Noticing Multilingual and Non-dominant Students' Strengths for Learning Mathematics and Science

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Abstract This chapter examines the strengths multilingual and non-dominant learners bring to school for learning mathematics or science. We connect research on learners' strengths from two sets of literature: research in mathematics education and in science education. The examples illustrate how research in mathematics and science education can inform policy and teaching in multilingual classrooms. This research assumes that learners from multilingual communities bring strengths, not deficits, to classrooms. We provide and illustrate three recommendations for effective policies and teaching: (1) noticing learners' strengths, (2) recognizing mathematics and science practices, and (3) expanding what counts as practices in STEM disciplines. We use examples from previously published research in United States classrooms to illustrate how to notice the strengths multilingual learners bring to learning math and science, recognize practices associated with STEM disciplines in student contributions, and expand what we include in such practices. Although the examples are drawn from classroom-based research in the United States, those findings have important implications that extend to other settings (communities, nations, or learning environments).

Keywords Equity · Strengths · Science · Mathematics · STEM practices · Language diversity

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1 Introduction

This chapter focuses on noticing the strengths of multilingual and non-dominant learners for science, technology, engineering, and mathematics (STEM). We use a Vygotskian approach to learning and teaching that emphasizes learners' potential, not the mistakes they make. Approaches focusing on misconceptions and errors have been shown to be insufficient to support student learning (Hammer, 1996; Moschkovich, 1998, 1999a; Smith et al., 1994). Thus, it is important that teaching and policy for multilingual and non-dominant STEM students include strengths. Most importantly, deficit models of multilingual learners often neglect to notice any strengths that these learners bring to STEM classrooms (Barwell et al., 2017). This paper illustrates the strengths that multilingual learners bring for learning mathematics or science in school. We connect research in mathematics education to research in science education (in the United States), exploring these two sets of complementary findings. The chapter uses five examples from previously published research in United States classrooms to illustrate three recommendations for policy and practice.

A focus on learners' strengths can inform policy and teaching by first assuming that learners bring strengths to STEM learning, not deficits (Aguirre et al., 2013; Moschkovich, 2002). Beyond that assumption, we make three recommendations for policy and practice to: (1) notice learners' strengths (Mason, 2002; Watson, 2009), (2) recognize practices associated with the disciplines of mathematics or science[1] (Rosebery et al., 1992; Warren et al., 2001) in students' contributions, and (3) expand what counts as STEM practices. Although noticing students' strengths is necessary, it is only a first step. Practitioners need to not only notice strengths but also notice the disciplinary practices in what students do or say. Only by recognizing disciplinary practices in students' contributions can practitioners build on strengths and support students as they develop further disciplinary expertise.

Language policies facilitate or constrain multilingual students' access to rigorous STEM coursework (NASEM, 2018). Classifying students by proficiency in the language of instruction can have unintended consequences. For example, if students are placed in STEM courses according to their language proficiency, this can lead to systematic exclusion through "tracking" (NASEM, 2018). Such placement practices are based on beliefs that language must be mastered before students can engage with content or that language is learned separately from content. These unproductive beliefs (Faltis & Valdés, 2016) undergird language policies and practices in STEM education. Instead, policies should assume that, given appropriate conditions, multilingual students learn at least as well as their monolingual peers (Barwell et al., 2017).

We use bilingual, multilingual, and non-dominant to refer to learners from communities whose members speak one (or more) language(s) (or language varieties) different from the language of instruction (LOI). We use non-dominant (Gutiérrez,

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[1] We will call these STEM practices, disciplinary practices, science practices, or mathematical practices.

2008) to include learners from marginalized communities and acknowledge power issues for communities and learners which may or may not be labeled multilingual. We use *multilingual* to emphasize student competencies instead of deficiencies (i.e., English learners or learners of the LOI). Valdes-Fallis' (1978) definition of a bilingual speaker is "the product of a specific linguistic community that uses one of its languages for certain functions and the other for other functions or situations" (p. 4). Policy and instruction should leverage what students have, not focus on what they do not know (Faltis & Valdés, 2016). Equitable teaching practices for multilingual learners need to shift from focusing on perceived deficits to uncovering, honoring, and building on students' strengths, in particular the "repertoires of practices" (Gutiérrez & Rogoff, 2003) students bring to classrooms. This chapter provides examples of noticing such strengths, recognizing STEM practices in student contributions, and expanding what counts as STEM practices. Only then, after these three recommendations are met, can policy and teaching build on these students' strengths.

2 Theoretical Framing

The first recommendation, noticing student strengths, depends on noticing as a practice. We draw on *professional vision* (Goodwin, 1994) to frame noticing student strengths. Louie (2018) frames teacher noticing as a teaching practice laden with the values of the larger educational system. Noticing is not neutral but has culturally based affordances and constraints (Goodwin, 1994; Louie, 2018). Our theoretical framework connects noticing student strengths to STEM practices. Multilingual students' strengths can enrich learning opportunities only when these strengths are noticed, when STEM practices in student contributions are recognized, and when we expand what counts as STEM practices. Only then can teaching build on those strengths.

Teachers learn to notice (i.e., attend, interpret student contributions) in a variety of ways. For example, teachers can focus on students' emerging reasoning or on errors, misconceptions, and perceived deficits. Louie (2018) emphasizes that noticing is socially constructed, not politically neutral, so whether teachers privilege reasoning or misconceptions has consequences for learning. As teachers refine their noticing practices, they reproduce ways of noticing that privilege certain students over others (Louie, 2018). Teachers are inculcated into noticing practices and influenced by the educational culture. Often, noticing practices focus on what students do not know, using a deficit lens. Such deficit views negatively impact students' classroom experiences, course placements, and opportunities to learn STEM. This intellectual, symbolic, and epistemological violence can have material consequences on student outcomes (Martin, 2019; NASEM, 2018).

