Enhancing Science Lessons to Support Multilingual Students' Engagement in Science and Engineering Practices

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Every student enters our classroom with incredible insight gained from their lived experiences and with fascinating ideas about how things work and why things are the way they are in our natural world (Russ and Sherin 2013). Unfortunately, not all students' ways of expressing ideas about scientific phenomena, or conveying solutions to problems, are recognized and valued in our schools. This is especially so for multilingual students—students whose assets teachers do not always know how to tap into and whose linguistic needs they may not know how to address (National Academies of Sciences, Engineering, and Medicine [NASEM] 2018). We intentionally use the term *multilingual* instead of English language learner because it highlights students' multiple resources and knowledge of languages in addition to English. Multilingual students represent an extremely varied group of individuals who differ across numerous factors, including—but not limited to—the languages they know and speak (as well as their fluency in these languages), birth country, circumstances for living in the United States, schooling and family backgrounds, and levels of English proficiency (NASEM 2018). Most important, multilingual students have a wealth of knowledge and skills that teachers must learn to notice and leverage; doing so is crucial for improving the learning experiences of all students.

It is essential to consider the experiences of multilingual students in the context of the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013). Bringing to life the reform-oriented learning described in the *NGSS* requires that teachers shift their instructional practices to ensure all students engage in rich sensemaking when investigating questions or solving problems. To do this sensemaking work, students need to authentically engage in science and engineering practices (SEPs; Schwarz, Passmore, and Reiser 2017). Table 1 includes a list of the eight SEPs highlighted in the *NGSS* (for details, see Bybee 2011). Meaningfully engaging in these practices requires students to use language in increasingly complex ways (González-Howard, McNeill, and Ruttan 2015). This complexity goes beyond how we typically think about language (e.g., writing and speaking) to also include the use of nonlinguistic modes, such as drawing, graphing, or gesturing (Grapin 2019). These nonlinguistic modes are valued ways of analyzing and communicating information in the fields of science and engineering (Lee et al. 2019) but often go unnoticed and untapped in science classrooms. Thus, for all students to have meaningful opportunities engaging in SEPs, it is necessary that teachers notice and value the different ways students might use language when sensemaking and that they consider and address the language demands embedded in these practices.

TABLE 1: The eight science and engineering practices.

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematical and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

In this article, we share 10 strategies for supporting multilingual students' engagement in SEPs and illustrate how five of them could be used to enhance middle school science lessons. These strategies were identified through an extensive review of educational research focused on understanding aspects of teacher instruction that support multilingual students' sensemaking. Although we describe and illustrate five strategies in the context of particular SEPs and middle school science topics, these strategies can help multilingual students across grade levels partake in all SEPs to "figure out" (Schwarz, Passmore, and Reiser 2017) a range of disciplinary core ideas. Further, many of these strategies are things a science teacher can immediately incorporate into their instruction to improve the sensemaking experiences of their multilingual students.

FIGURE 1: Strategies for supporting multilingual students' sensemaking experiences. Asterisks refer to highlighted and exemplified strategies in the manuscript.

