Making Science Multilingual: Supporting Equity through Design Principles

Introduction

Science offers students powerful tools for understanding the world and engaging with complex issues in their lives and communities. All students need and have a right to learn science. The importance of making science accessible to all students is emphasized in the *Call to Action for Science Education: Building Opportunity for the Future* (NASEM, 2021). It states that

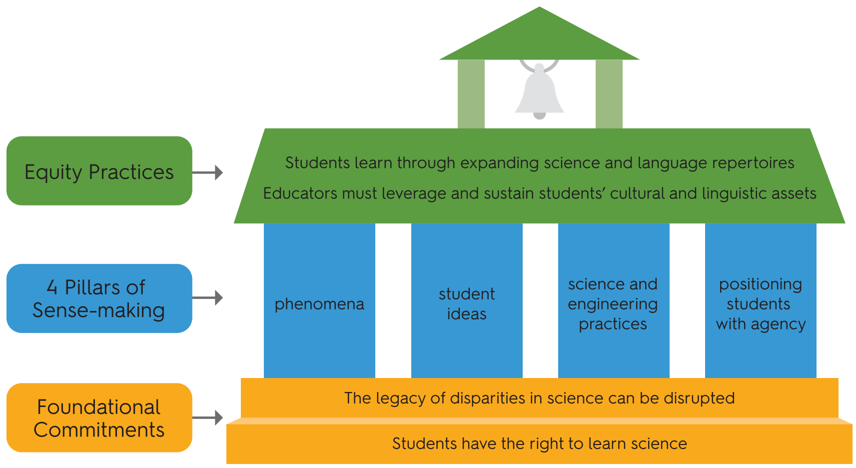
> Students' everyday languages are essential resources for engaging in sensemaking and allow multilingual learners at all stages of proficiency to co-construct scientific knowledge with their peers (NRC, 2012; Molle et al, 2022).

- "The accomplishments and discoveries of science are inspirational, especially for children, as they come to understand their world and develop a sense of agency within it." (p. 14)
- "Understanding science and the practice of scientific thinking are essential components of a fully functioning democracy." (p. 16).
- "… expanding the pool of talent is important for ensuring that science takes up questions and problems that are important for a wide range of communities. Building a diverse scientific workforce can help ensure that science better serves all people." (p. 18)

Yet, we have a long way to go in ensuring that multilingual learners in every community have access to the high-quality science education that supports their understanding of the world, access to college education and STEM careers, and engaged civic participation (NASEM, 2018; NASEM, 2021).

Today's focus on sensemaking in science, guided by the three-dimensional view of science learning explained in *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council [NRC], 2012) creates new opportunities to make science more inclusive and meaningful to multilingual learners. To realize those opportunities, WIDA brought together experts in science and language education to collaborate on a project called Making Science Multilingual (MSM). Their goal was to develop a set of principles that 1) articulate how language and science intersect and 2) identify key elements that support the equitable inclusion of multilingual learners.

The product of this collaboration, the *Design Principles for Engaging Multilingual Learners in Three-Dimensional Science* (MacDonald et al, 2020), describes opportunities for language development and culturally sustaining education (Paris, 2012) within the collaborative discourse-rich reasoning of contemporary three-dimensional science instruction. This method of teaching has eight principles grouped into three themes:



1. Foundational commitments to science education
2. Four pillars for sensemaking in science instruction
3. Assurance of equity for multilingual learners

This Focus Bulletin will highlight key points of the MSM design principles and will offer reflection questions and additional resources to help you explore and expand your work toward equitably engaging multilingual learners in science.

Foundational Commitments to Science Education

Our work toward a more just future for all young people in science must offer alternatives to the long-standing beliefs and practices that limit multilingual learners' access to the field. MSM's first two principles establish a firm foundation for this work:

- Principle 1: Students have the right to learn science
- Principle 2: The legacy of disparities in science can be disrupted

These two principles call us to examine and revise some longstanding beliefs and approaches. We need to examine policies and practices that exclude English learners from rigorous science courses until they have reached a certain level of English proficiency (NASEM, 2018). We also need to understand that the language for learning and engaging in science need not be considered a prerequisite, but can be developed by *doing science*, and that linguistic and science knowledge develop concurrently when students interact together in meaningful activities (NASEM, 2018; Lee 2021).