Teachers must notice students' strengths and also recognize STEM practices in students' contributions. Professional vision can expand so that student strengths are not rendered irrelevant by narrowly defined practices. Educators need to both notice strengths and recognize STEM practices to provide opportunities for students to engage in STEM disciplinary practices in ways that build on student strengths.

We start with the assumption that students bring strengths (Gholson et al., 2012; Martin, 2019) and linguistic competence (Martínez & Mejía, 2020) to learning STEM in school. We make three recommendations for connecting students' strengths to STEM practices through the professional vision of teachers (Louie, 2018). First, educators should notice students' strengths, rather than the errors of "imperfect language" (Faltis & Valdés, 2016; Moschkovich, 2013). Second, educators should recognize the STEM practices in students' contributions. Third, educators should expand what "counts" as mathematics and science practices—so that those strengths are valued as crucial knowledge, expanding the unnecessarily narrow views of STEM practices (Bang et al., 2012). This expansion "desettles" (Bang et al., 2012; Harris, 1995) expectations so that community knowledge is valued alongside traditional definitions of STEM disciplinary knowledge or practices.

Our examples of particular strengths for STEM learning and disciplinary practices are not a prescription for teaching students from any particular community or group. Cultural practices vary according to the historical context, goals, and purposes of a community (Gutiérrez & Rogoff, 2003). Therefore, one cannot assume that the cultural practices of one group will necessarily be the same in another group that shares the same heritage.

We use the United States mathematics standards, the Common Core State Standards for mathematics (CCSS, 2010), and United States science standards, the Next Generation Science Standards (NGSS, 2013) as current policy embodiments of the STEM practices that should be available to students in school. Although these standards are informed by research on STEM professional practices, the standards do not capture everything important about STEM learning, nor are these standards assessment tools for student learning. The standards serve only as a shorthand for the disciplinary practices that researchers, practitioners, and policy makers in the United States agreed are central foci for STEM teaching and learning.

We focus on mathematical practices emphasized in the CCSS (2010), such as constructing arguments, reasoning abstractly, generalizing from mathematical structure, and modeling. We also focus on science practices emphasized by the NGSS (2013), including asking questions, analyzing and interpreting data, and arguing with evidence. These practices overlap with STEM professional practices and are recommended for classroom STEM instruction.

3 Mathematics Examples

Although traditional approaches focused on mastering mathematical procedures, we start with a broader definition of mathematical proficiency (Kilpatrick et al., 2001) and add mathematical practices (Moschkovich, 2013; Schoenfeld, 1992). Adding mathematical practices provides students opportunities to engage in the activities that mathematicians or those who use mathematics actually use, e.g., describing mathematical objects (examples 1 and 2) or making inferences from data (example 3). The following examples illustrate our three recommendations. Examples 1 and

2 describe students' strengths and show how we can recognize STEM practices in students' contributions. We use the third example to illustrate what is meant by expanding what counts as STEM practices.

3.1 Math Example 1: Noticing Students' Strengths in Abstracting and Generalizing

This excerpt is from a Grade 3 (eight and nine years old) classroom with multilingual students in an urban elementary school in California (Moschkovich, 1999b). Students received instruction in both English and Spanish; this lesson was part of a geometry unit on classifying shapes. The teacher began by holding up a rectangle and asking students to describe it (Moschkovich, 1999b, p. 13).

Eric: A rectangle has…two…short sides, and two…long sides.

Teacher: Two short sides and two long sides. Can somebody tell me something else about this rectangle? If somebody didn't know what it looked like, what, what…how would you say it?

Julian: Paralel(o). [holding up a rectangle]

Teacher: It's parallel. Very interesting word. Parallel, wow! Pretty interesting word, isn't it? Parallel. Can you describe what that is?

Julian: Never get together. They never get together. [runs his finger over the top length of the rectangle]

Teacher: What never gets together?

Julian: The parallela…the…when they go, they go higher [runs two fingers parallel to each other first along the top and base of the rectangle and then continues along those lines] they never get together.

Antonio: Yeah!

Teacher: Very interesting. The rectangle then has sides that will never meet. Those sides will be parallel. Good work. Excellent work.

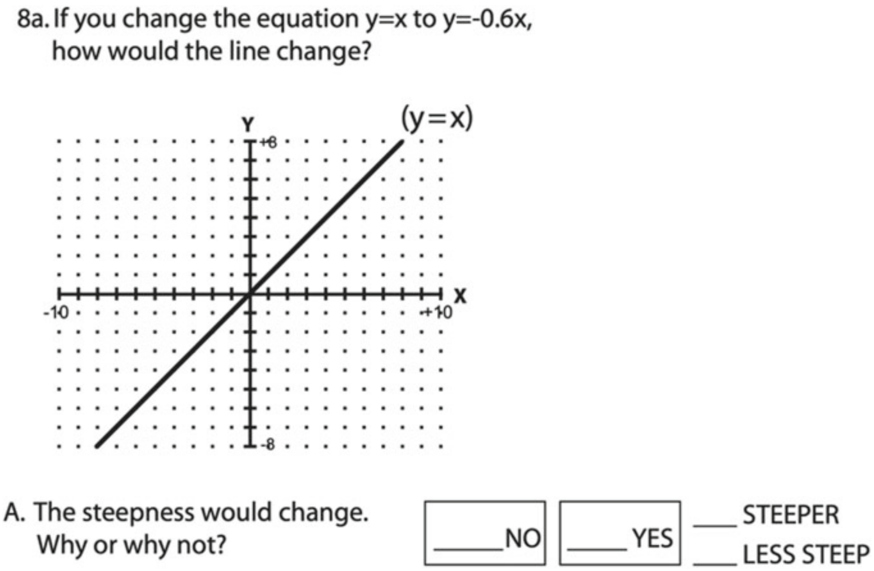
Several strengths are evident in these contributions. First, Julian used gestures and objects to support his claim, making these strengths for communicating mathematically. He also used his first language (pronouncing "paralelo" in Spanish) to support his participation in this mathematical discussion. Instead of translating that word to English, he used the Spanish word. Next, he used everyday language to describe a property of parallel lines. Even though his claim "they never get together" is not formal, it does communicate a correct mathematical idea. There were also two mathematical practices in Julian's contributions. Julian was abstracting, describing an abstract property of parallel lines (one cannot see where lines do not "get together)." He was also generalizing, saying that parallel lines will never meet, not only today or tomorrow, or here in this classroom, but never.

