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Designing instruction to support meaningful, relevant, and engaging learning experiences for all students

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A Framework for Equitable Lesson Development

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By Rachel Ruggirello and Alison Brockhouse

ABSTRACT

Equalizing opportunities for students to learn science and engineering in the ways described in the *Next Generation Science Standards* (*NGSS*) requires intentional planning. In this paper, we describe a framework for designing equitable and inclusive science lessons. We then share an example of how this framework was applied to the launch of a fifth-grade science unit, specifying the instructional strategies used to provide students with a meaningful, relevant, and engaging learning experience.

Keywords: 3-5; NGSS; asking questions and defining problems; differentiation; grouping strategies; assessment; earth and human activity; earth science; developing and using models; systems and system models

A Framework for K–12 Science Education calls for adequate opportunities for all students to learn science through exploring the natural and designed world using science and engineering practices and applying the lens of the crosscutting concepts (NRC 2012). To realize this vision, science classrooms must intentionally reduce barriers to access and make science relevant, engaging, and accessible for all students. In 2021, the mySci Program at the Institute for School Partnership at Washington University in St. Louis, in partnership with K–8 educators, took on this challenge.

The mySci Program is a collaboratively designed K–8 instructional program consisting of an educative instructional resource, professional learning, leased kits of materials, and consulting services to support implementation of inquiry-based science instruction centered around real-world problems and engaging phenomena. Each mySci unit is designed using ambitious science teaching practices (e.g., Windschitl, Thompson, and Braaten 2018) to provide students with meaningful sensemaking opportunities that require them to combine their knowledge about multiple cross-disciplinary core ideas, science and engineering practices, and crosscutting concepts to construct explanations or design solutions. mySci lessons use the 5E instructional model (Bybee 2014) to promote inquiry-based instruction as students figure out how and why an anchoring phenomenon works and/or design and test solutions to a problem.

The mySci Program serves as the science instructional resource for over 100,000 students in more than 250 elementary schools, reaching 72% of K–5 students in the St. Louis region. Given the program's wide reach, it is critical to attend to equity in designing mySci's instructional materials so that teachers can adapt lessons for students across a spectrum of needs and experiences.

To create a more equitable and high-quality science resource, a team of researchers and practitioners developed a set of criteria that support the equalization of opportunities for students to learn science and engineering in the ways described in the *Next Generation Science Standards* (NGSS; NGSS Lead States 2013). Drawing from practical knowledge and research from cognitive science and sociocultural perspectives on education, the framework identifies six key categories that must be considered to design equitable and inclusive lessons (Figure 1).

Accessible

To support equitable science instruction, materials must address the needs of all students, including those with disabilities. Accessible lessons should provide multiple ways for students to represent their learning and consider alternative reading, writing, speaking, or listening assignments, especially for multilingual learners, students with special needs, or those who read well below grade level. Lesson materials should be created with the principles of Universal Design for Learning in mind—using simple, clear language and providing visuals that support learning.

Relevant

Science instruction is more equitable when it is relevant and engaging for all students. When science education centers on phenomena that students are motivated to explain or problems they can solve, students can build general science ideas in the context of their application in the real world, leading to deeper and more transferable knowledge (NRC 2012). Students who come to see how science ideas can help explain compelling real-world situations can learn to appreciate the social relevance of science. This may mean examining problems or controversial topics that engage students in personally relevant scenarios while empowering them to find real-world solutions (Morrison et al. 2017).

Rigorous

Rigor is directly related to the amount and level of thinking a student is required to do. Rigorous lessons are inquiry-based and challenging and engage students in content, resulting in increasingly complex levels of understanding. Creating rigorous lessons means the activities must support students to access grade-level content. To do this, lessons must be designed with the belief that all students can do the

FIGURE 1

Criteria for attending to equity and inclusion in the mySci program.

