science Classroom

This vignette shares the design features of two high school experiences that connect science instruction to students' interests and experiences by framing learning around current events — in this case, the COVID–19 pandemic.

One of the guiding principles of A Framework for K–12 Science Education is that connecting science instruction to students' interests and experiences helps students to "develop a sustained attraction to science and … to appreciate the many ways in which it is pertinent to their daily lives." Not only is this connection linked to later educational and career choices, but engaged students are more likely to be attracted to challenges, use effective learning strategies, and make appropriate use of feedback.[1]

One way to connect science instruction to student interest and experience and therefore to make learning more authentic is to frame learning around current events. In spring 2020, the COVID–19 pandemic affected nearly every aspect of life across the country, and a clear opportunity arose to help students both process their transformed world and experience just how relevant science can be in their day-to-day lives. The following examples show two approaches to addressing this pivotal event in high school science classrooms: One is a brief, flexible activity intended to last 1–2 class periods, and the other is a robust unit intended to last three weeks.

Science News in High Schools

The *Science News in High Schools* outreach and equity program of the Society for Science nonprofit organization focuses on connecting high school students to science-related phenomena and events currently going on in their world through activities and other exercises that feature the latest research and real-world applications of science from their journalism outlet, *Science News*.

An internal team of educators and science editors and an external team of curriculum writers developed the *Visual Models for How a Virus Spreads* high school science activity, which centers on a June 2020 *Science News* article titled *COVID–19 case clusters offer lessons and warnings for reopening*. As written, this activity is intended to last 1–2 class periods.

FEATURES OF THIS ACTIVITY

Connecting to Recent Research or Current Events

This activity supports students to connect classroom science to current events and exposes them to the latest research and real-world data. The primary source article that the *Visual Models* activity is centered on includes interactive models in addition to the raw data, providing a rich resource as the foundation for the activity. After reading this article, students analyze data about one set of coronavirus clusters. This supports teachers who are looking for supplemental resources with relevant, real-world connections to science concepts.

Authenticity Feature: Students integrate skills with core knowledge of science and engineering professions.

Students integrate knowledge and practice to create a visual model to show how another set of virus clusters formed and expanded. Based on the models, students discuss how data and their presentation can inform public health officials who are developing and evaluating plans to restrict or reopen communities.

1. National Academies of Sciences, Engineering, and Medicine. (2018). *Learning Through Citizen Science: Enhancing Opportunities by Design* (page 90). Washington, DC: The National Academies Press. https://doi.org/10.17226/2518

Science News in High Schools (continued)

In this activity, students understand, analyze, and compare models of multiple data sets before creating their own model for displaying the data. They then use their data knowledge to come to evidence-based conclusions and demonstrate an understanding of how data and its presentation can inform and affect public health decisions related to preventing the spread of the COVID–19 virus.

Maximizing Flexibility for Teachers

The design of the *Visual Models* activity encourages teachers to bring their own expertise to the table to improve the activity's implementation and allow teachers to make adjustments for their own context, making the activity more individualized; thus, it is not prescriptive in terms of pedagogy or assessment. As part of their offered professional learning, *Science News in High Schools* openly encourages teachers to make adjustments to the supplemental resource. As a result, teachers often use these activities in a variety of ways.

Facilitating Student Collaboration

The majority of the *Visual Models* activity is group work, incorporating opportunities for scientific discourse, peer feedback, and model comparison so students push each other's thinking as real scientists would. The activity provides prompts for teachers to encourage student discussion as well as things to listen for.

Authenticity Feature: Students learn by engaging with both peers and adults.

Students engage in collaborative group work, discourse, peer feedback, and model comparison and push each other's thinking. The activity provides teachers with the following student discourse prompts:

- Encourage students to discuss what defines "enough" information for the model.
- Students may wish to discuss how public health decisions must take into account the safety of individuals and the entire population while also maintaining the stability of the economy and social and cultural needs of the population.
- How might someone change the way they present data to make specific trends and patterns clearer to their audience?

Connecting to Local Communities

The audience for this activity is spread across the country, but because its audience is spread across the country, the activity includes data specific to Codogno, Lombardy, Italy, and Chicago, IL, to increase relevance and to make the issue more concrete to students. There are also opportunities for students to consider decisions that affect them, their families, and their local communities.

COVID–19 and Health Equity (continued)

COVID–19 and Health Equity

This high school unit developed collaboratively by BSCS and OpenSciEd is centered on the question, *How can we slow the spread of the COVID–19 virus to protect our communities?* The learning experience asks students to figure out how the COVID–19 virus spreads, what mitigation strategies are available and why they work, and why the virus disproportionally affects communities of color in the United States. The unit makes real-world connections among the sciences, public health, and the impact of historical and systemic racism on public health outcomes in the United States. As written, the unit could last from 15 to 17 days depending on educator priorities and adjustments.

The unit is being field tested in 2020 in high schools and will be revised once more before its final publication.