Strategy	Description and *rationale*
*Adapt anchoring phenomena to be local, meaningful, and accessible	Adapt a lesson or unit's anchoring phenomena to your local context, keeping in mind students' home cultures and languages. *This can help make the phenomena more accessible for your multilingual students, which in turn can support their sensemaking.* (Dong 2009; MacDonald, Miller, and Lord 2017)
Intentionally group students to support English language use and development	Depending on the goals of a lesson, intentionally group multilingual students with certain peers (sometimes with peers who know the same languages as them, and other times with peers whose English language development is slightly more advanced). *Thoughtful grouping that varies throughout a unit allows multilingual students to benefit from working with different peers and learn from the uses of other students' linguistic resources.* (González-Howard et al. 2017; NASEM 2018)
*Provide students with opportunities to talk in small groups before whole-class discussions	Before students engage in whole-class discussions, let them first talk with others in pairs or small groups about their ideas. *Smaller group structures offer multilingual students a chance to engage in sensemaking with their peers as well as the space to use their linguistic and nonlinguistic resources to express their ideas (and learn from other students' uses of these resources too).* (González-Howard et al. 2017; Grapin 2019; MacDonald, Miller, and Lord 2017; NASEM 2018)
*Encourage students to use linguistic and non-linguistic modes to express their ideas	During moments when students are tasked with expressing their ideas, allow them to do so through linguistic (oral and written language) and nonlinguistic modes (e.g., drawings, graphs, symbols, gestures). *Making connections between written or spoken words and nonlinguistic representations helps multilingual students generate richer understandings of scientific phenomena.* (Grapin 2019; NASEM 2018)
*Allow students to use both content-specific and everyday registers to express their ideas	When communicating ideas, encourage students to use both content-specific and everyday registers. This helps students fully express themselves, allowing peers to evaluate, question, and build off their ideas. *Switching back and forth between different registers is especially important for multilingual students because it helps them draw on their full range of meaning-making resources.* (NASEM 2018)
Highlight cognates in science	When applicable, call attention to cognates. Cognates are words that are similar in both spelling and meaning across languages. Many science vocabulary words have cognates (e.g., photosynthesis in English = fotosíntesis in Spanish). *Highlighting cognates can support multilingual students in making connections between their home language(s) and new science vocabulary in English, vocabulary they may then use to do sensemaking work.* (Dong 2009)

Figure 1 provides an overview of the strategies we identified in our review of educational research. When used thoughtfully, these strategies can help foster classroom environments in which multilingual students do meaningful and challenging sensemaking work with peers. In Figure 1, the left column names the strategy, while the right column describes it and explains how the strategy supports multilingual students' sensemaking. Understanding each rationale (which is italicized) is very important. When teachers comprehend why and how a certain strategy is helpful, they can meaningfully apply the

FIGURE 1: (continued) Strategies for supporting multilingual students' sensemaking experiences. Asterisks refer to highlighted and exemplified strategies in the manuscript.

Strategy	Description and *rationale*
Use multiple types of representations to develop students' understanding of new vocabulary	When students learn new vocabulary, have them represent the new term in multiple ways. They can (1) write the term, (2) draw a representation of the term, (3) use their own words to write an explanation for what the term means, and (4) use the new term in a sentence. *Doing so helps multilingual students form a deeper understanding of new vocabulary related to the focal science topic.* (Marzano and Pickering 2005)
*Explicitly address how language is used for scientific sensemaking	Spend time discussing with students how language is used to engage in scientific sensemaking (e.g., to construct questions, or make claims that are supported by evidence). This can be done in many ways, such as having students analyze an exemplar text to identify what about its language makes it strong, or brainstorming as a class different ways to express ideas around a topic using linguistic and nonlinguistic modes of communication. *This transparency will allow multilingual students to more deeply understand how language can be used to partake in science and engineering practices.* (González-Howard et al. 2017; NASEM 2018; O'Hallaron, Palincsar, and Schleppegrell 2015; Symons 2017)
Unpack the meaning of certain words in the context of science	Break down the meaning of scientific words that are central to a lesson, especially if these words have different meanings in different contexts (i.e., in science vs. everyday use). *This provides multilingual students the chance and space in which to discuss any preconceptions about the meaning of the word(s), and to draw on their personal experiences.* (NASEM 2018; O'Hallaron, Palincsar, and Schleppegrell 2015)
Purposefully use sentence starters to scaffold productive language	When necessary, use sentence starters to model particular oral or written language production skills, like forming scientific questions and explanations or engaging in argument from evidence. It is important that such scaffolds be used purposefully and removed when no longer needed. *Sentence starters help multilingual students develop English language skills all the while expressing their ideas to peers.* (González-Howard et al. 2017; Rodriguez-Mojica 2019)

strategy to their own instruction in contexts different from those described in this article. The strategies in Figure 1 vary, from providing students opportunities for small-group talk before whole-class discussions (e.g., González-Howard et al. 2017; MacDonald, Miller, and Lord 2017) to highlighting cognates in science (Dong, 2019). Although the strategies are presented and described separately, they could be combined. For instance, students might be given sentence starters (e.g., Rodriguez-Mojica 2019) to guide their small-group talk.