Students' everyday languages are essential resources for engaging in sensemaking and allow multilingual learners at all stages of proficiency to co-construct scientific knowledge with their peers (NRC, 2012; Molle et al, 2022). Similarly, we need to examine our curricula and lesson materials to make sure that we represent the cultural and linguistic diversity of scientists. All students benefit from seeing examples of scientists from diverse cultures and languages. By actively finding and showcasing a diverse scientific population for the students, we show them that successful careers in science are open to everyone.

Additionally, it is important to broaden the view of science, so that students experience science education not as fact memorization, but as a social endeavor for explaining phenomena and solving problems that are relevant to many people's daily lives and communities. Discussing complex issues, such as science-based decisions that benefit some while negatively affecting others, is an important part of science education.

"Language development and concept development occur simultaneously: ... and are inextricable" (NASEM, 2018, p. 57).

"Language is a product of doing science, not a precursor or prerequisite for doing science and ELs need ample opportunities to do science" (NASEM, 2018, p. 65).

Ms. Guzmán's fourth grade science class is beginning a new unit about natural events that shape the earth's surface. The students view a slide show of satellite and close-up images of the same coastline before and after a hurricane. Ms. Guzmán asks students to share what they notice about the images. Then, Ms. Guzmán explains that the images were taken before and after Hurricane Matthew battered the Haitian coastline. She presents basic information about the hurricane—including when and where it occurred—and related weather conditions. She asks students if they have ever been in a hurricane or strong storm, and if they noticed differences in land or water features before and after it. She also asks, "Does every storm cause changes to land features or damage to roads and buildings?"

Reflecting on Foundational Commitments

1. In your context, how does a student's English language proficiency influence students' access to science learning activities? Have you had opportunities to learn how to support multilingual learners as they engage in science?
2. What opportunities do your culturally and linguistically diverse students have to see or interact in some way with scientists who look or sound like them? Are there opportunities to interact with science professionals of diverse backgrounds from the community?
3. How does science instruction address the social complexity of issues that involve science in your community? What openings exist in your curriculum to consider science-related issues from multiple perspectives, and consider how issues impact different communities? What opportunities do students have to learn how science is being used to solve problems in your community?

Resources/Suggestions

1. Examples of diverse scientists, from the Harvard Gazette Science & Technology web page "This is what a scientist looks like."
2. Cards showing types of scientists and what they do, a free resource from AmplifyScience, a publication from the Lawrence Hall of Science, University of California, Berkeley.
3. Strategies for reflection about equity, a resource titled "Strengthening Equitable Discourse Skills for Students and Teachers" from an NSF-funded website.

Four Pillars for Sensemaking in Science Instruction

Science for all students, but especially multilingual learners, should engage learners with relevant phenomena and encourage sensemaking activities that simultaneously combine previous experience with the learning of new content and language through firsthand three-dimensional learning.

> *Learning is a process of actively reconstructing and reorganizing what you know, using a variety of resources to compare your current understandings against those of peers and against evidence of the world.... All students come to school with remarkable experiences that should be invited into discussions—they cook, build things, ramble around playgrounds, care for pets, engage in sports, take pictures, observe what happens in the sky.... Teachers need to reveal and talk about these resources in the classroom to see which of them can be used, together with instructed ideas, to help students construct knowledge that they can then use to solve problems and answer questions that are meaningful to them* (Windschitl, Thompson, & Braaten, 2018, p. 86).

To support this process, the MSM design emphasizes these four pillars of sensemaking:

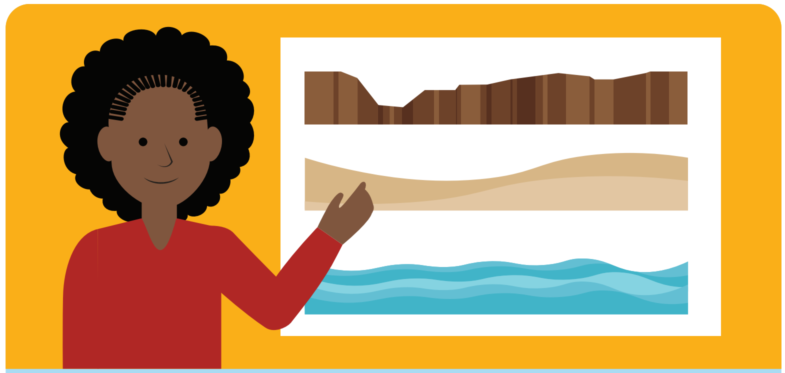
- Principle 3: using relevant phenomena to engage students in sensemaking
- Principle 4: eliciting student ideas as a starting place for sensemaking, or for co-constructing explanations of phenomena
- Principle 5: using the science and engineering practices to anchor content learning and language use and development in sensemaking