FEATURES OF THIS ACTIVITY

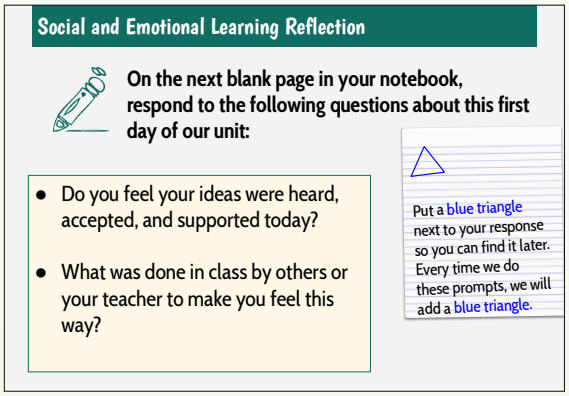
Centering Learning Goals on Science, Social Emotional Learning, and Social Justice

As the devastating impact of this virus has led to trauma in families across the country, the authors thought it was important to include not only Science and Engineering Practices and Crosscutting Concepts from the Next Generation Science Standards (NGSS), but also Collaborative for Academic, Social, & Emotional Learning (CASEL) Core Competencies as learning targets.

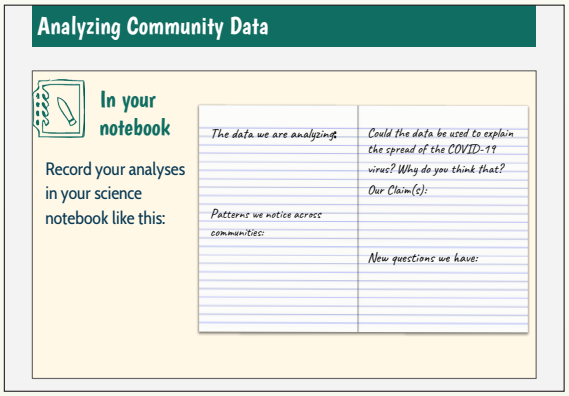
The unit also includes learning targets outside of NGSS and CASEL. These include core science ideas around the transmission of the virus, understanding the compounding mathematical probabilities of combining mitigation strategies, and understanding that systemic racism and historical practices can help explain why some communities are more impacted by COVID–19 than others. This cross-disciplinary approach lends itself to collaboration between disciplines (e.g., social studies and science disciplines) and may be flexibly used by teachers as appropriate.

CASEL Learning Targets

- Self-Awareness: The ability to accurately recognize one's own emotions, thoughts, and values and how they influence behavior.
- Social Awareness: The ability to take the perspective of and empathize with others, including those from diverse backgrounds and cultures. The ability to understand social and ethical norms for behavior and to recognize family, school, and community resources and supports.



Social Emotional Learning Reflection



Science and Engineering Practice Data Analysis Example

COVID–19 and Health Equity (continued)

Prioritizing Students' Engagement, Lived Experiences, and Identities

Developers of this unit surveyed students to learn more about what they are interested in and find engaging, and those responses were then broken down by subgroup to ensure no group of students was excluded from the resulting analysis. The design team then incorporated these components into the unit without relying entirely on assumptions about what high school students would find important.

The unit begins by eliciting prior experience and knowledge of students, asking, "How have you been impacted by COVID–19? What do you already know about COVID–19?" Using the same storyline instructional model as other OpenSciEd units, this learning experience is student-centered and provides students with the agency to make sense of something through engaging in science knowledge and practice.

The authors of this experience noted that strictly focusing on the science-related components of the COVID–19 virus would not honor real-lived experiences of students because it does not impact everybody the same way. Thus, the connections to social justice, systemic racism, and policy choices allow this learning to have more realistic connections to students' lives and identities.

The unit provides guidance for teachers to support students who have been personally impacted by COVID–19, experienced systemic racism, and who do not believe COVID–19 is a public health crisis. This guidance allows educators to adjust instruction and address the needs of their students depending on their experiences and identities.

Authenticity Feature: Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.

Students were surveyed so actual student interests could be reflected in the unit. In addition, the connections to social justice, systemic racism, and policy choices allow this learning to have more realistic connections to students' lives and identities.

Incorporating a Variety of Methods of Investigation and Inquiry

While this unit is intended to be used for years to come, it was also designed with remote instruction in mind so it can be used while communities are still being affected by the virus. Rather than hands-on laboratory experiences, this experience relies on data and simulations accessible through Google Drive. (See an example simulation handout here).

Students make sense of how people can slow the spread of COVID–19 to protect their communities by engaging in a variety of practices. The unit asks students to engage in components of five science and engineering practices from the NGSS as well as three crosscutting concepts, allowing students to view the problem and potential solutions through different lenses and strategies.

Authenticity Feature: Students integrate skills with core knowledge of science and engineering professions. Students use science to explain the world around them and solve problems that matter to society.

Students integrate a variety of practices with knowledge to answer the question: How can we slow the spread of the COVID–19 virus to protect our communities?

COVID–19 and Health Equity (continued)

Variety of Assessment Opportunities

The summative culminating project for this experience requires the transfer or application of knowledge to a new situation: students are asked how they can take what they have figured out and use it to prepare for a future pandemic. They take on roles of different stakeholders who all have different perspectives on public health and prepare for a Public Health Forum in a public health emergency, using the science, social emotional learning, and social justice knowledge they gained to discuss possible solutions.