In this classroom discussion, the teacher did not correct Julian's English or object to his use of the Spanish word "parallela," in contrast to policies that restrict classroom talk to the language of instruction or teaching practices that focus solely on the mastery of vocabulary. Instead, he *revoiced* (O'Connor & Michaels, 1993) Julian's comments, asked questions to discover what Julian meant, and focused on the mathematical content, the particular features of parallel lines. Listening to students' contributions is the essential first step in noticing. Revoicing can build on students' own use of mathematical practices, or a student contribution can be revoiced to reflect new mathematical practices (Moschkovich, 2015). In this case, the teacher's revoicing made Julian's claim more precise, introducing a new mathematical practice: attending to the precision of a claim. The teacher's claim, "The rectangle then has sides that will never meet. Those sides will be parallel," is more precise because it refers to the sides of a quadrilateral, rather than any two parallel lines.

3.2 Math Example 2: Recognizing Mathematical Practices When Comparing Lines

The transcript below is from an interview with two Grade 9 students (14 and 15 years old) conducted after school (Moschkovich, 2011). The students had been in mainstream, English-only mathematics classrooms for several years. One student, Marcela, had some previous mathematics instruction in Spanish. The students were working on the problem in Fig. 1 after they had worked on problems with positive slopes greater and less than 1.

The students had graphed the line $y = -0.6x$ by hand on paper (Fig. 2) and were


8a. If you change the equation y=x to y=-0.6x, how would the line change?

A. The steepness would change. Why or why not?

______ NO

______ YES

___ STEEPER

___ LESS STEEP

Fig. 1 Problem for Example 2

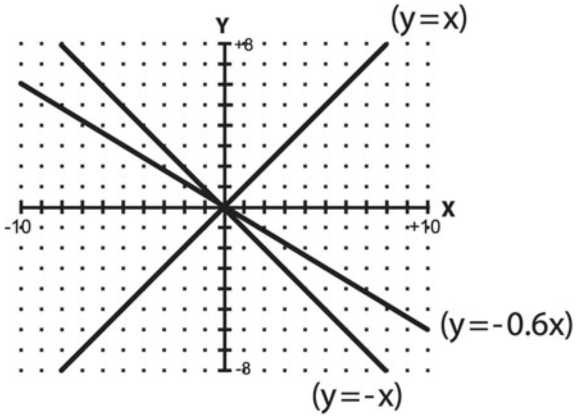


Fig. 2 Lines drawn by students

discussing whether this line was steeper than the line $y = x$.

Giselda proposed the second line was steeper and then decided it was less steep. Marcela repeatedly asked Giselda if she was sure. In the excerpt below, Marcela proposed that the line was less steep and explained her reasoning to Giselda. (Transcript annotations are in brackets; Translations are in italics beneath Spanish phrases.)

Marcela: No, it's less steeper…
Giselda: Why?
Marcela: See, it's closer to the x-axis…[looks at Giselda]…isn't it?
Giselda: Oh, so if it's right here…it's steeper, right?
Because look, let's say that this is the ground.

Entonces, si se acerca más, pues es menos steep
Then, if it gets closer, then it's less steep

…'cause see this one [referring to the line $y = x$]…is…

está entre el medio de la x y de la y. Right?
is between the x and the y.
Marcela: Porque fíjate, digamos que este es el suelo.
Giselda: [Nods in agreement.]
Marcela: This one [referring to the line $y = -0.6x$] is closer to the x than to the y, so this one [referring to the line $y = -0.6x$] is less steep.

Several strengths are evident in this discussion. First, the students combined multiple modes of communication, symbol systems, registers, and languages to communicate about a mathematical idea. Marcela coordinated several modes of communication—speaking and reading text, a graph, an equation. She coordinated two mathematical symbol systems, the graph (the line $y = x$, the axes) and the equations. She was reading, interpreting, and understanding not just the meaning of the

English text in the problem, but also reading, interpreting, and understanding the meaning of the equation and the lines on the graph.

Marcela also combined everyday and academic ways of talking to clarify the mathematical meaning of her description. She used two phrases typical of academic mathematical discourse: "Let's say" and the construction "If__, then__." Marcela used her everyday experiences and the metaphor that the x-axis is the ground ("Porque fíjate, digamos que este es el suelo" [*Because look, let's say that this is the ground*]). The everyday experience of climbing hills provided a resource for describing the steepness of lines (Moschkovich, 1996). Everyday meanings were strengths, not obstacles. Lastly, the students used two languages for their explanations and discussion, showing that both home and school languages are strengths for mathematical reasoning. Teachers must learn to notice how everyday language and experiences, including home languages, are, in fact, strengths for communicating mathematically.