RELEVANT

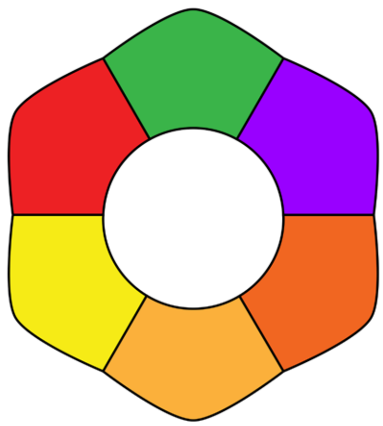
- Connects content to students' lived experiences
- Elicits student questions and ideas and uses them to motivate activities
- Treats students' cultural knowledge, practices & experiences as legitimate ways to learn science
- Provides students opportunities to navigate different perspectives and make sense of conflicting arguments on issues that impact our everyday lives

ACCESSIBLE

- Written materials use direct, comprehensible language
- Includes clear, simple visual supports
- Uses everyday language as a springboard for developing formal science language
- Developmentally appropriate
- Allows for multiple ways for students to demonstrate learning
- Contains appropriate reading, writing, speaking or listening alternatives for comprehensibility across all learners

STUDENT- AND CLASS-CENTERED

- Students actively co-construct knowledge with peers and teacher through meaningful explorations
- Students go public with their thinking and listen, add on, and/or respectfully question each other's ideas (and not the person)
- Students engage in the practices as scientists and engineers do



RIGOROUS

- Incorporates grade-level appropriate reading, writing and thinking
- Emphasizes productive struggle as an indicator that students are doing the intellectual work
- Presents high cognitive tasks and questions that invite students to do something with ideas
- Demonstrates expectation that students can do the work with appropriate scaffolds/tools
- Ensures all students have stretch opportunities

COMMUNITY-CENTERED

- Focuses on phenomena that draw on everyday experience in students' homes, schools, and communities
- Provides science and engineering activities that can have an impact on students' communities
- Presents opportunities to tap intergenerational community member knowledge
- Students have opportunities to share their science learning with the community
- Classes explore the history of students' communities, how and why they changed over time, and how human activity, science, and technology have impacted them

REPRESENTATION

- Celebrates the brilliance, contributions and experiences of marginalized groups in STEM, including : women, LGBTQA+ individuals, people with disabilities, and Black, Indigenous, Latinx, Asian, Polynesian, Pacific Islander, and other historically racialized group
- Provides students opportunities to consider their potential for STEM fields

work with appropriate support, and they must create conditions for students to engage in productive struggle through cognitively demanding tasks that require students to do something with ideas.

Student- and class-centered

Ambitious science teaching is focused on supporting students to engage in the activities of scientists and engineers, including carrying out investigations, developing explanations and solutions, and revising scientific models (NRC 2012). Equitable *NGSS* instruction supports students to actively co-construct knowledge in a learning community through meaningful explanations and discourse with their peers. Designing lessons that encourage student discussion through purposeful questioning and participation structures can ensure all student voices are being heard.

Community-centered

Equitable science instruction provides opportunities for students to connect their learning to their communities. Such connections are supported by participatory learning experiences that give students the opportunity to build understanding and insights through questioning and dialogue with the community. Students should come to value knowledge, practices, innovations, and technologies from their communities as science and see the community as an asset in their own science learning. Students should also be encouraged to share their learning with and develop solutions that have an impact on their school and the broader community (Lee and Grapin 2022).

Representation

To encourage student participation, lessons must be designed to incorporate perspectives that are representative of society. Specifically focusing on the brilliance, contributions, and experience of those under-represented in science expands the circle of influence for students. In addition, science teachers should present and expose students to careers in science and expand what counts as science by connecting to policy, advocacy, and community ways of knowing. Lessons should intentionally serve as windows and mirrors (Bishop 1990)—students should see themselves reflected in the learning while also observing science in worlds they have not experienced to better understand the world, how they fit into it, and how we can address complex local and global problems.

Overview of unit

In this section we provide specific strategies aligned to the criteria for attending to equity and how they are used in the initial lesson of a fifth-grade unit called Using Our Resources Wisely. We designed this unit with our equity criteria in mind and in partnership with regional teachers. This unit, available on the *NGSS* website (*www.nextgenscience.org/resources/examples-quality-ngss-design*), addresses the following performance expectations: 5-ESS2-1, 5-ESS3-1, 5-ESS2-2, 4-ESS3-1, 3-5-ETS1-2 and 3-5-ETS1-3.

In this unit students investigate the anchoring problem: We need farms to grow food, but the process of producing food for all of us can harm Earth systems. This unit is broken into three sections driven by student questions. These questions support students to investigate what is on a farm and how farms are a part of Earth's systems; the problems on the farm, including the use of natural resources and impact on Earth's systems; and potential solutions that reduce our use of natural resources and protect Earth's systems (see Figure 2).