In addition to the summative assessment, the unit also provides a variety of formative and reflective assessment opportunities embedded within each lesson, noting, "The purpose of this unit is to engage students in timely and important problems for understanding the world in which they live. Thus, the learning goals and assessment opportunities in the unit match the purpose of the unit" (Teacher Edition, page 12).

Authenticity Feature: Students engage in a variety of assessment processes that showcase ongoing learning and promote confidence.

Assessments in this unit focus on students integrating knowledge and practice to understand the world around them and formative processes promote growth and motivation.

Lesson 6	Develop a class model supported by data to explain the cause-and-effect relationship between community disinvestment, systemic racism, and the disproportionate number of COVID–19 cases and deaths in Black and Hispanic/Latinx communities in Chicago.	**What to look/listen for:** In this lesson, the sense-making is done through modeling and discussing as a class. At the beginning of day 3, there is a Consensus Discussion. This Consensus Discussion is intended to give you an opportunity to check for understanding and for students to share their thinking aloud as a class to come to agreement on what they have evidence to support. In student responses, look for the use of cause-and-effect relationships to explain the connection between racial segregation and disinvestment to the impacts of the COVID–19 virus in communities. Individually, students do not need to have every connection explained but as a class they should make a throughline explanation for each of the economic conditions in Part B (food, housing, healthcare, job opportunities).

Example of a learning goal and assessment opportunity given to teachers for one of the lessons. These descriptors are given for each lesson in the unit.

This vignette highlights the design features of two physical science units that reimagine the ways traditional physics and chemistry content was once taught with the goal of providing more rigorous, meaningful science experiences for high school students.

High school science courses can be a powerful opportunity for students to develop and cultivate interest and confidence in science disciplines and may be students' last formal opportunities to gain exposure and experience in disciplinary concepts and practices prior to making decisions about colleges, careers, and other postsecondary paths. Therefore, it is essential that students engage in authentic experiences in which all students see themselves as capable doers of the discipline throughout the course.

Authentic experiences that explicitly connect to students' homes, cultures, and community may be more common in some science topics than others due to the ability to explore phenomena that are more easily accessible and tangible in the classroom. For example, some topics in life science might lend themselves to more concrete phenomena about variation of traits or local ecosystems, whereas some topics in physical science include more abstract concepts to explore, such as wave properties and electromagnetic radiation.

This vignette highlights assets of two physical science units — an area with topics at the high school level that are frequently abstract and may be difficult to visualize — that provide opportunities for students to engage in authentic experiences while making sense of a phenomenon or designing solutions to a problem using the three dimensions of the Next Generation Science Standards (NGSS). The units were developed in collaboration with local universities to enhance students' authentic experiences in their high school courses. These two physical science units are:

- Interactions Unit 1 — Why Do Some Clothes Stick Together When They Come Out of the Dryer? This unit was developed as a collaborative effort between the CREATE FOR STEM Institute at Michigan State University, the Concord Consortium, and the University of Michigan.
- How Your Cell Phone Works. This unit was developed in partnership with Bettendorf Public Schools and University of Northern Iowa.

Interactions Unit 1 — Why Do Some Clothes Stick Together When They Come Out of the Dryer?

FEATURES OF THE UNIT

Connecting to Lived Experiences

In this unit, students engage in learning about electrostatic interactions by trying to answer a question about a phenomenon that is relevant to their lives — *why do some clothes stick together when they come out of the dryer?* In the first activity of the unit, students observe phenomena, discuss initial ideas, and

Authenticity Feature: Students use science to explain the world around them and solve problems that matter to society.

The unit is centered on a phenomenon that is relevant to students and motivates sense-making of a real-world problem.

Interactions Unit 1 — Why Do Some Clothes Stick Together When They Come Out of the Dryer? (continued)

ask questions. At this point, the teacher encourages students to elaborate and explain their ideas based on their observations, prior experiences, and prior knowledge, but not to push for "correct answers" yet. The teacher is provided with a list of possible guiding questions, such as those in Guiding questions below, to elicit students' prior experiences.

Guiding questions provided in the *Interactions Unit 1*

- How many of you do your own laundry?
- Do any of you fold laundry in your house?
- Have you ever found a sock stuck to a shirt?
- What do you see?
- Have you ever wondered why?

Engaging in Practices of Professional Scientists and Engineers

In this unit, students use practices of professional scientists and engineers by developing, revising, and using models throughout the unit to demonstrate their ability to give meaning to their experiences with the unit phenomenon.

Electrostatic interaction is an example of an abstract key idea that students need to understand to explain the unit phenomenon as they answer the unit's driving question of *Why do some clothes stick together when they come out of the dryer?* One of the models students design, revise, and use to learn this science idea that they eventually use to make sense of the unit phenomenon is a "pie pan demonstration" using a Van de Graaff generator. Students develop a model of the demonstration in the first lesson and return to their model to make revisions based on new learning throughout the rest of the unit. As shown in Activity 5.4 below, in the last lesson of the unit, students connect their learning on attractions between charged and neutral objects to their models of the pie pan demonstration. Students then engage in discourse with their peers to evaluate their models and collaboratively develop a consensus model that best fits the evidence they've collected throughout the unit.