Next, we illustrate how five of these strategies (indicated by an asterisk in Figure 1) could be used to enhance middle school science lessons that follow the 5E instructional model (Bybee 2015). Figure 2 provides an overview of the 5E instructional model; the left column names each phase of this instructional model, and the right column describes it.

Designing and/or carrying out science lessons that follow the 5E instructional model have the potential to provide students with opportunities for doing sensemaking work with peers, especially if each phase incorporates authentic and meaningful student engagement in SEPs. However, there are additional changes that teachers could make to further enhance each phase of a 5E science lesson for multilingual students. These changes, exemplified in the following sections, leverage multilingual students' linguistic resources and address language needs they might have, improving the richness of the sensemaking experience for all students in the class.

Engage

Example strategy—adapt anchoring phenomena to be local, meaningful, and accessible. As a teacher plans the Engage phase of their lesson, it is important to not only engage students' interest, but also activate their prior understandings about the focal phenomena or problem being studied so that these understandings can be built on or shifted throughout the lesson. For example, in a lesson where students are asked to "evaluate design solutions for maintaining biodiversity in an ecosystem" (MS-LS2-5; NGSS Lead States 2013), the teacher might engage students by introducing an image of an ecosystem, such as a coral reef. To generate and later evaluate design solutions for maintaining the ecosystem's health, students need to have a strong understanding of what this ecosystem is and what makes it healthy. However, students might find it challenging to think and talk about ecosystems they have not seen in person. To support multilingual students with this aspect of the lesson, a teacher could adapt the anchoring phenomena to be local, meaningful, and accessible (Dong 2009; MacDonald, Miller, and Lord 2017). Including a familiar ecosystem in this lesson opener makes the concept of a healthy ecosystem more accessible, and this familiarity offers multilingual students more language resources to draw on when describing and evaluating what they see. In turn, this can help multilingual students better grasp the goal of designing solutions for keeping an ecosystem healthy, which would ultimately support their sensemaking throughout this lesson.

Explore

Example strategy—encourage students to use linguistic and nonlinguistic modes to express their ideas. In the Explore phase of a lesson, students investigate and gather more information about the focal phenomenon or problem under study. For example, in a lesson focused on "designing, constructing, and testing a device that either minimizes or maximizes thermal energy transfer" (MS-PS3-3; NGSS Lead States 2013), students could participate in an investigation to test the conductivity of different materials as a precursor to designing their own device. In such an activity, a teacher might ask students to record their findings and ideas for their potential design solutions in their science notebooks. To enhance this phase of the lesson, a teacher could encourage students to use both linguistic (e.g., written words) and nonlinguistic modes (e.g., drawings or graphs) to express their investigation findings and subsequent design ideas (Grapin 2019; NASEM 2018). Doing so not only allows multilingual students to tap into all their resources to communicate with their peers, but also supports them in making connections between written words and nonlinguistic representations. With the notebooks holistically capturing students' ideas, students will have more fully developed and complex design solutions to share with their classmates as they begin to plan the construction of their device.

Explain

Example strategy—explicitly address how language is used for scientific sensemaking. During the Explain phase of a lesson, teachers facilitate opportunities for students to develop and share their initial explanations of the focal phenomenon or problem. In a lesson in which students are asked to "construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales" (MS-ESS2-2; NGSS Lead States 2013), students might have just completed an exploration of satellite data showing that Mt. Everest moves 4 cm every year (OpenSciEd 2020). Then, during the Explain phase, students might develop and share their initial explanations for how this evidence supports the idea that the Earth is changing over time. To enhance this phase of the lesson for multilingual students, a teacher could explicitly discuss with students how language is used when constructing evidence-based explanations. For instance, a teacher might introduce students to the claim, evidence, and reasoning (CER) framework for crafting scientific explanations (McNeill and Martin 2011) and then have the class brainstorm sample statements for each framework component (González-Howard et al. 2017; NASEM 2018; O'Hallaron, Palincsar, and Schleppegrell 2015; Symons 2017). To express reasoning, students might think of the phrase "The data supports my claim because ____." We suggest these ideas be displayed somewhere easy for students to reference (e.g., on a poster or handout). This transparency will allow multilingual students to more deeply understand how language is used for constructing explanations, which will improve their sensemaking experiences.