We propose that teachers notice strengths by noticing the mathematical practices in what students say and do. Marcela's contributions reflect mathematical practices; she stated assumptions explicitly and connected her claims to two mathematical representations (graphs and equations). The phrase "If__, then__," reflects the practice of reasoning abstractly, and the phrase "Let's say this is__," reflects the practice of constructing arguments. She was also participating in the practice of paying attention to precision, by stating an assumption explicitly when she said, "Digamos que este es el suelo, entonces……" [*Let's say that this is the ground, then……*] (to decide whether a line is steeper or less steep, we first need a reference line for making this claim). She also connected a claim to the graph, another important mathematical practice. She supported her claim by making a connection to a mathematical representation; she used the graph, in particular the line $y = x$ and the axes, as references to support her claim that the second line was less steep. She used the axes as reference to support a claim about the line saying "Está entre el medio de la x y de la y" (*is between the* x *and the* y).

Opportunities for students to use strengths that are mathematical practices will depend on the quality and the activity structure of the tasks and policies enacted in classrooms. In this task, students needed to show conceptual understanding of slope, particularly when it is negative and less than 1. Explaining why the line would be steeper or less steep provided an opportunity for justifying one's reasoning. The activity structure required that students discuss their individual responses, arrive at a joint solution, and record that solution and explanation after reaching agreement (and before graphing the equation on the computer). Without this activity structure, the task might not reveal the student strength of mathematical practices such as constructing viable arguments and critiquing the reasoning of others. In this example, the students used Spanish and English without restrictions. Again, in contrast to policies that would restrict classroom talk to only the language of instruction, these students used home, school, and everyday languages to make sense of the mathematics.

3.3 Math Example 3: Leveraging Student Strengths and Expanding Classroom Math Practices

In this example, we examine a mathematics intervention (Rubel et al., 2016) and describe how it leveraged student strengths and expanded classroom mathematical practices to include community knowledge.

Using place-based pedagogy and critical mathematics approaches, a unit on statistics drew on the knowledge of Grade 12 students (17 and 18 years old), using the lottery as context. Students used and produced maps with digital tools to think critically (Rubel et al., 2016). The lottery provided a context that made the students' Funds of Knowledge (González et al., 2001), including linguistic resources, relevant. Students studied the lottery using maps that showed median income, total lottery spending, and net loss to the area under investigation (e.g., at neighborhood or state levels). They collected data and conducted interviews with community members. The unit supported statistical concepts, such as median, percentage, proportion, and inference. The unit went beyond procedures to support student engagement with STEM disciplinary practices such as modeling with mathematics (CCSS, 2010; NGSS, 2013), constructing arguments (CCSS, 2010), and arguing from evidence (NGSS, 2013).

The unit also supported students in participating in the mathematical practice of informal statistical inference (Makar & Rubin, 2018), related to modeling with mathematics (CCSS, 2010), and arguing from evidence (NGSS, 2013). Students combined their knowledge of the problem context (playing the lottery, characteristics of neighborhoods in their community) to use the data at hand as evidence to draw conclusions. The unit supported statistical literacy, requiring that students read data, find relationships within data, make claims beyond the data, and read behind the data to question its source (Morris, 2013; Shaughnessy, 2007). Students engaged in the "constant shuttling back and forth," (Pfannkuch, 2011, p. 29) between data and the real-world context, and the iterative cycle of creating and assessing conclusions required knowledge of the context (Wild & Pfannkuch, 1999).

The unit leveraged two student strengths in particular: street-level knowledge of the community, relevant to the construction and interpretation of maps and collecting data, and speaking Spanish, essential for conducting the interviews. Students made connections between data in the maps and their own experiences in those spaces. Knowledge of the context supported student engagement with the mathematical practice of modeling and the science practice of analyzing data. By engaging in statistical inference, the students also developed critical stances toward the lottery.

Spanish competency, another strength, supported data collection and interpretation. Using Spanish to conduct interviews allowed students to gather important interview data regarding lottery patronage from a sample representative of the community. Thus, they avoided excluding certain populations when gathering and interpreting data, allowing for more robust mathematical claims. Moreover, Spanish speakers were positioned as leaders because their linguistic resources were crucial for conducting interviews with monolingual community members. The unit design drew on students' strengths and the teaching practices assumed students brought such strengths. Students drew on these strengths to participate in disciplinary practices (constructing viable arguments, critiquing the reasoning of others, and using appropriate tools strategically) as they used maps and data to make arguments about the fairness of the lottery. The view of Spanish as a strength is particularly important because it eschews subtractive schooling policies and practices (Gibson, 1998; Valenzuela, 2005) that privilege assimilationist stances and would otherwise prohibit or denigrate its use.

This unit was based on the assumption that students bring mathematical and linguistic strengths such that their engagement with data collection, statistical analysis, and mathematical modeling would be productive. Furthermore, the unit expanded on what typically counts as mathematical practices in a classroom setting to include community knowledge. The success of this unit relied on students' everyday knowledge to make inferences from data. In this way, instruction honored students' knowledge of their own community as central to data collection and analysis.

