Engaging Bilingual Mathematics Learners With Principle-Based Instruction

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Abstract

This paper uses a framework of four key principles and considers the research question: "How did four middle school mathematics teachers' instruction align with these principles to engage bilingual mathematics students in mathematical work in meaningful ways?" Findings from qualitative methods provide examples from teachers' practice, demonstrating how they: (1) used bilingual learners' funds of knowledge and resources; (2) provided bilingual learners with cognitively demanding work; (3) provided bilingual learners opportunities for rich language and literacy exposure and practice; and (4) identified academic language demands and supports for bilingual learners.

Discussion And Reflection Enhancement (DARE) Pre-Reading Questions

1. What are meaningful ways to engage bilingual students in both mathematics and language before, during, and after lessons?

2. What goals should mathematics teachers have when working with bilingual students in their mathematics classrooms?

3. What are the key principles mathematics teachers should have for working with bilingual students in their mathematics classroom? How would instruction differ with and without such principles?

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As the number of bilingual students across the US increases, there is an urgent need for all mathematics teachers to be prepared to provide meaningful learning environments for these students. Despite this need, bilingual students are often in classrooms where they have few opportunities to learn rich mathematical content (Iddings, 2005; Planas & Gorgorió, 2004). Simultaneously, the mathematics teaching community (e.g., National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) is calling for all students to be immersed in rich mathematical work. However, teachers often struggle with how to approach such work, particularly for bilingual students. This paper uses a framework of four key principles to engage bilingual mathematics students in mathematical work in meaningful ways and considers this research question: "How did four middle school mathematics teachers' instruction align with principles to engage bilingual mathematics students in mathematical work in meaningful ways?"

Theoretical Framework

This study is organized around four key principles drawn from prior work of scholars in the field of mathematics education. These principles support teachers to engage bilingual mathematics students in mathematical work in meaningful ways (Roberts & Bianchini, 2019; Roberts et al., 2017). These principles are understood as reinforcing and overlapping. The first principle is: *Use bilingual learners' funds of knowledge and resources* (Lee et al., 2008; Moll et al., 1992; Moschkovich, 2002). In using this principle, teachers identify, celebrate, and use the knowledge and skills of students, their families, and their communities during mathematics teaching. For example, a teacher might use a student's home language to support mathematics instruction.

The second principle is: *Provide bilingual learners with cognitively demanding work* (Stanford Graduate School of Education, 2013; Tekkumru-Kisa et al., 2015). Here, teachers ensure that bilingual learners can engage in the same kinds of activities and assignments often singularly reserved for those students who only speak English (Iddings, 2005; Planas & Gorgorió, 2004). For example, teachers should ensure that they do not provide an assignment with less cognitive demand for their bilingual students. Teachers should focus on engaging students in the mathematical practices, while balancing conceptual understanding and procedural fluency (Moschkovich, 2013).

The third principle is: *Provide bilingual learners opportunities for rich language and literacy exposure and practice* (Khisty & Chval, 2002; Lee et al., 2013). For example, teachers could create opportunities for bilingual students to receive comprehensible input through listening and reading and provide opportunities for bilingual students to produce comprehensible output through speaking and writing. Opportunities for communicating mathematical ideas should be emphasized over low-level language skills (Moschkovich, 2013).

The fourth principle is: *Identify academic language demands and supports for bilingual learners* (Aguirre & Bunch, 2012; Lyon et al., 2016). For example, teachers could attend to the language demands in the tasks they implement, providing appropriate supports, such as sentence frames, so that all students could share their ideas and reasoning in whole class and small group discussions.

Method

Context

This research took place in the Western United States in a large metropolitan school district with approximately 37,000 students. Within the district, 38% of the students were classified as "English learners[1]." These students came from over 135 countries and spoke over 115

[1] The author uses the term "bilingual" in the paper to identify students who spoke more than one language to acknowledge the resources of these students; however, the district identified these students as "English learners."

languages, with 86% of the “English learners” being Spanish-speakers. Additionally, 69% of the students in the district received free or reduced lunch. The “English learner” demographics of the classrooms of participating teachers mirrored those of the district, with students in the participating teachers’ classrooms classified at varying levels of English proficiency after taking the ACCESS (WIDA ACCESS Placement Test—W-APT, 2020; i.e., non-English proficient [NEP], limited English proficient [LEP], and full English proficient [FEP]). The middle schools in the district all used *Connected Mathematics Project 2* (*CMP2*; Lappan et al., 2009a). The content of the tasks included: finding area and perimeter of rectangles and triangles; working with linear functions and writing equations; and working with fractions, decimals, and percent.