- Principle 6: positioning students with agency and authority, so that their contributions are integral to sensemaking in science

These four principles work together to create opportunities to engage students in learning science in different ways. For example, imagine how a teacher might begin a unit on photosynthesis. In a more traditional approach, a teacher might begin with an abstract question like, "How do plants get food and grow?"

By contrast, a sensemaking approach might begin with a teacher showing students a time-lapse video of a plant growing and asking questions such as, "What do you see happening here? What do you notice? What does the plant need in order to grow that big?" Using a natural phenomenon (Principle 3) that introduces a science concept and anchors the learning throughout a unit of instruction provides students an opportunity to engage, instead of learning a science concept from a textbook.

It is best to select a phenomenon that students are familiar with and can connect to in some way. A well-chosen phenomenon should have the potential to connect multiple science ideas, so that students will have extended opportunities to explore and integrate several science concepts as they work together to inquire, figure out, collect, and make sense of evidence, build claims, and make connections to the real world. Here is a fourth-grade example that incorporates one of NRC's Next Generation Science Standards:

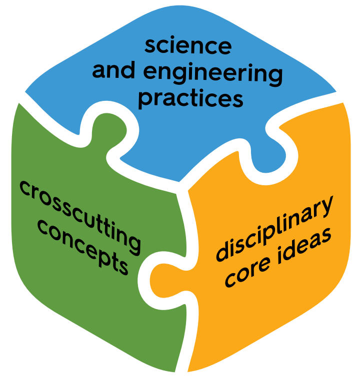


After the students share their ideas and experiences, Ms. Guzmán instructs them to work in small groups to experiment with a tub filled with a mixture of sand and dirt on one side and water on the other. The students then mimic the conditions of a hurricane by creating waves, using a watering can to create heavy rain and a fan to imitate the wind. Students vary the conditions to see the different effects on the model and later co-construct only those that could have changed the coastline so dramatically.

Then, Ms. Guzmán asks each group to depict a model on a poster that explains how an event like a hurricane can change a coastline. Their models need to include words, drawings, and symbols that describe observable and unobservable features and processes. They should also include conditions before, during, and after the hurricane.

A recent storm brought an unusual amount of rain to the area, causing a lot of local erosion. Streams overfilled their banks and became deeper and wider, and lots of dirt was carried away and deposited in other places. Mrs. Allen used this natural phenomenon to engage her fourth-grade students in the earth science, working toward the related standard: Make observations or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation (4ESS2-1).

When science is taught using a phenomenon to drive inquiry, student contributions become integral to the collective learning (Principle 4), and students engage with one another's ideas as they explore the concepts and co-construct new understanding. When science is made meaningful in this way, students build and expand their identities as capable learners, sense makers, users of science, and full participants in learning communities engaged in meaningful, consequential pursuits (see the Closer Look at the end of this bulletin to learn more about how to choose engaging phenomena for exploration).



Teaching with an emphasis on the science and engineering practices (Principle 5) anchors students' contributions in an ongoing effort to build, test, revise, and justify the scientific ideas and models students create, and keeps students' evolving meaning-making skills at the center of their scientific practice. This approach to inquiry and co-construction engages students in the communication-rich science and engineering practices, disciplinary core ideas, and cross-cutting concepts, which make up the three dimensions of today's science instruction (NRC, 2012) and helps students build scientific understanding and develop language simultaneously. This collective sensemaking, both in the moment and across time, supports gradual shifts in language use. Supporting students to gather evidence, coordinate that evidence with others' ideas and evidence, and weigh the strength of evidence allows for shared sensemaking about phenomena and makes space for students to critique different ideas and to build knowledge and language together.