Attending to equity at the beginning of a unit

Unit launch

Attending to equity at the launch of a unit is crucial to maintaining equitable practices as the unit progresses. In the first lesson, students may not yet have the language or background knowledge to describe the concepts covered, but they will be able to express ideas in their own language and from their own experiences. It is crucial for teachers to pay attention to and honor the legitimacy of these ideas and forms of knowledge, and to attend to how students learn new terms that will be used throughout the unit. Making sure the lesson's key ideas are accessible and student-centered promotes student engagement from the outset, supporting all students to participate in the discussions, questioning, and investigations that follow.

The unit launches with a Driving Question Board (DQB), a tool for eliciting student thinking and organizing questions about an anchoring phenomenon or problem. After watching a short video about how farms produce food, students write down any questions they have about the unit's anchoring problem: We need farms to grow food, but the process of producing food for all of us can harm Earth systems. For example, students may wonder what kinds of things happen on a farm, or why growing food might harm Earth's systems. Working in groups, students categorize their questions as the teacher guides them to think about the unit's central themes. Then students' categorized questions are kept where they can be easily referenced throughout the unit. Figure 3 shows two DQBs created in partner teachers' classrooms, demonstrating the range of student questions clustered to support learning aligned to the sections of this unit. Over the coming lessons, the teacher returns to the DQB to revisit, add to, and answer student questions.

The DQB is an opportunity for formative assessment: Teachers can find out what students already know and what interests them about a topic, and they may choose to adjust their instruction based on student questions. It also builds relevance by reminding students that their learning is being driven by things that they care about and questions they asked. mySci's teacher guide (see Online Resources) for this unit contains an additional idea for enhancing the relevance of the unit launch by guiding students to talk about their own favorite foods and using this for the basis of a conversation about farms and food production. This conversation brings personal, place-based, and community-centered connections into focus and allows students to see their own interests reflected in the learning.

Engage

During the Engage portion of the lesson, students co-construct a model of a farm environment. The teacher prompts students to think about the different parts of a farm

FIGURE 2

Unit flow chart.

Unit 22: Sections Quick View		
Section 1 **How are farms part of Earth's systems?**	Section 2 **How does our use of natural resources on farms affect Earth's systems?**	Section 3 **How can farmers use resources wisely to protect Earth's systems?**
Total time: 6 days LESSON 1 **How can we describe the different parts of the Earth?** *(3 days)* LESSON 2 **How do Earth's systems interact?** *(3 days)*	*Total time: 11 days* LESSON 3 **What are natural resources and how do humans use them?** *(3 days)* LESSON 4 **How does our use of fossil fuels affect Earth's systems?** *(3 days)* LESSON 5 **How does our use of water affect Earth's systems?** *(3 days)* LESSON 6 **How does animal waste affect the environment, and what can we do about it?** *(2 days)*	*Total time: 9 days* LESSON 7 **How can people use resources in a way that is less harmful to the Earth?** *(3 days)* LESSON 8 **How can we use farms to harness wind energy?** *(3 days)* LESSON 9 **How can farms make better use of animal waste?** *(3 days)*

environment, and after a Turn and Talk, students share their ideas with the class. Using chart paper or another large drawing surface, the teacher records student ideas by drawing a model. Importantly, the teacher prompts students to name and label parts of the model. Many students will use everyday language rather than scientific terminology to describe their ideas. This supports equitable instruction by keeping the unit student-centered and honoring student language and ideas. It also offers an accessible springboard for engaging in the rigorous practice of modeling.

Modeling is an important science and engineering practice in this unit. An initial whole-class model is developed with teacher guidance to scaffold students as they engage in this process. The goal of this activity is not to create a comprehensive and fully correct model; rather, the goal is to enable students to use their own ideas as a starting point for engaging in the practice of modeling and sharing their initial ideas about farms. Working together to develop a farm model maintains the focus on student thinking as this unit unfolds. The class will return to and revise this model as they learn, and students will also create and revise their own farm models to reflect their evolving understanding. Figure 4 shows examples of student models from partner teachers' classrooms.

Explore

In the Explore portion of this lesson, students make and classify observations about their surroundings to prepare to learn about Earth's systems. In groups of three or four, students walk around their schoolyard or another outdoor location. It is important for teachers to select a safe location for students to explore, clarify safety expectations for students, and ensure adequate adult supervision during this activity. As they walk, students identify natural parts of the environment and write, draw, or photograph their observations. They might notice things like clouds, puddles, rocks, or trees. They use their journals to record and classify their observations. During this phase, students are actively

FIGURE 3

Driving question boards from partner teachers' classrooms.