Participants

Four White monolingual English-speaking middle school mathematics teachers (three females and one male) from four different middle schools in the district participated in this study. The teachers had 2.5-6.5 years of teaching experience. Ms. Wilson taught sixth grade, while Mr. Xavier, Mrs. Yost, and Ms. Zelner all taught seventh grade. Pseudonyms are used for all participants. The district chose these teachers as “exemplary” teachers of bilingual students, because of their record of good teaching with bilingual students (i.e., as related to test scores and reputation).

Data Collection

I videotaped 10 class periods of the same class for each teacher over the course of a single spring semester. The mean length of each video was 65 minutes, and the video footage collected totaled 42.75 hours. One camera focused on the teacher, who wore a lapel microphone. I also took detailed field notes during each observation. Teachers were not exposed to the principles during the study; these were instead used as an analytic framework.

Data Analysis

The first step of the analysis process was to create field notes during data collection, noting moments of interest related to how teachers attended to bilingual students. Next, I created content logs of videos (Jordan & Henderson, 1995) to enhance field notes. Then, I created transcripts of videos, reading through the data, identifying key pieces of talk related to the four principles for working with bilingual mathematics students, and noting key ideas and relationships, while also developing tentative ideas about how to categorize data (Maxwell, 2013). Table 1 provides a list of example codes I created in this process. I coded the corpus of data for all four theoretical categories and further differentiated the codes in each category. Following coding, I created a data matrix of the coded data according to each category to look for consistencies and inconsistencies across single and multiple participants (Yin, 2011).

Table 1
Example Codes Developed from Theoretical Categories

Theoretical Category	Example Codes
Use Student Resources and Funds of Knowledge	• Home language • Prior knowledge • Prior experiences
Cognitively-Demanding Work	• Sustained use of high cognitive demand tasks • Focus on student mathematical reasoning • Questioning
Opportunities for Rich Language and Literacy Exposure	• Practice with speaking, writing, representations
Academic Language Demands and Supports	• Helping students produce spoken and/or written discourse • Provide scaffolds for language

Findings

The participants varied in how they engaged bilingual students with the principles. The findings in the next sections provide pivotal examples of practice from the participants' classrooms.

Using Students' Resources and Funds of Knowledge

The teachers used the context of problems in *Connected Mathematics* (Lappan et al., 2009b) as a mechanism to *use students' resources and funds of knowledge*. Across the classrooms, participating teachers made many efforts to engage with students' prior experiences as well as with real-life experiences (Moschkovich, 2002; Stanford Graduate School of Education, 2013), as they were linked to problems in the texts. For example, when the students began a series of problems on planning a bike trip, Mr. Xavier had students discuss what it was like to ride bicycles and here is the opening of that conversation:

> **Mr. Xavier**: How many of you guys have ever ridden a bike? How many of you guys own a bike right now? (Most students raise hands.) Cool. Tell me about your bike experience. What do you like about it? Dameon, what do you like about it?
> **Dameon**: You can do a wheelie.
> **Mr. Xavier**: That we can do what? Do a wheelie? OK.
> **Julio**: You can go down a hill super, super fast.
> **Mr. Xavier**: You can go down a hill really fast.
> **Mateo**: I like when the cool breeze splashes in your face.
> **Mr. Xavier**: Getting a cool breeze. What else?
> **Duante**: That you could have a ride, transportation anywhere you want…It's like having a car without the gasoline.
> (Mr. Xavier, 3/9/12, Lines 51-62)

Following this exchange, students then worked with partners for five minutes to write on paper to complete the following prompts from the text: "How far do you think you could ride in a day? How do you think the speed of your ride would change during the course of the day? What conditions would affect the speed and distances you could ride?" (Lappan et al., 2009b, p. 6). Based on students' prior conversations and the students' own experiences, Mr. Xavier continued to elicit students' own thoughts and experiences.

Once the class got to the middle (the "explore" section) of the class period, Mr. Xavier created a shared experience for the students. In this particular problem, students collected data on jumping jacks. Mr. Xavier had students in groups of four, and every student collected data, did jumping jacks, and tracked the time. Here, Mr. Xavier provided each student with the opportunity to engage in the community and drew on students' resources in this mathematical data collection. Mr. Xavier noted that the next step would be the following: "We'll continue to look for patterns in our table…And that goes back to your objective: Record data and then look for relationships in the table" (3/9/12, Lines 683-685). Students would work together to analyze their data.

