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Rethinking Language in Mathematics for English Learners: Connecting Theory, Research, and Practice

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With a rapidly growing population of English Learners, the future of the U.S. school system has promise to be increasingly multilingual, intercultural, and connected. However, many school systems and math teaching practices have remained in the past, not meeting the full needs of or realizing the immense potential of students who are bureaucratically designated as "English Learners." Such students are a rapidly growing population, increasing by more than 50 percent from 2011 to 2021, to over 2.2 million English Learners in grades 6–12 (Irwin et al., 2024). Most English Learners, who in many states are additionally labeled "Long Term," have been in the category their entire school careers and do not identify with their bureaucratic designation as "English Learners" (Brooks, 2022; Kibler et al., 2018). They must navigate multiple barriers to access grade-level coursework (Thompson, 2017; Umansky, 2016). Education systems' failure to adequately challenge and support English Learners is reflected in the 2024 National Assessment of Educational Progress, in which 5 percent of 8th grade English Learners are at or above Proficient in mathematics, compared to 29 percent of their non–English Learner peers (National Center for Educational Statistics, n.d.).

Approaches to language in secondary-level mathematics teaching have tended to treat language as a prerequisite (de Araujo & Smith, 2022). However, this brief asserts that language development is a consequence of—not prerequisite for—deep conceptual exploration and thinking (Walqui & Bunch, 2019; Walqui et al., 2025).

In this brief, we explore three ideas about language and mathematics taken from theory and research. Specifically, the brief synthesizes sociocultural approaches to second language acquisition and systemic functional linguistics to inform and reshape how educators approach the role of language in learning (Chu & Hamburger, 2022; Walqui & van Lier, 2010). We then offer secondary educators three practical ideas based on that theory and research that they can implement in their classrooms instead of more prevalent—but generally less productive—approaches.

What Research and Theory Say About Language and Mathematics

We introduce three ideas about language by centering on students and their ideal learning experiences. By focusing on the desired learning for students, we can then identify the necessary conditions and teacher actions to achieve that learning. We offer three propositions concerning the relationship between language and concepts, the modes of communication, and growth over longer periods of time. In each case, we offer what theory or research says and what we have observed in field trials of the *Reimagining and Amplifying Mathematics Participation, Understanding, and Practices* (RAMPUP) summer bridge among students bureaucratically designated as "English Learners." This 3-week summer bridge program for rising 9th grade students is an enrichment course designed to engage students with crosscutting concepts such as patterns and equivalence (Chu & Hamburger, 2022; Chu & Jackson, 2025). Over two summers, we conducted field trials, which included classroom observations, through an iterative development process that refined the usability and feasibility of the RAMPUP materials. The classroom observations provided real-world examples of these three key ideas about language.

In brief, these ideas are that, first, language and concepts develop in conjunction with each other as students engage in mathematical inquiry. Second, students' language use fluently integrates multiple modes of communication, including speaking, listening, reading, and writing, as well as other symbol systems (such as graphs). Third, language growth can be observed as students' uses of language become more monologic, authoritative, and technical over sustained periods of time and with meaningful opportunities.

Students Develop Language and Concepts Simultaneously

Language is not a prerequisite for conceptual development. Rather, under ideal learning conditions, language and conceptual understandings develop simultaneously. Vygotsky (2012) studied language and conceptual development by interviewing individual children as they developed more formal "scientific" concepts beyond the "spontaneous" concepts they encounter in everyday life. He found that, early in their development, students may attend to surface-level features or construct long chains of associations in which the end points may not actually have much in common. Over time, students are able to both apply concepts that are more abstract and attribute-driven and articulate these concepts more fully with language. This connection between conceptual understanding and language also occurs in math learning. That is, students initially form working definitions of various math ideas, which enables them to carry out inductive investigations. They then progress to learn more formal definitions of these math ideas as their language skills also develop, which enables them to use deductive reasoning (Chu et al., 2022).