Finally, positioning students with agency and authority (Principle 6) emphasizes that students have important ideas to contribute and are capable of expressing them in complex, precise, and explicit ways using everyday language. Positioning students in ways that elicit their ideas is central to supporting their engagement as competent members of a learning community. Positioning students and teachers as co-inquirers—whose interests, questions, and contributions are valuable for sensemaking—is essential for making science and language meaningful for learners.

As students start creating their models, Ms. Guzmán encourages them to begin with their own ideas and words and reminds them that they will be revising their models as they learn more. She also reminds them to take time to hear everyone's ideas before deciding what to include in their group's model.

Once all groups have had a chance to develop an initial model, Ms. Guzmán asks each group to explain it to the class. As students listen, they jot down similarities and differences they notice among the models, and questions they have about them. Examples of these questions, such as "What does this symbol represent? What is happening in this part of your model?" are posted on a wall in the classroom to help each group clarify and revise their models.

WIDA

Reflecting on Sensemaking in your School, District, or State

1. How is science taught? Do you see students engaging with phenomena? Do you see students collaboratively building explanations of phenomena? Do students have opportunities to make choices about their science learning? How often do students have opportunities to discuss and analyze evidence that supports a scientific claim or question?
2. How are the science and engineering practices used to support the simultaneous learning of content and language? Do students utilize these practices to gather evidence, discuss and evaluate that evidence with others, make claims based upon the evidence, and then communicate that evidence to others using scientific argumentation?
3. Are students and teachers positioned as "co-inquirers" in the learning process? How can the classroom learning environment be adapted so that questions and contributions from all students are valued in the science sensemaking process? How do these ideas connect to the real world? And finally, can students take action in their communities by exploring solutions to local problems as a result of their science learning?

Resources/Suggestions

1. Supporting sensemaking dialogue, WIDA Focus Bulletin that explores ways to strengthen reasoning and language in STEM.
2. Choosing phenomena for classrooms, a resource from the Next Generation Science Standards website.
3. Working with different student ideas, a Practice Brief published on the NSF-funded website "STEM Teaching Tools."
4. Encouraging productive student dialogue, a Practice Brief published on the NSF-funded website "STEM Teaching Tools."
5. Understanding and leveraging translanguaging, a WIDA Focus Bulletin that explores translanguaging strategies for educators.

Assurance of Equity for Multilingual Learners

The four pillars of sensemaking already discussed highlight ideas that provide rich opportunities for engagement in science learning and language development. Equitable inclusion of multilingual learners requires more than the creation of these opportunities, however. The final set of design principles identifies additional essential elements:

- Principle 7: Educators must leverage and sustain students' cultural and linguistic assets
- Principle 8: Students learn through expanding science and language repertoires

Students' life experiences are the foundation from which they make sense of the world, and connecting science learning to their experiences and ideas is essential for sensemaking. We need ways to learn about students' experiences and ensure that phenomena or problems used as the basis for sensemaking are those to which students can connect.

Students take part in sensemaking using their ways of knowing about the world and communicating their ideas. By starting where students are—with their languages and their ideas—we open up sensemaking to all students, and support deeper understanding of scientific concepts (Principle 7). Multilingual students may have lived in parts of the world where they have had significant experience of a phenomenon being discussed. Inviting them to contribute their knowledge to the class discussion provides a space for their experience and enriches the entire classroom community. In addition to that, multilingual students who speak Spanish may already use in their everyday language some of the terms that other English speakers see as advanced science vocabulary, (such as carbón: coal/carbon, oxidado/a: rusted, and bicarbonato: baking soda), allowing them to support their other English-speaking classmates in hearing and learning more precise science terms.

Multilingual learners' experiences and languages can be directly used to expand their understanding of science and language use. For example, when students are ready to state a claim based on evidence, it presents an opportunity for them to explore the level of certainty they can express through sets of words and phrases with accompanying quantifiers, such as "it is impossible that," "it is doubtful that," "it is unlikely that," "perhaps," "possibly," "I am almost certain," "we are certain that," "assuredly," "it is clear that," "clearly," "the evidence suggests," and "the evidence is conclusive."

When we model and discuss additional ways of stating something, provide activities that expand on an experience, or ask questions that call for stating evidence-based reasoning very clearly, we expand students' ways of using language as well as their ways of understanding the world through science (Principle 8). When language development is embedded in students' sensemaking, students can consider the pros and cons of different ways of expressing ideas and develop the awareness that will help them communicate their science knowledge effectively in a variety of contexts.