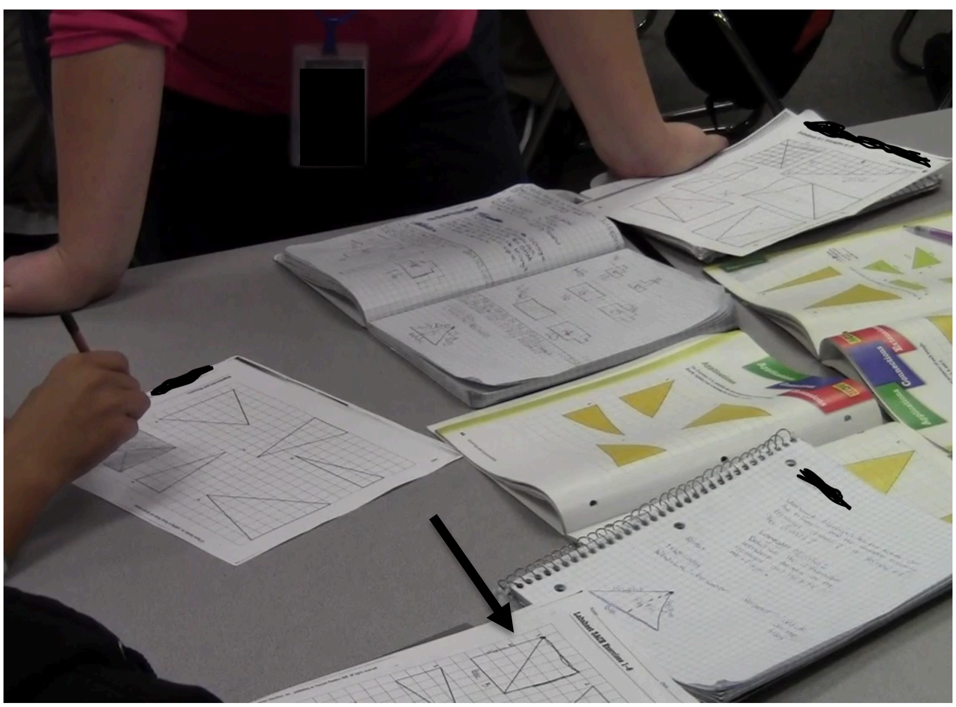
Mr. Xavier initially made connections about how much students knew about bikes, providing connections to students' prior knowledge. Then he created a common experience from which all students could draw while they were completing their mathematics task. He also drew on another language principle, creating an extended rich language opportunity by having students talk about their prior experiences, and he used those experiences to set-up and engage with their textbook problem. In doing this work, students were able to see that their experiences were valued in the mathematics classroom, thereby humanizing the mathematics (Gutiérrez, 2013; Yeh & Otis, 2019); Mr. Xavier provided more buy-in for students to do mathematics in the classroom and for them to make meaning of that mathematics. This work allowed students to begin to understand the meaning of the mathematics around the topic of slope—such as varying speeds and constant speed—which would have been harder for students to understand without shared language and a lived experienced (and discussion of that experience) of the actual phenomenon.

Providing Learners with Opportunities for Cognitively Demanding Work

Mrs. Yost helped students self-regulate or self-monitor as a method for *providing learners with opportunities for cognitively demanding work* in her class (Stein et al., 2000). One method the students used for monitoring their progress was explaining their thinking to their peers and then sharing their thinking with Mrs. Yost. This occurred in a number of settings, such as in summaries of lessons and when peers talked to one another in small groups. An example of this self-regulation occurred during a lesson on developing the formula for area of triangles. Mrs. Yost walked around the room while students worked, and she asked two students, Juan and Teddy, to explain their thinking, as illustrated in the following passage and in Figure 1:

> **Juan**: Don't you divide 25 by 2?
> **Teddy**: There's not (25 squares) in the triangle, [but there is in the rectangle.]
> **Juan**: [It's like you're adding another half to the] triangle.
> **Mrs. Yost**: Listen to what he is saying to you. Say that again.
> **Juan**: That, that you could, you could divide 25 by two, because you're adding one more piece to the rectangle, I mean to the triangle, to make it a half-equal pieces. But then, after you got, after you know how much the pieces here, divided by two….
> **Mrs. Yost**: Okay, so hold on. We have this idea of base and height. So, you're telling me base times height (turns to Teddy), and then you're telling me that I have to cut it in half (turns to Juan) or divide by two.
> **Juan**: You could, the rectangle strategy is going to be, and if, because you know that there is, like, 25 (unit squares), and this is half of the rectangle, so if you do 25 divided by two, that would give you the are-, the space of, the.
> **Teddy**: That would give you the triangle.
> **Juan**: So, yeah, you add the rectangle, and then you do that.
> **Mrs. Yost**: You do what?
> **Juan**: You do 25 divided by two.
> **Mrs. Yost**: OK, so how did I get to the 25? What did I do? So, let's not use any more numbers. Let's take our numbers out for a second, and let's start using some math words.
> **Juan**: You did base time height.
> **Mrs. Yost**: Okay, so I had the base times the height. Then that gave me 25. And then what did I do?...And why did dividing it by two makes sense?...Well, that works for this triangle. Is it going to work for all triangles?
> Note: [ ] denotes overlapping speech, and … denotes omitted talk.
> (Mrs. Yost, 1/25/12, 36:50-38:30)