For example, in many RAMPUP modules, we have created sorting tasks for a variety of purposes, including support for students to develop the concept of a "pattern" (Chu & Lopez, 2024). Sorting through pictures of real-world objects enables students to make connections with broad ideas such as patterns. These include patterns from the built environment (e.g., floor tile patterns), clothing (e.g., woven patterns), and nature (e.g., sunflowers). Sorting tasks are most engaging and evocative of student-generated ideas when students create groups of objects and then label those different groups. In the RAMPUP sessions, students sort photographs of everyday life and geometrical diagrams and then write labels on sticky notes for the differing groups they create (see Figure 1 and Table 1). Students often begin this activity with a focus on the real-world context or surface-level features, such as color.

Figure 1. Four Student Groups Created Different Categories and Labels in Four Different Colors

Table 1. Transcribed Categories and Labels Created by Four Groups

Sticky note color	Labels created by students
Purple	holes, interesting patterns, carpet patterns, black and white patterns
Red	black and white logos, the blues, hexagons
Yellow	black and white, brown pattern/objects, liquids, paintings/designs, floral pattern
Pink	monochrome, rugs, shapes, holes, wallpaper, tiles, circular

These ideas represent how students initially talk about patterns of repetition. Over time, students' notions of pattern become more precise as they are engaged in describing patterns of growth and change, such as the growing patterns of shapes that we describe below. Because those patterns of growth have multiple representations and contexts, as well as rates of change, students develop greater nuance about types of patterns.

These initial explorations reflect the beginning of a more sophisticated understanding of what changes and what repeats, which extends through questions of equivalence spanning algebra, geometry, and statistics (Chu & Jackson, 2025). As students are beginning to explore how to find structure and regularity in mathematical ideas and representations, their language grows more precise as they communicate about a variety of patterns.

Students Speak, Listen, Read, and Write Flexibly to Make Meaning

The complexity of human communication integrates multiple modes (speaking, listening, reading, and writing) in addition to multiple symbol systems to make meaning. With regard to modes of communication, oracy was originally introduced as a parallel to literacy, which includes and integrates both reading and writing (Wilkinson, 1968). Oracy refers to the complex ways in which speaking and listening are intertwined in meaningful interactions that can become learning opportunities (Gaunt & Stott, 2018). Learning opportunities that are well designed and well implemented integrate and connect both oracy and literacy (Office of English Language Acquisition, 2021). For example, offering students some time to write individually in response to an enticing prompt can assist them in having deeper discussions when they share their ideas in small groups (Chu et al., 2023).

Mathematics is a complex system of symbols and representations through which students can make meaning (O'Halloran, 2005). It is widely understood that English Learners need meaningful opportunities to create and connect various mathematical representations (Roberts et al., 2021). Such representations are powerful opportunities for English Learners when they provide invitations into sense-making and reasoning that offer connections to other representations, real-world contexts, or metaphors and analogies (Chu & Rubel, 2013).

At the same time, English Learners and their classmates often engage in writing and thinking that are multimodal, combining multiple symbol systems or representations simultaneously (Lemke, 2003). For example, in one "jigsaw" activity within RAMPUP, a group of students explore a growing geometric pattern about which they become experts so that they can teach their peers about how that pattern is growing. This learning unfolds over several activities.

First, each student in a group of four receives a card with a picture that is a term in the sequence. They are not allowed to show their card to others, and they have to describe it so that the group can figure out the order together. This initial activity illustrates oracy in that as students are listening to others, they are simultaneously looking at their own card and thinking about how they might speak when they say what they see. In this initial stage, the discussion is purely dialogic and reciprocal and is in the moment.

Eventually, the students reveal the cards and proceed to more deeply analyze the patterns of growth that they can all see now. Then, they begin to develop written descriptions as drafts of what they will say to others. In these drafts, they often create multimodal representations that weave together diagrams with text. Specifically, the students are navigating visual images, verbal descriptions, and numerical inscriptions of sequences. Later, these sequences may become generalized with multiple formulas that correspond to different descriptive approaches.

In one of our field trials, students engaged in an expert group in which four students—Quincy, Nasir, Boris, and Uzma—each received one card that they had to describe and put in order with the others. There were a total of five cards that fit into a sequence of growing shapes. The following is a transcription of these students' interaction during part of the activity.

Quincy: It's a triangle. It got blue on top and some green over here.

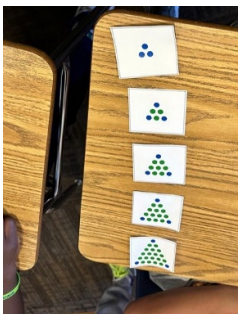
Nasir: It is triangle. It has three circles. And in the middle it had green colors. Seven.