4 Science Examples

There are varying and changing views about what counts as scientific thinking and practices. In their major review of scientific thinking research, Lehrer and Schauble (2015) argue that the current focus on science-as-practice, which became the basis for the policy document NGSS (2013), best captures the disciplinary practices of scientists and frames the most promising approach to policy in science education. Traditional approaches, often focusing on science as conceptual change (Lehrer & Schauble, 2015) focus on science as facts to be learned or processes (e.g., the scientific method) to be mastered. Similar to our analysis of mathematical examples, we use two science examples to illustrate our three recommendations: noticing students' strengths, recognizing science practices in student contributions, and expanding what counts as science practices. In particular, we focus on science practices emphasized by the NGSS (2013), including asking questions, analyzing and interpreting data, and arguing with evidence, as well as NGSS cross-cutting themes, specifically systemic thinking. These practices and themes overlap with scientists' disciplinary practices and are central to policy recommendations for classroom science instruction. We show that these practices and cross-cutting themes also reflect everyday cultural reasoning practices used by students from particular multilingual and non-dominant communities.

4.1 Science Example 1: Noticing Cultural Practices as Strengths, Recognizing Arguing as a Science Practice, and Expanding Science Practices

Unless policy makers and educators notice the strengths of children from marginalized communities, they may see them as underperforming. Hudicourt-Barnes (2003) rejects the idea that children from different communities should give identical responses when asked the same question. This expectation has led some researchers to paint a negative picture of the scientific abilities of Haitian immigrant students in the United States (Lee & Fradd, 1996; Lee et al., 1995), claiming that Haitian children's classroom strategies were inconsistent with the norms of science discourse. In contrast, Hudicourt-Barnes' work (2003) illustrates how to notice learners' strengths for learning, documenting Haitian children's classroom participation in sophisticated conversations about scientific phenomena using a conversational practice common in Haitian communities.

Haitian culture emphasizes spoken language for entertainment as well as communication. Adults and children participate in the social practice of *bay odyans* or *lodyans* which involves animated and entertaining interactions about a range of topics. These conversations take various forms, such as storytelling, reminiscing about previous experiences, and arguments (also called *diskisyon* or discussion) and occur in public settings, involving all members of the community (Hudicourt-Barnes, 2003). Usually, one person makes a claim and calmly defends it as one or more challengers question the claim, bring evidence, and engage the larger group. Other members of the group join in with laughter, approval, and other reactions. The goal is to entertain, but also to find the truth through argumentation.

Hudicourt-Barnes (2003) identified the social practice of bay odyans as a strength of Haitian students and recognized how it reflects argumentation using evidence in classroom science lessons, a key science practice. According to the NGSS, "As children move through the higher grades, they should participate more directly in comparison and critique of conflicting claims, including weighing respective strengths and weaknesses" (Lehrer & Schauble, 2015, p. 31).

In one observation of a group of Haitian students from a Grade 5/6 classroom (10 and 11 years old), students were documented expressing their arguments, evidence, and questions in a discussion about where mold would and would not grow (Hudicourt-Barnes, 2003). Children were asked to reflect on their life experiences, their previous learning, and their observations of mold growing on slices of bread in their classroom to inform their arguments. One child made a claim that mold grew easily in bathrooms. This prompted other children to engage with the idea, taking turns to provide evidence and questioning. Multiple children voiced their arguments and took on the role of challenger while the teacher acted as moderator, encouraging students to defend their positions. This example shows children providing explanations and evidence to support their perspectives by challenging one another using a familiar conversational pattern that is a strength for learning science. The example also provides evidence of their participation in the scientific practice of engaging with arguments using evidence (Hudicourt-Barnes, 2003).

In contrast with the question and known-answer format of traditional westernized classroom practices, the teacher from this classroom provided space for children to explore ideas using argumentation skills they developed in the practice of bay odyans (Hudicourt-Barnes, 2003). Because the teacher was aware of this cultural practice, they expanded what counts as a STEM practice beyond traditional expectations. This and intentional facilitation of a classroom discussion allowed children to engage more fully in the scientific practices than if they had followed westernized classroom dynamics (Hudicourt-Barnes, 2003). The student discussions included laughter and interjections, important elements in the practice of bay odyans. If the teacher in this classroom had held to a more rigid view of science practices, the rich student conversations may have been viewed as non-academic and shut down. The strengths children showed in the classroom discussion about mold mirror the authentic science practices of scientists and these practices need to be recognized in student discussions. When teachers provided opportunities for children to engage in bay odyans and employ their existing culturally relevant conversational practices during a science lesson, they were able to notice students' strengths (Hudicourt-Barnes, 2003), and recognize scientific practices. By investigating classroom discussions, researchers have shown that Haitian immigrant students' community practices reflect authentic scientific practices such as acquiring knowledge and searching for scientific meaning (Ballenger, 1997; Conant et al., 2001; Rosebery et al., 1992; Warren & Rosebery, 1995). This study also illustrates a more expansive and less culturally biased view that policy makers, researchers, and teachers can use to define what constitutes valid science practices (Hudicourt-Barnes, 2003).

4.2 *Science Example 2: Recognizing Students' Strengths in Systemic Thinking and Expanding Science Practices*

Considering what counts as science practices, Bang et al. (2012) discuss "settled expectations" (p. 303, citing Harris, 1995) in science and school that determine what are considered appropriate ways of talking, explaining, and understanding phenomena (Medin & Bang, 2014). For example, one biology practice involving categorizing objects and organisms as living versus nonliving fits an approach to science that prioritizes facts to be learned. Such settled expectations in science separate science from everyday experience, imposing on students what Bang et al. (2012) call the "nature-culture divide" (p. 303), preventing students from engaging with ideas at the boundary between their own experiences and the tenets of science. In line with our recommendation of expanding what counts as STEM practices, Bang et al. (2012) invite readers instead to "imagine the kinds of meaning-making that can arise within a desettling paradigm—that is one focused on…explicitly engaging students…at the nature-culture boundary." (p. 304).