Authenticity Feature: Students integrate skills with core knowledge of science and engineering professions.

The unit provides multiple opportunities for students to develop and use physical science ideas along with high school level science and engineering practices to make sense of a real-world phenomenon.

Activity 5.4 - Introduction

Page title:
Revising pie pan models

Your teacher will show you videos of two phenomena that you have already observed and created models to explain. You will now revise those models using what you have learned about atomic structure and its role in the attraction, repulsion, and charging of objects.

1. [drawing prompt] Review your model of the pie pans and Van de Graaff generator from Investigation 1, and revise it by adding ideas that you have learned since then. Create a series of drawings that show why the pie pans behaved the way they did. Be sure your new drawings include some atomic-level details.
[text prompt] Explain your model.

If you want to see the demonstration again, click on the following link: Pie pan demonstration.

Activity 5.4 - Introduction

Discussion
Select a few students' models to post (representing the range of students' ideas). Have the class compare and contrast the different models. Ask students to choose aspects of each model that they agree with and disagree with using ideas, information, and evidence explored in the unit.

Have the class build a consensus model that best accounts for all the evidence. Make sure students can support the consensus model with evidence. The student model should now present a more causal explanation of the phenomenon.

In addition, select two students' models, and compare their initial models (at the beginning of Inv. 1) with their revised versions (from the end of Inv. 1 and Inv. 4) and their current models. Discuss how their models have changed.

Possible questions:
- *Which models do you think best explain this phenomenon?*
- *Do the models present a causal mechanism to explain the phenomenon (i.e., a step-by-step process showing how the phenomenon occurred)?*
- *Are the models consistent with the evidence and information we have?*
- *Is there anything missing from this model that you would add?*
- *How would you change this model?*

In lesson 5 of Interactions Unit 1, students revise their models of pie pans on a Van de Graaff generator, and then engage in a discussion with their class to develop a consensus model.

Interactions Unit 1 — Why Do Some Clothes Stick Together When They Come Out of the Dryer? (continued)

Supporting individual and group reflection

Although the unit materials are delivered primarily through a virtual platform, the unit provides guidance on how to create a classroom environment where students can discuss their initial ideas, observations, and thoughts throughout the unit.

One consistent practice found throughout the unit is engaging students in a Driving Question Board (DQ Board)[1] to organize relevant information such as "questions students raise during discussions, key pieces of evidence, and explanations or models that students have agreed on" (page 8, Investigation 1). Students return to the DQ Board frequently to reflect on what they have already learned and what they have yet to figure out. In addition, students are supported to frequently update and revise their models of phenomena throughout the unit as they increase their understanding based on new data and class conversations.

Authenticity Feature: Students learn by engaging with both peers and adults.

The unit provides guidance for the teacher to support students in engaging in meaningful discourse with their peers and teacher where they can reflect and share their learning while responding to one another's ideas.

Concluding the Lesson

Revisit the unit-level driving question, *"Why do some things stick together and other things don't?"*.

Possible questions:

- What have we learned to help answer the question, "Why do some things stick together and other things don't?". (Add ideas to the DQ board that help answer the question. Modify models on the board to better answer the question.)
- How does this help explain why some clothes stick together when they come out of the dryer?
- What questions do we still have about what makes some clothes stick together in the dryer'?
- What do we need to figure out to develop an even better answer?

How Your Cell Phone Works

FEATURES OF THE UNIT

Connecting to lived experiences

The unit is centered on students making sense of the relevant question — *how does my voice travel across the country when I use my cell phone?* Because cell phones are tools used by most, if not all, students, by engaging in learning focused on a phenomenon that is relevant to their lived experiences, students can better connect how science ideas help them explain features of the world around them.

Authenticity Feature: Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.

The unit elicits students' prior knowledge and experiences for students to make connections between their sensemaking of the unit phenomenon and their own lives and shared experiences.

In the first lesson of the unit, students observe the phenomenon by watching their teacher receive a phone call from the teacher's grandma and then try to figure out how they think it was possible for two people to talk even though they are so far apart.

1. A Driving Question Board is often a posterboard or a virtual board that presents the unit or lesson driving question, and usually includes many sub-questions related to the driving question. Most DQBs are developed jointly by the teacher and students and returned to throughout a unit or lesson.

How Your Cell Phone Works (continued)

Engaging in Practices of Professional Scientists and Engineers

In this unit, students use practices of professional scientists and engineers by developing an initial model of how they think sound travels using cell phones. In the first lesson of the unit, the teacher is guided to allow students to develop their initial models from their prior experience and knowledge by reminding students that there are no limits on their explanation and model of the phenomenon. Students use an Incremental Model Tracker (IMT) throughout the unit to return to and revise their model based on new learning.