Elaborate

Example strategy—provide students with opportunities to talk in small groups before whole-class discussions. The goal of the Elaborate phase is for students to apply the knowledge and skills they have developed thus far in the lesson to a related, but different, context as that of the focal phenomenon or problem. For example, consider a lesson where students have already "gather[ed] and synthesize[d] information about technologies that have changed the way humans influence the inheritance of desired traits in organisms" (MS-LS4-5; NGSS Lead States 2013). So far in the lesson, students might have learned about this topic in the context of genetically modified foods. Therefore, during the Elaborate phase, teachers could have students think about and share out other organ-

FIGURE 2: 5E instructional model.

Phase Name	Description
Engage	The goal of the Engage phase is to grab and focus students' attention on a particular natural phenomenon or problem that needs to be solved. This can take on many forms (e.g., observing a teacher demonstration, viewing a video of a discrepant event, reading about a local problem in the newspaper) and last anywhere from a few minutes to the length of an entire lesson. During the Engage phase, teachers can also get a sense of their students' current understanding around the focal phenomenon or problem.
Explore	The purpose of the Explore phase is for students to engage in a variety of activities (this can occur over multiple days) to further investigate the focal phenomenon or problem. Ideally, these explorations are driven by students' own inquiry and questions that they developed during the Engage phase. During this phase, the teacher facilitates students' explorations and offers supports if/when needed.
Explain	During the Explain phase, students use experiences from the prior two phases to construct their initial explanations for the focal phenomenon or problem. Referencing moments from the Engage and Explore phases, as well as students' initial explanations, the teacher then introduces and labels some of the disciplinary core ideas and SEPs students have engaged in.
Elaborate	The goal of the Elaborate phase is for students to apply the knowledge and skills they have developed thus far to a related, but different, context as that of the focal phenomenon or problem. This transfer of knowledge and skills supports students in expanding and deepening their understandings.
Evaluate	Ideally, teachers carry out formative assessments throughout all of the previously described phases. However, the purpose of the Evaluate phase is for teachers to assess what students figured out around the focal phenomenon or problem. These assessments should be authentic and mirror the activities and SEPs students engaged in during earlier phases.

isms whose traits humans have influenced. To better support multilingual students with this phase of the lesson, a teacher could provide students with opportunities to talk in small groups before engaging in whole-class discussions (González-Howard et al. 2017; Grapin 2019; MacDonald, Miller, and Lord 2017; NASEM 2018). Smaller group structures offer multilingual students a chance to engage in sensemaking with their peers, and they also offer them the space to use their linguistic and nonlinguistic resources to express their ideas (and learn from other students' uses of these resources too). When students then share their ideas as a whole class, it is more likely that the ideas will represent contributions and sensemaking from all class members.

Evaluate

Example strategy—allow students to use both content-specific and everyday registers to express their ideas. Finally, the Evaluate phase is an opportunity for teachers to assess what students figured out around the focal phenomenon or problem. For instance, a lesson might conclude with students "develop[ing] a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem" (MS-LS2-3; NGSS Lead States 2013). The model that students generate by the end of the lesson can serve as an excellent assessment of learning. However, teachers must ask themselves: Is it more important that students' models demonstrate deep conceptual understandings about the cycling of matter or that they use perfect, academic English? To better help multilingual students fully express what they know during the Evaluate phase, a teacher might encourage students to use both content-specific and everyday registers (NASEM 2018). A register captures how an individual uses language in different ways under different circumstances (e.g., how a student speaks with a teacher vs. a peer vs. their parent). Switching back and forth between these different registers is especially important for multilingual students because it helps them draw on their full range of meaning-making resources. Through continued engagement in authentic SEPs, such as modeling, students will become more familiar and comfortable using academic language to carry out sensemaking work.

Concluding thoughts

It is important to note that the previous examples are not meant to be exhaustive or prescriptive, but instead offer a few ways that these strategies could be incorporated into a science lesson plan that follows the 5E instructional model. As mentioned earlier, a teacher might use multiple strategies simultaneously during any phase of the lesson. Ultimately, which strategies you choose to employ in your lessons (and when) will depend heavily on the content being addressed, the SEPs students will engage in, and the individual and composite needs of your multilingual students.