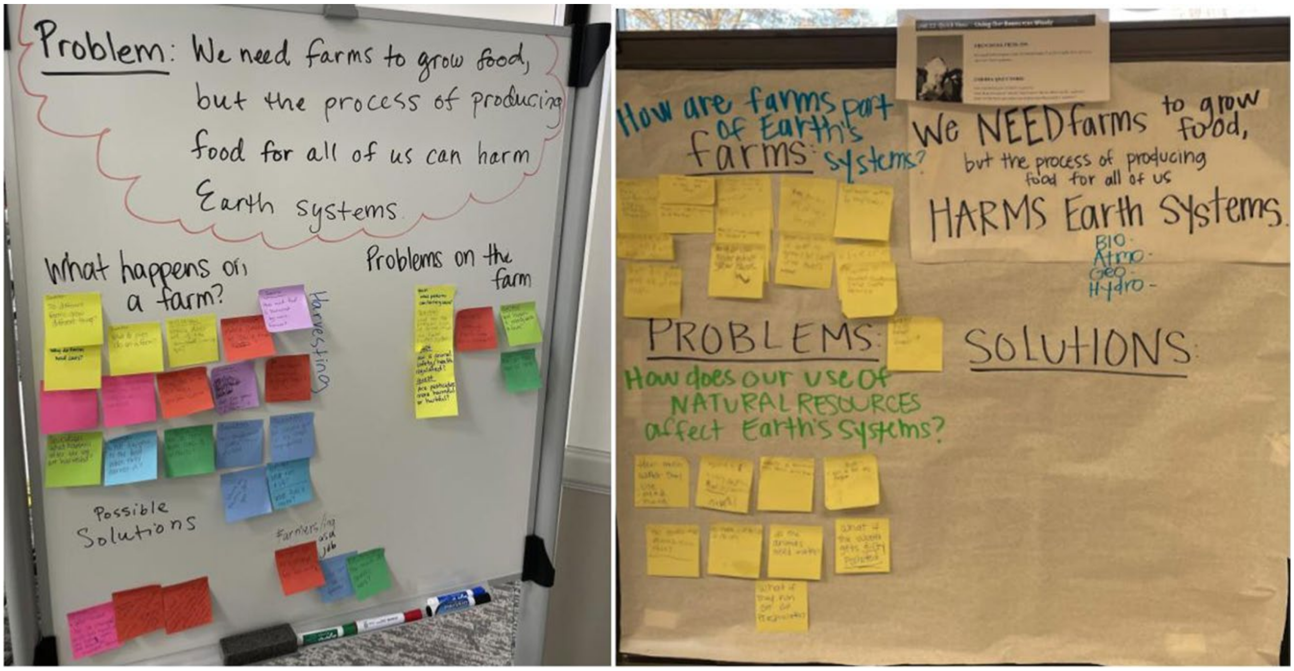


FIGURE 4

Student models of the farm system revised over the course of the unit.

involved in making observations, allowing students to move and connect with the natural world. This supports students who might struggle to remain still and seated in a classroom setting.

Following this activity, students will use scientific vocabulary to describe Earth's systems. By first exploring and classifying parts of their own environment in everyday language, students are supported to make concrete connections between Earth's systems and their own experiences. Students are also prompted to see how their own environment is similar to or different from the Earth systems present on a farm. These connections help make this lesson both relevant and community centered.

This lesson includes two callouts that further support connections to our equity framework. The first introduces the self-documentation technique (Pratt 2013), an approach in which students use photographs to capture parts of their everyday lives and environments around school or at home and uses those photographs as the basis for pursuing STEM investigations. This technique aligns with and expands on student exploration of the schoolyard, encouraging students to tap into sources of knowledge from their own cultures and communities as they consider how elements of their own lives might be resources for learning about Earth's systems. The second call-out encourages teachers to use equitable grouping strategies when setting up the exploration activity. Research demonstrates that heterogeneous groups of three or four students in which each student is assigned a significant role are supportive of learning. Such grouping practices support students to engage in conversation and co-construction of knowledge with peers who might have different perspectives, experiences, and ways of thinking.

Explain

This portion of the lesson introduces the scientific terms for Earth's systems—the geosphere, biosphere, atmosphere, and hydrosphere. Students watch videos defining each system and discuss their understanding as a class before recategorizing the parts of the environment from their observations as belonging to one of Earth's spheres (ESS2.A). Providing students with the opportunity to express new ideas with their peers supports vocabulary acquisition. This strategy, combined with vocabulary slides with visuals and in both English and Spanish support access for multilingual learners. Students use visual methods and common language while their scientific vocabulary catches up with their ideas.