Using the IMT, students, like professional scientist and engineers, keep track of:

- Each lesson's driving question that will help them make sense of the overall unit phenomenon of *my voice travels across the country when I use my cell phone.*
- The activities and investigations they engage in to find evidence to support the driving questions.
- The evidence they have collected to make sense of the driving question.
- Their revised models that represent how their models have changed after new learning from each lesson.

Authenticity Feature: Students integrate skills with core knowledge of science and engineering professions.

The unit provides multiple opportunities for students to develop and use physical science ideas along with high school level science and engineering practices to make sense of a real-world phenomenon.

MODEL TRACKER

Unit question: How does a cell phone allow us to talk to someone across the nation?

Question	Source of evidence (and where this evidence source is located)	What we figured out	Representation or application of our ideas

The Incremental Model Tracker worksheet that's used throughout the How Your Cell Phone Works unit

How Your Cell Phone Works (continued)

Building Collaborative Community to Support Student Growth

This unit provides multiple intentional activities where all students can share their observations, thinking, and questions. It provides guidance to teachers to engage students in Scientist Circles where they can share their ideas and learning with their class and receive and provide feedback. Scientist Circles are often followed by visiting the unit Driving Question Board where students can reflect on questions they've answered from their learning and identify questions that still need to be answered or add questions that have arisen due to new learning. Students also get peer feedback on their models several times during the unit and are given opportunities to reflect on the feedback and decide how to incorporate it.

Authenticity Feature: Students engage in a variety of assessment processes that showcase ongoing learning and promote confidence.

In addition to engaging in science and engineering practices, students are provided with multiple formative assessment opportunities that allow them to reflect on their learning at different points in the unit.

Scientist Circle

1. What made a good system?
2. What problems did groups have in developing their systems?
3. What could you do to be more accurate in your transmission? Would there be any disadvantages to this?

An example of the guided questions students engage in during a Scientist Circle

Building Bridges from High School to University Science: The Opportunity Network's Summer Science Research Program

This vignette highlights an adaptation of a summer science research program designed to prepare students who identify as members of underrepresented communities for science learning beyond high school while carefully considering students' identities, interests, and prior learning experiences.

Engaging in the practices of real scientists and engineers is a key feature of authentic science experiences in science classrooms. Science learning that focuses solely on engaging students in the practices of scientists isolated from real-world examples, however, is unlikely to help students authentically understand what it means to do science and may also fail to motivate and prepare students for science beyond high school.[1] Ensuring that high school science experiences are providing an authentic bridge between students and professional science endeavors requires balancing multiple priorities for design, beginning with understanding of where learners are in their learning, what they value, and what barriers may exist between students and the science careers they aspire to.

The Opportunity Network's Summer Science Research Program (OppNet SSRP) aims to create a collaborative research community of high school students who identify as a member of a historically and systemically underrepresented community (e.g., Black, Indigenous, people of color [BIPOC]; first-generation college students) and have a household annual income under $125,000. Designed by, led by, and created for underrepresented STEM communities, the program seeks to prepare students to succeed in spaces where they have been historically undervalued or unwelcome. It does so by helping students develop foundational scientific research skills that will prepare them for challenging college STEM coursework to support their research/medical aspirations while amplifying their own and each other's voices.

The program was launched in late spring 2020, when it became clear that the COVID–19 pandemic would prevent the program's fellows from experiencing the prearranged program design, which included interning in laboratories or hospitals during the summer of 2020. Many other programs of this type converted to lecture-based programs or canceled programming altogether. OppNet SSRP's designers were determined to find a way to design a meaningful experience that would achieve their goals, even if students wouldn't be able to engage in a site-based science internship.

From the program's application process to the final presentations following six weeks of research, OppNet's designers made it clear to students that the program was a time to explore students' interests and passions and science with the goal of preparing them for future success in STEM careers. Program participants were never called "students" but rather referred to as "Fellows" or "Scientists" and they would be paid a $1,000 Summer Opportunity Research Grant, upon successful completion of the program.

FEATURES OF THE PROGRAM

Connecting to students' lives

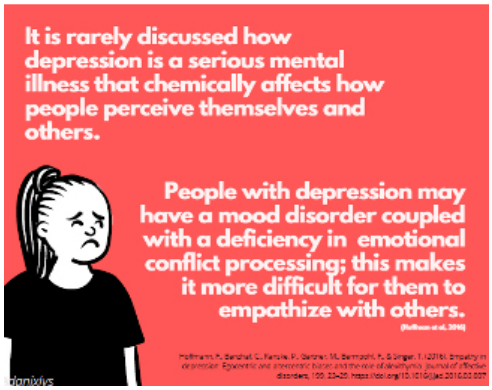
OppNet received applications from Fellows about a variety of topics directly relevant to their interests and experiences — including their siblings' illnesses, historical virology, how lack of sleep impacts student learning, the impact of drug and alcohol use on decision-making, and how exercise impacts mental health. Student research questions reflected the everyday phenomena they were wondering about in their lives along with the problems they hoped to solve.

Authenticity Feature: Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.

The OppNet SSRP allowed students to spend six weeks exploring a question that was meaningful and important to their lives.