Figure 1
Mrs. Yost, Teddy, and Juan working through Area of a Triangle



Note. Juan (holding a pencil) is explaining to Teddy the need to divide the rectangle (where the arrow points) by two.

Mrs. Yost supported these students to self-regulate their thinking and check their own thinking for accuracy by having Juan and Teddy explain their thinking related to finding the formula for the area of a triangle. Mrs. Yost focused on the mathematics that students were working through and, in turn, she also created a rich language opportunity. Mrs. Yost's questioning played a key role in her maintenance of the cognitive demand while supporting these students' self-monitoring and self-regulation. NCTM (2014) notes the importance of posing purposeful questions. This questioning helped to immerse students in the mathematics further and provided students with an expectation that they would discuss mathematics while working in small groups. It is notable that Mrs. Yost focused on getting students to talk about the mathematics, even if their mathematical language was still developing. It was not until the end of her turn with the students that she told them, "Let's take our numbers out for a second, and let's start using some math words."

Opportunities for Rich Language and Literacy Exposure

Each teacher in this study tried to provide students in their classroom with *opportunities for rich language and literacy exposure and practice*. For example, as noted above, both Mr. Xavier and Mrs. Yost used large and small group discussions. Opportunities for rich language and literacy were similarly present in Ms. Wilson's classroom during a data analysis lesson. She had students write sentences about data toward the end of the school year:

> [C]an you tell me all about Jasmine's [a character in the problem] reaction time? What are you going to tell [your language arts teacher]? If [your language arts teacher] can't see the tables and graphs, what are you going to tell [your language arts teacher]?
> (Ms. Wilson, 5/1/12, Lines 459-460)

Students first brainstormed, as a class, all the words they knew for comparing data, and wrote all these words on the board at the front of the room. They then worked in groups to create data comparisons that included tables, graphs, and written sentences.

The next day, Ms. Wilson selected student work and shared some of the student sentences with the whole class. The class worked together on the document camera, with Ms. Wilson helping the class work to make the sentences clearer through general editing, clarifying terms, and using more formalized mathematical terms in some cases. For example, in the following interaction, the class revised a pair's sentence about reaction times:

> **Ms. Wilson**: "The reaction Nathanial gave in Trial two was the quickest as opposed to Trial four and five where it took the longest to react."…What details do you want to add?...Where do you want me to put it?...Marquis thinks we need to add more details, like how quick was Trial two. Where should we add that? What should we do?....70…"The reaction time Nathanial gave in Trial two, (Teacher adds a comma) .70 was the quickest"…Can you just stick a number in or do you have to describe it?...Is it .7 hats? Is it .70?
> **Jason**: Milliseconds.
> **Ms. Wilson**: Seconds…Let's just say seconds right now. Don't forget the milliseconds for now. "The reaction time Nathanial gave in Trial two, 70 one-hundredths of a second was the quickest as opposed to Trial four and five where it took the longest to react." Anything else we can add?...
> **Marquis**: You could add the slowest reaction time.
> **Ms. Wilson**: What was the slowest reaction time?
> **Mateo**: 93 hundredths.
> **Ms. Wilson**: .93….The reaction Nathanial gave in Trial two , 70 hundredths of a second was the quickest, as opposed to Trials four and five, where it took the longest to react. Where do you want to add 93 hundredths of a second?...I like this sentence because…it gives me data. Does it tell me the trials?...Does it tell me the times?...And does it tell me about the story? Does it use quickest, slowest, reaction? So, it tells me the data and it tells me about the data. Good sentences.
> (Ms. Wilson, 050212T, Lines 666-719)

Ms. Wilson worked with the students to develop their academic language over the course of two class periods, developing both their mathematics and their language in this final phase while revising their sentences and attending to both their mathematics and language. She provided opportunities for students to use multiple modes of communication and mathematical representations, engaging students in a rich language opportunity and including academic language demands and supports. Ms.