As students discuss and apply knowledge about Earth's systems, they express their understanding in multiple ways: They record ideas as drawings or write in their journals, they talk with their peers to come up with their own definitions of each term, and they fill out graphic organizers categorizing their observations. Teachers can formatively assess students' understanding of part of disciplinary core idea ESS2.A as they observe how students categorize their observations into different Earth systems and provide additional support if needed by revisiting videos or going over examples as a class. This supports equity through both access and rigor: Students engage in and express their learning using multiple modalities, and they are required to stretch their thinking to express themselves using the practices of scientists and engineers.

Elaborate

In the Elaborate portion of the lesson, students develop their own farm models using what they have learned about Earth's systems so far. The class model acts as a scaffold for this activity, as does the creation of a "gotta have it" checklist. First, the teacher prompts students to revisit their ideas about how a farm works by asking, "What have we learned about so far that we might want to include in our models?" The teacher uses their responses to create a "gotta have it checklist," a list of essential elements for their models. Having students co-construct this checklist, rather than the teacher providing it up front, makes students active participants in deciding what counts as important in their scientific explanations. This checklist also presents an opportunity for formative assessment: The teacher may use student responses to identify what students do and do not yet understand about farms and Earth's systems.

Teachers have several options for differentiating and scaffolding this activity. For students who need extra support, the teacher could provide a template and guide the class through clear drawing and labeling conventions. The teacher could provide practice time, scrap paper for initial sketches, and photographs of elements students may want to include in their models. Additional adults such as aides or special education teachers can provide support by working with students one-on-one or in small groups. For students who are above grade level, the teacher can suggest adding additional elements to their model beyond those listed in the "gotta have it" checklist or ask advancing questions to prompt students to explain the cause-and-effect relationships between various elements of their models.

As in the previous lesson, both rigor and accessibility are supported through multiple modes of representation: Students talk through ideas in small groups or as a class, then have the option of drawing, writing, or constructing a physical model (Figure 4). Relevance is maintained as students connect what they noticed in their communities to the unit's anchoring problem. To support model creation, students watch videos featuring a dairy farm and immigrant farmers; this incorporates representation into the activity, as students examine different ways that farms and farmers might look.

Evaluate

During the final portion of this lesson, students compare farm models with a partner and give each other feedback using the collaboratively developed "gotta have it" checklist before discussing the similarities and differences with the class. The checklist supports peer assessment and provides the teacher an opportunity to assess ESS2.A and the crosscutting concept system and system models as they look for representations of different things (components) found on a farm (system) and provides labels identifying the Earth systems these things are part of. Engaging in dialogue in their classroom community promotes the creation of rigorous work as students consider multiple ways of representing their understanding within their models. Students change their own models based on the feedback they received, and the class consensus model is revised to include the Earth systems students have identified. As the lesson closes, the class revisits the DQB to answer student questions and add new ones that have emerged from student learning so far. Returning to the DQB helps maintain relevance and center student thinking as the lesson concludes.

Maintaining equity as the unit progresses

Certain equity-supportive strategies show up repeatedly to maintain equity as the unit progresses. Self-documentation, group work, at-home suggestions, and student talk structures are all incorporated throughout the unit. Equity callouts are used to promote equity and inclusion within each lesson as well. The DQB is used to launch each subsequent lesson, and students are encouraged to notice when their questions have been answered and use these questions to promote sharing their own sensemaking with the class. The class revises its consensus farm model throughout the unit, adding knowledge of appropriate disciplinary core ideas and crosscutting concepts to their representation. As the model becomes increasingly sophisticated, students use it to explain how farm system components and their interactions may damage the environment, and how farms can use strategies to mitigate that damage.

Applying this framework to your own classroom

We encourage teachers to adapt their lessons in ways that make science learning more equitable and see this framework as a resource for guiding these adaptations. This framework attends to equity in design and opportunity (accessibility and rigor), authentic engagement (relevance, student-, class- and community-centered) and inclusivity (representation). To apply this framework, it is essential that teachers consider who their students are and learn more about the communities in which they live. Getting to know your students as individuals as well as understanding their families and communities can provide rich opportunities to create learning that values all students.

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ONLINE RESOURCES

Teacher Guide, *www.nextgenscience.org/resources/grade-5-mysci-using-our-resources-wisely*

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