1. Schwartz, R., Lederman, N., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610–645. https://doi.org/10.1002/sce.10128

Summer Science Experiences (continued)



An excerpt from OppNet SSRP Fellow Danielys Batista's project. Batista explored the role of empathy is individuals with Major Depressive Disorder. She presented her findings through a series of infographics.

Connecting to the Community

OppNet Fellows had a clear but challenging task of conducting research and building a presentation in just six weeks, and this would be the first time that many of the program's students would grapple so deeply with science ideas and engage in practices to build an explanation for the research question they had selected. Fortunately, students were not left alone to accomplish this task. They received three forms of support that included:

- A team of STEM Research Educators, all first-generation college upperclassmen who themselves had successfully persisted through traditional STEM weed-out courses despite the odds, worked alongside a career educator to design a learning experience that included whole class, small group, and regular one-on-one mentor meetings.
- A weekly journal club, in which students were assigned a science research article to read and collaboratively discuss. The journal club acknowledged that the task would be challenging and that reading and discussing science research articles was a new but important experience for most students, "Talking out loud in Science is hard. This is practice."

Authenticity Feature: Students integrate skills with core knowledge of science and engineering professions.

Students obtained, evaluated, and communicated information from a variety of sources to construct an explanation for their research question.

- A Networking with STEM Professionals event, in which a public health researcher, a STEM professor, a neurosurgeon, and a veterinary medicine student spoke with the Fellows about their experiences in STEM, both academically and professionally.

- What is your lifestyle like in your field – hours, typical salaries, dress, creativity, work environment?
- Can you describe a time that you made a professional mistake or failed and how you recovered from it?
- How has your support system played a role in your achievements and/or research?
- How do you incorporate aspects of your identity in your work and/or research?

Sample questions from OppNet's Networking with STEM Professionals Event. Student questions reflect a desire to understand the personal and professional identities of scientists they met, as well as what has led to their success.

Summer Science Experiences (continued)

Authenticity Feature: Students learn by engaging with both peers and adults.

OppNet Fellows received regular support and feedback from their peers and a team of instructors. They also had the opportunity to network with STEM professionals.

> We didn't just teach skills to support Fellows in overcoming the intimidation of finding, accessing, reading, discussing, synthesizing, and citing scientific journal articles — we also supported them in developing mindsets needed for college and career success.
>
> Stephanie Nudelman, OppNet SSRP Program Director

OppNet wanted students to leave the program understanding that science was both a way to make sense of the world around them and also a powerful tool that had the ability to positively impact their communities. Students were charged with communicating the findings of their research to an audience of their choice — one for whom their research could have immediate, real-world, positive impact. Fellows were able to choose the format they would use to communicate their findings. While many Fellows chose to make a slide presentation, which was also easily shareable via social media, Fellows also created blog posts, one-pagers, literature reviews, and video presentations.

Authenticity Feature: Students use science to explain the world around them and solve problems that matter to society.

Students researched a question of concern to them and communicated their findings in a format that would be most useful for their target audience.

Engaging Tennessee High School Students Through Educator-Designed Classroom Tasks

This vignette tells the story of a community of practice that sought to increase understanding of how they can assess what truly matters in science education: a student's ability to make sense of the world around them. Their design process prioritized reaching all students — particularly those traditionally underserved by science programs — with more meaningful and relevant classroom science tasks.

Systems of education that provide authentic science experiences to students also need ways to authentically measure student learning. A community of practice in Tennessee, the Tennessee District Science Network (TDSciN), sought to increase understanding in its community of how assessments can measure what truly matters in science education — students' ability to make sense of the world around them. Not only was this group of six districts tackling a new way of assessing students, but it also wanted to prioritize how to reach all students — particularly those traditionally underserved by science programs in Tennessee and across the country — with more meaningful classroom science tasks that allow students to show what they know and can do.

The network developed 10 teacher workgroups, four of which focused on developing classroom assessment tasks in earth and space science, physics, chemistry, and life science for high school, while the other six workgroups focused on grades 3-8. These workgroups participated in a summer program through NextGenScience. The program launched with a professional learning session on high-quality and equitable assessment task features and was followed by small group writing sessions and rounds of feedback and revision supported by a consultant with expertise in today's science standards, assessment, and equity. Each workgroup developed two classroom tasks, which became the Tennessee District Science Network Task Library.

Development Priorities

The work began with a meeting of district science leaders across all six districts at which they co-developed TDSciN's vision for science education and how the work fits into their overall strategic plans for science and supporting their teachers.

With this vision for science education in mind, TDSciN leadership identified priorities for the task development and capacity-building project using adapted Science Task Screener criteria. These included:

Authenticity Feature: Students use science to explain the world around them and solve problems that matter to society.

Tasks incorporate meaningful phenomenon- and problem-based scenarios so students could see and make connections to the real-world local, universal, or global relevance.

Tasks include phenomenon- or problem-based scenarios that avoid common traditional instructional contexts. The task must be centered on students figuring out some uncertainty associated with either a phenomenon (an observable event that can be explained with science ideas) or a problem (something that somebody wants to change). This scenario should be relevant and real-world while avoiding contexts commonly used in classrooms (e.g., using roller-coasters to study physics).