Reflecting on Equity Principles

- What opportunities and resources do you have to learn about students' connections to science?
- What resources do you have for selecting phenomena that will be both relevant and effective?
- In your classroom, when do students have opportunities to use their everyday language(s)? How do you support transitions between everyday language and language that is more specialized or technical?
- Do you have resources to support students' language development in different ways and for different purposes (e.g., formal writing in science vs. making contributions to a group discussion)?

Resources/Suggestions

1. Integrating family knowledge, an article from the National Science Teaching Association webpage.
2. Working with indigenous students and families, a Practice Brief published on the NSF-funded website "STEM Teaching Tools."
3. Strengthening reasoning and language, a WIDA Focus Bulletin that explores this issue in STEM education.

Conclusion

The MSM design principles are both a call to action and a foundational resource to help teachers, curriculum designers, and policy makers create more opportunities for multilingual students in science education. They guide educators in building more equitable spaces for all students to make connections and contributions to the communities in which they live and to build agency and authority while engaging in the process of learning science. Taken together, MSM's principles, reflection questions, and resources offer guidance to explore and expand our efforts to more equitably engage multilingual children and youth in science.

Learning More

Ambitious Science Teaching (Windschitl, Thomson, & Braaten, 2018) offers guidance on a highly interactive science pedagogy, where teachers actively solicit the ideas of students, engaging them in multiple rounds of creating and revising scientific models, explanations, and evidence-based arguments.

Science in the City: Culturally Relevant STEM Education (Brown, 2019) examines ways to rethink STEM education through the lens of contemporary research on urban science teaching and multiple stories that illustrate the linguistic and cultural aspects of teaching and learning science.

STEM Teaching Tools is a collection of over 80 practice briefs that highlight ways of working on specific issues that come up in STEM education.

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Using phenomena to drive sensemaking in science provides many opportunities for multilingual learners to strengthen both their science reasoning and the language they use to express it. By choosing phenomena that have relevance to our multilingual students and providing extended opportunities for discussing and deepening ideas, the more successful we will be at engaging them in our science classrooms. This checklist will help you select relevant and effective phenomena.

What makes a phenomenon relevant to students and effective for learning science?

Considerations for selecting relevant and effective phenomena

Checklist	Reflection questions
❑ Connects with students' everyday experiences	• Is the phenomenon observable to students? Is it something that students have likely observed during their everyday activities at home or in their community? • Does making sense of the phenomenon offer students opportunities to draw on their everyday knowledge or experience, and/or their familiar language(s)? • Have students expressed an interest in topics or activities that relate to this phenomenon? • Is it representative of the experiences and concerns of the students in the classroom, or their communities? • If the phenomenon doesn't exactly reflect the local context or students' experiences, can you still make connections?

❑ Builds on students' ways of knowing	• Do students know about this phenomenon through
	  ◦ art, stories, film, literature, music, dance, or other forms of expression?
	  ◦ family or community practices or history?
	  ◦ popular media?
	  ◦ social or political movements?
	  ◦ practical or work experience?
	• Does the phenomenon relate to something many people are likely to have some experience with and ideas about?

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Checklist	Reflection questions
❑ Drives deeper engagement with science ideas and concepts	• Does explaining the phenomenon involve multiple science ideas (e.g., energy in chemical processes, interdependent relationships in ecosystems, etc.) or concepts (e.g., energy and matter, stability, and change)? • Does it help students connect a science idea or concept with a relatable, real-world situation or event?
❑ Motivates engagement in science practices	• Is the phenomenon interesting or puzzling? Does it spark students' curiosity and ideas? • Does making sense of this phenomenon offer students opportunities to experience doing science? • Does it offer students meaningful opportunities to engage with texts, media, data sets, images, or mathematical representations?
❑ Provides a rich context for discussion and language development	• Is there a meaningful role for discussion and collaboration with peers in making sense of this phenomenon? • Does making sense of this phenomenon offer students opportunities to use multiple modalities (texts, videos, equipment, data displays, etc.) and their full linguistic repertoire? • Is the phenomenon complex enough to require students to work together in explaining it and revisiting/revising their explanation? • Is it complex enough to open related opportunities to use language in different contexts (e.g., posters, presentations) that can expand language use?

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