Categorizing living versus nonliving asks students to use rigid definitions and learn the categories defined by scientists. This approach contrasts with the aims of the NGSS (2013), which include encouraging students to use systemic thinking. One of the cross-cutting concepts of the NGSS that can be applied across disciplines, "systems and system models," focuses on defining the boundaries of the system under study (National Research Council, 2012). Bang et al. (2012) argue that students' attempts to engage in "thinking at the edges," also referred to as "possibility thinking" are often not recognized in classroom activities focused on the more settled work of learning existing categories. They discuss an example reported by Warren and Rosebery (2011) where Jonathan, an African American male student in grade 7 (12 years old) questioned the sun's place in the category structure of living vs nonliving. Jonathan asked how the sun can be dead if it helps living things to live. A Euro-American student and the teacher responded that the sun cannot be thought of as a living thing. Jonathan eventually backed off, seemingly resigned that his point was misunderstood and that his view did not fit the system the teacher was using. However, Bang et al. (2012) point out that Jonathan was engaging in systemic thinking about the sun and how it relates to life. They connected Jonathan's thinking with how microbiologists think "at the edges" about microbial life forms, contesting existing boundaries and pushing the definition of "life" into new territory. Bang et al. (2012) use Helmreich's (2009) anthropological study of microbiologists' work to argue that active scientists' definitions of life are increasingly systemic and that human cultural experience and science are "more entangled than previously thought" (p. 307). Rather than assuming a deficit in Jonathan's ideas, this example illustrates how to notice the complexity of this student's thinking as a strength and recognize how he is engaging in a central science practice.

Bang et al. (2012) consider what desettling activities around nature-culture relations might look like using several classroom-related examples. We focus here on their final example of a design-based study of science learning for an urban indigenous community. Bang et al. (2012) discuss how in the initial design of this learning environment, the community-based team considered ways that indigenous knowledge systems relate to, as well as contrast with, Western science. One focus was the distinction between seeing humans as either "a part of" or "apart from" the natural world. This distinction between psychological distance versus closeness with nature is a theme in work comparing Native American with European American participants from the same rural area in the United States (Medin & Bang, 2014). For example, when asked how two animals and/or plants go together (Unsworth et al., 2012), Menominee children as young as 5 years were more likely than Euro-American children to mention ecological relations, such as linking the two species in the food chain ("the chipmunk would eat the berries") or mentioning that both have similar biological needs ("both need water to live"). Menominee children also more often justified the pairings using human closeness to nature, such as saying "I eat berries." Several other studies show similar examples of closeness to nature and ecological systems in Native American children and adults' thinking about biological species (Medin & Bang 2014). Marin and Bang (2018) reported yet another relational way of thinking about nature. In their investigation of Native American families' forest walks, they describe examples of observational practices such as reading land, as “a critical practice for *being* in the world as it enables relationship building with the natural world.” (p. 92).

Noticing the strengths in systemic thinking that Native American youth bring to the classroom, and recognizing that these are, in fact, important science practices, the community-based design team emphasized relations among all things in nature (Bang et al., 2012). In focusing on river ecology, for example, they engaged students with activities in local settings, built on practices students had experienced (e.g., collecting edible and medicinal plants), and highlighted active relationships between organisms and habitats. In one case, they engaged students at an oxbow in a river—a place where changes over geological time can be noticed by reading land. When collecting water samples to assess the health of the river, teachers asked students to immerse themselves, wearing waist-high waders, and walking the river’s earlier path. In contrast to the Western assumption of humans as dominant over nature, they presented humans in deference to plants and habitat (see also Bang et al., 2014). These activities made visible and supported the strengths of Native American students as systemic thinkers and provided opportunities for students to engage in science practices such as exploring boundaries, intersections, and dependencies across species.

This example illustrates noticing students’ strengths, recognizing their links to science practices, and expanding the range of what are considered STEM practices. Bang et al. (2012) discuss ways that teachers and curriculum designers can assume students’ strengths rather than deficits, creating opportunities for students to engage with scientific content and in science practices connected to their own lived experiences. Noticing these strengths and recognizing their links to science practices supports students in thinking like scientists by considering the system they are studying within a complex and interrelated context rather than engaging only with pre-differentiated chunks of information to be passively learned. Moving beyond settled definitions thus expands what counts as science practices.

5 Discussion

We see three important ways that research on multilingual and non-dominant students’ strengths in mathematics and science education can inform policy and practices for STEM in multilingual settings. In this section, we review our three recommendations of noticing strengths, recognizing STEM practices in student contributions, and expanding what counts as STEM practices.

In the examples, we see important connections between science and mathematics policy standards and STEM practices relevant to instruction. Some practices—constructing arguments, using quantitative reasoning, and modeling—appear in both sets of standards and cut across disciplines. We note that asking questions is missing from current mathematical practice standards (CCSS, 2010) but is the first science practice (NGSS, 2013). This is puzzling given the extensive research on "problem posing" in mathematics education. Statistical inference is another practice that connects across mathematics and science, suggesting this may be an important cross-disciplinary practice for STEM instruction.

Research in mathematics and science education has resulted in policies recommending that instruction afford opportunities to participate in disciplinary practices to support students' STEM learning. As a start, multilingual and non-dominant learners need access to such opportunities. However, disciplinary practices need not be taught from scratch, some are already present in the practices of students' own communities or in students' contributions to classroom discussions, but often go unrecognized by instructors. We provided examples of how arguing with evidence and thinking about systems are science practices learners themselves bring to the classroom. We also illustrated how bilingual learners use their home language and everyday registers to communicate mathematically, thus making home and everyday ways of talking strengths students used to participate in mathematical practices (abstracting, generalizing, constructing arguments, and making claims more precise). We also showed that students' strength in local knowledge was central for collecting data, interpreting representations of that data, and making inferences.