Development Priorities (continued)

Authenticity Feature: Students integrate skills with core knowledge of science and engineering professions.

Each task requires students to integrate knowledge and practice to make sense of a real-world phenomenon or problem. Tasks define this required knowledge and practice through clear, grade-appropriate learning targets that align to the Tennessee Academic Standards for Science and the Next Generation Science Standards.

Authenticity Feature: Students' interests, culture, identities, and experiences are positioned as fundamental assets in the learning process.

In addition to integrating a variety of practices and science ideas to complete the tasks, tasks include multiple ways for students to make their thinking visible and offer choice so students can choose what's most comfortable or of interest to them and develop agency.

Tasks require students to engage in grade-appropriate science practice and knowledge together to make sense of something. Each task must have a three-dimensional assessment target as laid out by the Tennessee Academic Standards for Science that requires students to integrate science and engineering practices, disciplinary core ideas, and crosscutting concepts to figure out the phenomenon or problem in the task. This requires students to use reasoning rather than detailing rote, memorized content to complete the task.

Tasks are fair and equitable. The relevant phenomenon or problem driving the task allows students to make meaningful connections, cultivating interest and confidence in science. While the grade-appropriate learning targets are cognitively demanding, the tasks should also use accessible language to reduce barriers not associated with the science learning targets.

- **Tasks intentionally use a variety of question types so students can express their thinking in multiple ways.** Tasks use a variety of open-ended or supported-open-ended question types (e.g, Claim Evidence Reasoning [CER], modeling, evaluation of given information) with limited selected-response questions (e.g., multi-select, Evidence Based Selected Response [EBSR], multiple choice, completing sentence starters).
- **Tasks involve student choice**. Tasks should include some component of student choice, such as choosing the way they want to show their learning (e.g., writing or drawing) or choosing what aspect of the phenomenon they'd like to address. This will require that certain aspects of the task scoring guidelines are more flexible so that students meet the intended assessment target while benefiting from having more ownership and engagement while completing the task as a result of increased choice.

Tasks support their intended targets and purpose. This includes:

- **Tasks produce individual student artifacts that reveal how well students can use the learning targets to make sense of the phenomenon or problem.** This could be the sole focus of the task or part of a collaborative task that includes both group and individual artifacts. In addition, each task includes a rubric for the teacher to interpret a range of student responses and provide meaningful feedback.
- **While these tasks are not designed for any particular curriculum, some may be effectively used in the middle or the end of a learning experience.** If used at the end of a learning experience, a task could support students to transfer their learning to a new phenomenon or problem. If positioned in the middle of a learning experience, tasks may be used to support student growth by providing students with meaningful feed-

Development Priorities (continued)

Authenticity Feature: Students engage in a variety of assessment processes that showcase ongoing learning and promote confidence.

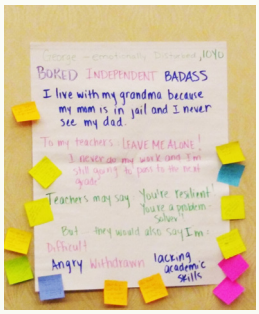
Each task includes a rubric and guidance that supports the teacher to give meaningful feedback to students based on the integrated knowledge and practice targeted. Some tasks also include self-assessment opportunities to foster student agency over their own learning.

back then explicitly adding opportunities for them to apply what they learned and demonstrate improved understanding of the learning targets later in the learning experience.

The full TDSciN Task Checklist that drove the development of these tasks is online here.

Development Process: Equity and Students at the Forefront

To ensure these priorities were realized, the task development process included activities and milestones that foregrounded equity and students.



Example student profile

Student Profiles. The task development learning process for teacher workgroups began inviting teachers to think about students who are often marginalized in science classrooms. Teachers thought of an individual student in this group and created a student profile, including:

- Three words to describe the student
- One thing the student wants teachers to know about them
- One key experience the student has had
- The student's favorite ways to show their learning
- How an asset-minded teacher may describe the student
- How a deficit-minded teacher may describe the student

The task developers continuously returned to these students and how they could develop meaningful tasks to build confidence, interest, and agency in them as learners of science and position student cultures and identities as assets in the learning process.

Piloting with Students. After receiving feedback and revising the tasks, teachers had the opportunity to pilot the tasks in the classroom and collect student work. They then had the opportunity to revise the tasks again based on student work analysis and with formal feedback from consultants. The tasks received a final review upon completion that outlines strengths and opportunities for improvement.

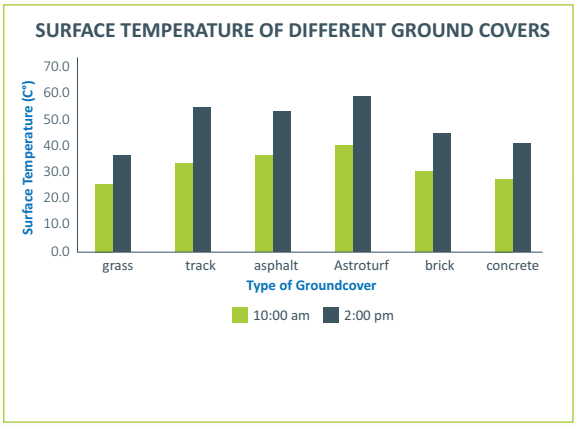
Development Process: Equity and Students at the Forefront (continued)

Outcome

This project resulted in a set of tasks requiring student reasoning using targeted knowledge and practice. Here are some examples:

Turf Task

See the high school physical science task here.