Grounding instruction in SEPs has the potential for making classrooms more equitable spaces. This potential is especially attainable if we learn to notice and value the wide-ranging ways that individuals make sense of the natural world (Bang et al. 2017). It will take time, effort, and practice for teachers and students to become more familiar with and comfortable engaging in SEPs. However, we strongly believe it is well worth the effort—doing so will result in science classrooms in which all students' ways of knowing and making sense of the natural world are appreciated and used to move forward the classroom community's knowledge construction work. ●

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REFERENCES

Bang, M., B. Brown, A. Calabrese Barton, A. Rosebery, and B. Warren. 2017. Toward more equitable learning in science. In *Helping students make sense of the world using next generation science and engineering practices*, eds. C. Schwarz, C. Passmore, and B.J. Reiser, 33–58. Arlington, VA: NSTA Press.

Bybee, R.W. 2011. Scientific and engineering practices in K–12 classrooms: Understanding a framework for K-12 science education. *Science and Children* 49 (4): 10–16.

Bybee, R.W. 2015. *5E instructional model: Creating teachable moments*. Arlington, VA: NSTA Press.

Dong, Y.R. 2009. Linking to prior learning. In *Challenging the whole child: Reflections on best practices in learning, teaching and leadership*, ed. M. Scherer, 107–118. Alexandria, VA: Association for Supervision and Curriculum Development.

González-Howard, M., K.L. McNeill, and N. Ruttan. 2015. "What's our three-word claim?": Supporting English language learning students' engagement in scientific argumentation. *Science Scope* 38 (9): 10–16.

González-Howard, M., K.L. McNeill, L.M. Marco-Bujosa, and C.P. Proctor. 2017. 'Does it answer the question or is it French fries?': An exploration of language supports for scientific argumentation. *International Journal of Science Education* 39 (5): 528–547.

Grapin, S. 2019. Multimodality in the new content standards era: Implications for English Learners. *TESOL Quarterly* 53 (1): 30–55.

Lee, O., L. Llosa, S. Grapin, A. Haas, and M. Goggins. 2019. Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education* 103 (2): 317–337.

MacDonald, R., E. Miller, and S. Lord. 2017. Doing and talking science: Engaging ELs in the discourse of the science and engineering practices. In *Science teacher preparation in content-based second language acquisition*, eds. A.W. Oliveira and M.H. Weinburgh, 179–197. Cham, England: Springer International.

Marzano, R.J., and D.J. Pickering. 2005. *Building academic vocabulary: Teacher's manual*. Alexandria, VA: Association for Supervision and Curriculum Development.

McNeill, K.L., and D.M. Martin. 2011. Claims, evidence, and reasoning. *Science and Children* 48 (8): 52–56.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2018. *English learners in STEM subjects: Transforming classrooms, schools, and lives*. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press. *http://www.nextgenscience.org/ next-generation-science-standards*

O'Hallaron, C.L., A.S. Palincsar, and M.J. Schleppegrell. 2015. Reading science: Using systemic functional linguistics to support critical language awareness. *Linguistics and Education* 32: 55–67.

OpenSciEd. 2020. 6.4 Rock cycling and plate tectonics: How and why does Earth's surface change? *https://www.openscied.org/access-the-materials/*

Rodriguez-Mojica, C. 2019. Instructional supports: Facilitating or constraining emergent bilinguals' production of oral explanations? *International Multilingual Research Journal* 13 (1): 51–66.

Russ, R.S., and M.G. Sherin. 2013. Using interviews to explore student ideas in science. *Science Scope* 35 (5): 19–23.

Schwarz, C.V., C. Passmore, and B.J. Reiser. 2017. Moving beyond "knowing about" science to making sense of the world. In *Helping students make sense of the world using next generation science and engineering practices*, eds. C.V. Schwarz, C. Passmore, and B.J. Reiser, 3–21. Arlington, VA: National Science Teaching Association.

Symons, C. 2017. Supporting emergent bilinguals' argumentation: Evaluating evidence in informational science texts. *Linguistics and Education* 38: 79–91.

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