Our first recommendation is to notice that learners bring strengths for doing and learning STEM. But noticing alone is not sufficient to create opportunities for students to participate in STEM practices. A necessary second step is to recognize disciplinary practices in what students say or do. The move is not only away from deficit views of multilingual learners and toward noticing students' strengths, but also to recognizing when and how those strengths reflect disciplinary knowledge and practices. In the words of Hudicourt-Barnes (2003, p. 76):

> We find that when Haitian children are in culturally familiar environments in classrooms focused on practicing science, the type of behavior they exhibit toward the acquisition of knowledge and the search for scientific meaning is deeply congruent with the practice of authentic scientific research.

Enacting policy that builds on student strengths requires considering how their strengths are relevant to classroom activity. The units and lessons described above leveraged students' linguistic strengths and community knowledge and supported student engagement with STEM disciplinary practices. However, home language practices and local knowledge can be strengths only if they are noticed and included. Activities were designed based on beliefs about students' strengths and engaging students in STEM practices. Local knowledge was a strength because it allowed students to engage in making sense. Language and life experiences helped children interpret data, bringing everyday and scientific practices together. In the science classroom, noticing and recognizing the similarity of argument structure in bay odyans with the argument structure in scientific reasoning led teachers to allow "everyday" argument as part of classroom work.

In this chapter, we have used an expansive view of student strengths and disciplinary practices. This unsettling perspective increases possibilities for students, so they use their own knowledge to contribute meaningfully to classroom work:

> In our view, desettling entails imagining multivoiced meanings of core phenomena as open territory for sense-making in the science classroom, similar to the kinds of meaning-making opportunities that are available to scientists in the field. (Bang et al., 2012, p. 308)

Such a desettling perspective goes beyond traditional definitions of science and mathematics as separate. For example, as illustrated in the lottery unit, science and mathematics can come together and students can engage in practices from both disciplines. Using the three recommendations, policy and practice can embrace this desettling perspective and shift to treating STEM practices as one—but not the only—set of cultural practices (Medin & Bang, 2014) relevant to STEM learning. In particular, expanding what counts as STEM practices, policy and practice can recognize student contributions as perhaps different, but still scientifically and mathematically valuable and a foundation for further STEM learning.

References

Aguirre, J., Mayfield-Ingram, K., & Martin, D. (2013). *The impact of identity in K-8 mathematics: Rethinking equity-based practices*. Reston, VA: The National Council of Teachers of Mathematics.

Ballenger, C. (1997). Social identities, moral narratives, scientific argumentation: Science talk in a bilingual classroom. *Language and Education, 11,* 1–14.

Bang, M., Curley, L., Kessel, A., Marin, A., Suzukovich, E., & Strack, G. (2014). Muskrat theories, tobacco in the streets and living in Chicago as indigenous land. *Environmental Education Research, 20,* 37–55.

Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling expectations in science education. *Human Development, 55*(5–6), 302–318.

Barwell, R., Moschkovich, J., & Setati Phakeng, M. (2017). Language diversity and mathematics: Second language, bilingual, and multilingual learners. In J. Cai's (Ed.) *Compendium for research in mathematics education* (pp. 583–606). Reston, VA: NCTM.

Common Core State Standards. (2010). *Common core state standards for mathematical practice*. Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers.

Conant, F., Rosebery, A., Warren, B., & Hudicourt-Barnes, J. (2001). The sound of drums. In E. McIntyre, A. Rosebery, & N. Gonzalez (Eds.), *Building bridges: Linking home and school* (pp. 51–60). Portsmouth, NH: Heinemann.

Faltis, C. J., & Valdés, G. (2016). Preparing teachers for teaching in and advocating for linguistically diverse classrooms: A vade mecum for teacher educators. In D. H. Gitomer & C. A. Bell (Eds.), *Handbook of research on teaching* (5th ed., pp. 549–592). Washington, DC: American Educational Research Association.

Gholson, M., Bullock, E., & Alexander, N. (2012). On the brilliance of black children: A response to a clarion call. *Journal of Urban Mathematics Education, 5*(1), 1–7.

Gibson, M. A. (1998). Promoting academic success among immigrant students: Is acculturation the issue? *Educational Policy, 12*(6), 615–633.

González, N., Andrade, R., Civil, M., & Moll, L. (2001). Bridging funds of distributed knowledge: Creating zones of practices in mathematics. *Journal of Education for Students Placed at Risk, 6*(1–2), 115–132.

Goodwin, C. (1994). Professional vision. *American Anthropologist, 96*(3), 606–633.

Gutiérrez, K. (2008). Developing sociocritical literacy in the third space. *Reading Research Quarterly, 43*(2), 148–164.

Gutiérrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher, 32*(5), 19–25.

Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research. *American Journal of Physics, 64*(10), 1316–1325.

Harris, C. I. (1995). Whiteness as property. In K. Crenshaw, N. Gotanda, G. Peller, & K. Thomas (Eds.), *Critical race theory* (pp. 276–291). New York: New Press.

Helmreich, S. (2009). *Alien ocean: Anthropological voyages in microbial seas*. University of California Press.

Hudicourt-Barnes, J. (2003). The use of argumentation in Haitian Creole science classrooms. *Harvard Educational Review, 73*(1), 73–93.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). Adding it up: Helping children learn mathematics (Vol. 2101). National research council (Ed.). Washington, DC: National Academy Press.