Quincy: And how many does it have on outside?

Boris: I have green dots and blue dots and they are making a triangle.

Uzma: I have blue dots and green dots and they total 20.

Nasir: How many green does everyone have? [Students give answers rapidly as they place cards face down in a row.] Bro, friends, what if we miss one the second one? [Points to the second card in their sequence.]



They put down the fifth card and then were able to successfully flip over all five cards as Nasir yelped in celebration, "Yay, okay! We won!" The group members then took some time to write individual descriptions, which they then shared orally in preparation to teach their pattern to their base group partners.

Later, students worked together to each write descriptions. Their dialogue included the following:

Nasir: It is bigger than first card. It has three green colors and three blue circles.

Uzma: First you have triangle with three blue circles. For second one draw greens inside and three blue on outside.

Nasir: Yes, easy, I get it. You have lots of green and blue circles and form triangle too like the first one. [Referencing second term in the sequence.]

Boris: Can we just take a picture and show other groups?

Nasir: Bro, we need to write things together.

Boris: Ok. we have one triangle with blue on corner. Then we look at next triangle.

Quincy: First one has three, second has six, and the third is ten.

As students talked, they were also writing and reading over each other's shoulders.

This activity was designed to recognize that human communication is multimodal and that engaging students, particularly English Learners, in speaking, listening, reading, and writing provides rich opportunities for learning both language and mathematical concepts.

Student Language Grows More Monologic, Authoritative, and Technical

The field of systemic functional linguistics (e.g., Derewianka & Jones, 2023) provides insights into the multiple dimensions along which language develops over long periods of time. The fundamental premise of analyzing how language is both systemic and functional is to consider how language use is embedded in social purposes. Such social purposes are often known as genres that serve particular purposes (Christie, 2002). These genres include multiple continua, such as mode, tenor, and field.

- **Mode** refers to how communication is organized—whether it is on the more dialogic or spoken-like end of the continuum (as in a verbal conversation or exchanges over text messaging) or the more monologic end of the continuum (like a written and edited text or a rehearsed and extended speech).
- **Tenor** refers to the relations between speaker and listener, which can range from the speaker and listener being peers or equals to the speaker being more authoritative or expert than the listener.
- **Field** refers to the domain or topic at hand, which can range from everyday topics (like what to have for lunch) to more technical aspects (like the best way to repair a broken car, as discussed by car mechanics).

Over time, language learners develop in ways that become more monologic (more extended and polished like a prepared speech rather than a dialogue), more authoritative, and more technical. These processes of language development and growth can be integrated with peer and self-assessment that enables learners to reflect on, recognize, and adjust their language learning (Heritage et al., 2015).

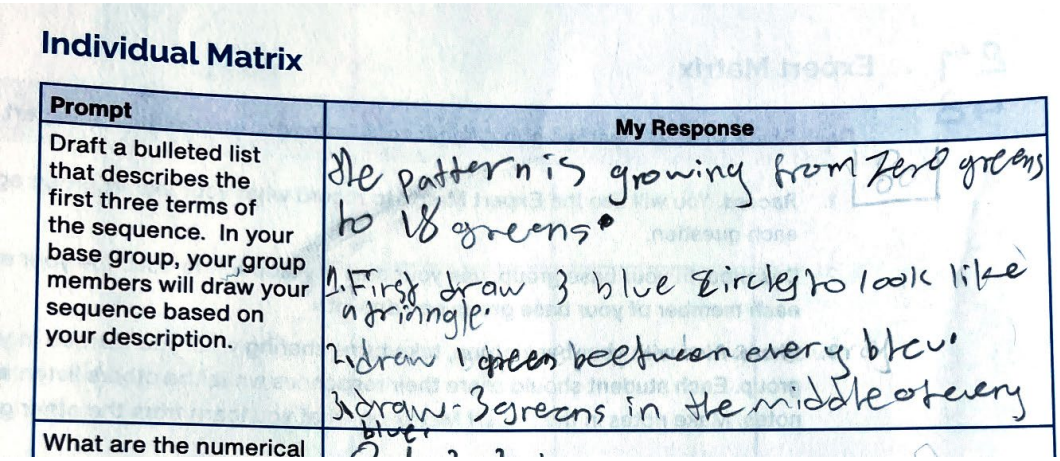
For example, in the jigsaw project introduced above, students first described individual shapes. Then they worked in groups to try to decide how they could describe not individual terms but rather the growth in terms of number, color, and shapes. Before they reached a consensus as experts, students took some time to individually write their descriptions of the first three terms of a sequence. They then shared these descriptions orally in a “round robin” format before they made edits to refine their descriptions and identify promising approaches. By the end of the jigsaw, they returned to their “base” groups and taught their patterns to their peers in ways that were more monologic, authoritative, and technical.