Data given to students completing the Turf Task

What are students figuring out? In this task, students figure out why temperatures are much higher on artificial turf than on regular grass fields when considering the best way to re-cover an old football field.

What is the learning target? Students apply an understanding of the quantitative and qualitative properties of energy and energy transfer through modeling, critically reading scientific literature, analyzing data, and constructing an explanation to describe how patterns in data and energy flow can help explain why artificial turf is hotter and more dangerous to athletes than natural grass.

How is it designed with equitable features to better reach all students? Students are able to make their thinking visible through explanations, mathematical calculations, and oral or written arguments, and scaffolds are provided for each question to help elicit the targeted student understanding. Students are given a choice in how to answer at least one of the prompts.

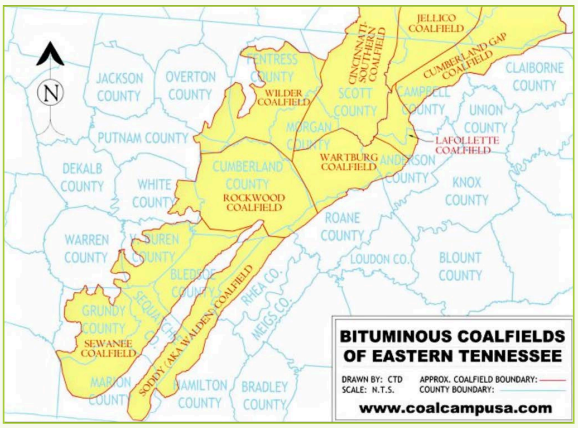
Briceville Task

See the high school earth and space science task and its evaluation here.

What are students figuring out? This cross-disciplinary task requires students to make sense of different patterns and factors to explain a local, real- world phenomenon regarding how the town of Briceville has changed dramatically in the last 100 years (e.g., economic changes, population trends).

What is the learning target? Students apply an understanding of how the availability of natural resources affects communities and individuals by comparing, integrating, and evaluating sources of information to communicate how factors associated with coal mining in the Briceville, TN, community have impacted individuals and the community over time.

How is it designed with equitable features to better reach all students? Students have multiple ways to make their thinking visible through scaffolded prompts with accessible language that help them make sense of the information before synthesizing it. The task outlines what students will be doing in the beginning so that the prompt sequence makes sense and is likely to feel logically coherent to students.



A map of Bituminous Coalfields of Eastern Tennessee by county given to students completing the Briceville Task.

The shaded region in the figure shows the location of major coal deposits in Tennessee as well as the location of Briceville, TN.

Considerations for the Design and Implementation of Authentic Science Experiences

Guidance for Educators

Start with one lesson or unit. As outlined in this resource, there are many pathways for designing authentic high school science experiences. Consider a measured approach, beginning to make these shifts one experience at a time.

Design for your students. Consider students' needs as well as approaches that students have found meaningful and effective. Use these ideas to identify features that may have the greatest impact on students and then build from there.

Educators are learners too. Authentic science entails a different way of organizing learning than what is typically done in classrooms, especially in high school. Teachers new to this kind of instruction, much like their students, need time to learn how to navigate in a new instructional format with different roles and routines.

Plan and reflect with colleagues. Collaborative planning and ongoing conversations about teaching can lead to meaningful shifts in teaching practice over time. Use these five core features of authentic science experiences and accompanying questions to organize discussions with colleagues around priorities for instructional design.

Find opportunities to seek and incorporate student feedback on instructional design. Many of these features require learning about and connecting to students' experiences and lives and inviting students to take greater ownership of the learning process. When adopting, designing, and revising learning experiences, seek student feedback to accurately gauge what is working and what needs to be improved.

Guidance for Leaders

Prioritize features when vetting or designing new materials. The features outlined in this resource can lead to meaningful shifts in learning for students. However, they also represent a major shift in the way science has traditionally been taught. High school science instructional materials vary widely in their design and many may not reflect these features. Instructional leaders should carefully consider these features when selecting, designing, or modifying curricular resources.

Focus on these features in professional learning opportunities. Create opportunities for educators to experience authentic science learning themselves and reflect on how this approach is meaningful for students. Support educators to analyze their curriculum through the lens of these features.

Foster collaboration among teachers. Educators should not be expected to make these instructional shifts alone. Provide structures that maximize collaboration and support opportunities to plan for and reflect on the teaching of high-quality experiences with other educators.

Seek out community and industry partners. Many of the best examples of authentic science experiences were designed in collaboration with individuals outside of a school or district. STEM professionals and community members from local organizations and businesses can enhance the design or facilitation of experiences by identifying community resources, interests, and challenges. These partnerships can play a critical role in the design and implementation of authentic science experiences.

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