Wilson had students examine data in tables and graphs, discuss the relationships they noticed, write sentences about the data relationships, and then work as a whole class to analyze these relationships and sentences—to have multiple modes of communication and multiple opportunities to examine the mathematics in the problem. Finally, Ms. Wilson provided student work exemplars, supported syntax, and facilitated a whole class discussion (Hakuta et al., 2013; Zwiers et al., 2014).

Academic Language Demands and Supports

The teachers provided a variety of *academic language demands and supports* for their students. For example, Ms. Zelner used practices associated with sheltered content instruction (Echevarria & Graves, 1998), such as having all her students speak in complete sentences (a practice with which all participants engaged their students) and providing students with gestures to understand concepts like x- and y-axes. She also occasionally provided students with sentence frames to support their writing, such as these for interpreting graphs:

> The independent variable is __________________.
> The dependent variable is ____________________.
> The graph that matches this story is ____________.
> A story for this graph is that __________________.
> (Ms. Zelner, 3/8/12, 2:15)

Ms. Wilson also used many sheltered instruction strategies, like pre-reading a text, and she tended to use academic language supports to develop content knowledge. While students learned about probability, Ms. Wilson used a number of general academic language supports within a single lesson to engage students with the content: using a whole class discussion, making sure that all students participated, using multiple mathematical representations, skimming through the text to get a sense for upcoming content, and using models of sentence writing.

The following example draws on many scaffolds from the first day of the probability unit, where Ms. Wilson had students familiarize themselves with probabilities of events and how they would state such likelihoods. Ms. Wilson also used these scaffolds to provide students with language rich opportunities, which engaged students in discussions with one another. She began by having students explore their new text. Then Ms. Wilson modeled what she expected from students, in an example of an academic language support. Ms. Wilson had students share the outcomes of events and prompted them for individual probabilities, finishing with the directions for the task, a probability written as a sentence. (Because of unclear audio, her students' responses were inaudible, as noted at several spots with "…"; however, she did revoice several student responses.) Ms. Wilson began the probability conversations in the following way:

> It has an outcome or a likelihood of something happening. Why between zero and one?
> I mean, can't the number be 7? I say the chances of it happening are 7. Does that make any sense?...Can someone else give us another example of a probability, the likelihood of something happening?...A two out of six chance that I'll get a red marble. Anyone else? Lots of probabilities you can come up with. You can make up a story… Okay here's the deal. I'm only getting a couple ideas. You have a full book of ideas of probabilities. You can come up with anything from sports, to school, to home… I need a sentence from you, and you get to make up the number.
> (Ms. Wilson, 2/23/12, 16:15-16:45;17:25-18:07;18:48-19:15)

Ms. Wilson was then able to engage her class in a whole class discussion, and she elicited students' thinking—an ambitious teaching practice (Lampert et al., 2013). When students were able to think through those probabilities and to communicate the mathematics to their peers, Ms. Wilson was able to make students responsible for this mathematical work—not just her, as the teacher. Ms. Wilson also modeled examples of target language before students attempted it (Khisty & Morales, 1999) and monitored the language that the class used (Khisty, 1996) as they provided examples of probabilities of events. Finally, she revoiced student answers (Moschkovich, 1999), giving value to student responses and giving all students a chance to hear what other students had said—clearly and slowly. All this work helped prepare students for the work they then completed in partners with the mathematical text. More importantly, Ms. Wilson's academic language supports with her students went beyond a focus on vocabulary and word problems and provided rich language opportunities.

Conclusions

Research has consistently shown that bilingual learners need opportunities to engage in supportive language rich environments, where teachers help students make sense of the academic language demands and use students' resources. Additionally, we know that bilingual learners are often provided with fewer opportunities to engage in cognitively demanding work. Teachers in this study were often able to draw on multiple principles at once as they worked with their bilingual students. This overlap might provide increased access to mathematics and language; it potentially provides students with more tools in their toolbox to work with rich mathematics and to engage, connect, and discuss mathematics.

Teachers often shy away from language rich tasks for fear that their students will not understand the mathematics and the language, and as a result, bilingual learners often get less access to rich mathematics. However, these teaching examples and the *CMP2* curriculum (Lappan et al., 2009a) reiterate that teachers can provide bilingual learners with rich mathematics opportunities. With this, more research is also needed around working with mathematics teachers of bilingual learners to support them in using these principles to assist their students in engaging with rich mathematics and developing academic language and discourse that goes beyond basic vocabulary.

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Discussion And Reflection Enhancement (DARE) Post-Reading Questions

1. How could you apply the principles discussed in the article to work with your own students (or in another classroom)?

2. How do the principles discussed in this article intersect in practice?

3. What principles might be missing from this list? Would you change any principles? Why?