Lee, O., & Fradd, S. (1996). Interactional patterns of linguistically diverse students and teachers: Insights for promoting science learning. *Linguistics and Education, 8,* 269–297.

Lee, O., Fradd, S., & Sutman, F. (1995). Science knowledge and cognitive strategy use among culturally and linguistically diverse students. *Journal of Research in Science Teaching, 32,* 797–816.

Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. In R. M. Lerner (Ed.), *Handbook of child psychology and developmental science* (7th ed.). John Wiley & Sons.

Louie, N. L. (2018). Culture and ideology in mathematics teacher noticing. *Educational Studies in Mathematics, 97*(1), 55–69.

Makar, K., & Rubin, A. (2018). Learning about statistical inference. In D. Ben-Zvi, J. Garfield, & K. Makar (Eds.), *International handbook of research in statistics education* (pp. 261–294). Switzerland: Springer.

Marin, A., & Bang, M. (2018). "Look it, this is how you know:" Family forest walks as a context for knowledge-building about the natural world. *Cognition and Instruction, 36,* 89–118.

Martin, D. B. (2019). Equity, inclusion, and antiblackness in mathematics education. *Race Ethnicity and Education, 22*(4), 459–478.

Martínez, R. A., & Mejía, A. F. (2020). Looking closely and listening carefully: A sociocultural approach to understanding the complexity of Latina/o/x students' everyday language. *Theory into Practice, 59*(1), 53–63.

Mason, J. (2002). *Researching your own practice: The discipline of noticing*. Psychology Press.

Medin, D. L., & Bang, M. (2014). *Who's asking? Native science, western science, and science education*. Cambridge, MA: MIT Press.

Morris, K. (2013). *Map reading framework*. Unpublished manuscript, Department of Teaching, Learning, Policy, & Leadership, University of Maryland, College Park, MD.

Moschkovich, J. N. (1996). Moving up and getting steeper: Negotiating shared descriptions of linear graphs. *The Journal of the Learning Sciences, 5*(3), 239–277.

Moschkovich, J. N. (1998). Resources for refining conceptions: Case studies in the domain of linear functions. *The Journal of the Learning Sciences, 7*(2), 209–237.

Moschkovich, J. N. (1999a). Students' use of the x-intercept as an instance of a transitional conception. *Educational Studies in Mathematics, 37,* 169–197.

Moschkovich, J. N. (1999b). Supporting the participation of English language learners in mathematical discussions. *For the Learning of Mathematics, 19*(1), 11–19.

Moschkovich, J. N. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning*, *4*(2&3), 189–212.

Moschkovich, J. N. (2011). Supporting mathematical reasoning and sense making for English Learners. In M. Strutchens & J. Quander (Eds.), *Focus in high school mathematics: fostering reasoning and sense making for all students* (pp. 17–36). NCTM: Reston, VA.

Moschkovich, J. N. (2013). Principles and guidelines for equitable mathematics teaching practices and materials for English language learners. *Journal of Urban Mathematics Education, 6*(1), 45–57.

Moschkovich, J. N. (2015). Scaffolding mathematical practices. *ZDM, The International Journal on Mathematics Education, 47*(7), 1067–1078.

National Research Council. (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

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

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

O'Connor, C., & Michaels, S. (1993). Aligning academic task and participation status through revoicing: analysis of a classroom discourse strategy. *Anthropology and Education Quarterly, 24*(4), 318–335.

Pfannkuch, M. (2011). The role of context in developing informal statistical inferential reasoning: A classroom study. *Mathematical Thinking and Learning, 13*(1–2), 27–46.

Rosebery, A., Warren, B., & Conant, F. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences, 2*(1), 61–94.

Rubel, L. H., Lim, V. Y., Hall-Wieckert, M., & Sullivan, M. (2016). Teaching mathematics for spatial justice: An investigation of the lottery. *Cognition and Instruction, 34*(1), 1–26.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook for research on mathematics teaching and learning* (pp. 334–370). New York, NY: Macmillan.

Shaughnessy, J. M. (2007). Research on statistics learning and reasoning. In F. Lester's (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 957–1011). Reston, VA: National Council of Teachers of Mathematics.

Smith, J. P., III, diSessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences, 3*(2), 115–163.

Unsworth, S. J., Levin, W., Bang, M., Washinawatok, K., Waxman, S. R., & Medin, D. L. (2012). Cultural differences in children's ecological reasoning and psychological closeness to nature: Evidence from Menominee and European American children. *Journal of Cognition and Culture, 12,* 17–29.

Valdes-Fallis, G. (1978). Language in education: Theory and practice: Vol. 4. In *Code switching and the classroom teacher.* Wellington, VA: Center for Applied Linguistics.

Valenzuela, A. (2005). Subtractive schooling, caring relations, and social capital in the schooling of US-Mexican youth. In *Beyond silenced voices: Class, race, and gender in United States schools* (pp. 83–94). NY: SUNY Press.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 38*(5), 529–552.

Warren, B., & Rosebery, A. (1995). Equity in the future tense: Redefining relationships among teachers, students, and science in linguistic minority classrooms. In W. Secada, E. Fennema, & L. Adajian (Eds.), *New directions in mathematics education* (pp. 298–328). New York: Cambridge University Press.

Warren, B., & Rosebery, A. S. (2011). Navigating interculturality: African American male students and the science classroom. *Journal of African American Males in Education, 2*(1), 99–115.

Watson, A. (2009). Thinking mathematically, disciplined noticing and structures of attention. In *Mathematical action & structures of noticing* (pp. 211–222). Brill Sense.

Wild, C. J., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. *International Statistical Review, 67*(3), 223–248.

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