One way to see a specific student’s journey is to follow Quincy from the expert group back to his base group. In the worksheet given to students for the jigsaw project described above, Quincy wrote the description transcribed below (also see Figure 2):

The pattern is growing from zero greens to 18 greens.

1. *First draw 3 blue circles to look like a triangle.*
2. *Draw 1 green between every blue.*
3. *Draw 3 greens in the middle of every blue.*

Figure 2. Quincy Wrote a Description of the Growing Sequence



Individual Matrix

Prompt	My Response
Draft a bulleted list that describes the first three terms of the sequence. In your base group, your group members will draw your sequence based on your description.	The pattern is growing from zero greens to 18 greens. 1. First draw 3 blue circles to look like a triangle. 2. draw 1 green between every blue 3. draw 3 greens in the middle of every blue.
What are the numerical	

What is notable, however, is that when Quincy returned to his base group, he did not strictly follow his own written description as a script of what to say. Indeed, the following verbal description he gave to his base group illustrates many of the ideas above about more monologic communication that is also becoming more technical and authoritative:

It's a triangle, and on the corner of every triangle, there is a blue circle. So, imagine a triangle, and on the corner draw a blue circle, but don't draw the triangle. So that's the first one. The second one, in between every blue there is one green.

That all of this growth occurred within a 40-minute span emphasizes that even greater growth is possible over longer time periods.

What Can Secondary Educators Do to Better Support English Learners' Language Development in Mathematics Classrooms?

Often secondary educators approach supporting English Learners by sprinkling in discrete strategies that do not match the aims of ambitious learning. However, educators must design learning for English Learners that supports both language learning and rigorous content-area learning.

This section discusses three prevalent practices used in U.S. classrooms with English Learners and shares new approaches to these practices, along with examples of what these approaches look like with students in the classroom setting. These approaches, which are informed by the theory and research described in the previous section, signal a shift in pedagogy for English Learners, as shown in Table 2 below.

Table 2. Educators Must Make Shifts in Designing Learning for English Learners

From...	To...
Preteaching vocabulary	**Developing concepts (ideas in their interconnectedness) and the language to talk about them**
Requiring sentence starters as rigid scripts	**Offering generative formulaic expressions to connect ideas and engage in practices**
Treating reading, writing, listening, and speaking as four separate modes of communication	**Integrating oracy and literacy in meaningful activities**

Develop Concepts and the Language to Talk About Them

Often teachers preteach vocabulary, such as definitions or formulas, ahead of the lesson. In frontloading and focusing on vocabulary, teachers are taking time away from engaging students in math concepts (Chu et al., 2022; Office of English Language Acquisition, 2021). For example, the College Preparatory Mathematics (College Preparatory Math [CPM] Educational Program, 2015, 2016) definition of "slope" is the following:

> *A ratio that describes how steep (or flat) a line is. Slope can be positive, negative, or even zero, but a straight line has only one slope. ... When the equation of a line is written in* y = mx + b *form,* m *is the slope of the line. A line has positive slope if it slopes upward from left to right on a graph, a negative slope if it slopes downward from left to right, zero slope if it is horizontal, and an undefined slope if it is vertical. Slope is interpreted in context as the amount of change in the* y*-variable for an increase of one unit in the* x*-variable. Some texts refer to slope as the ratio of the "rise over the run."*

This overly verbose definition does not highlight what is truly important about slope—that it is a unit rate of change (Hamburger & Chu 2019; Stump, 1999).

Sample Classroom Lesson on the Concept of Slope

Rather than teaching "slope" as a word to be memorized and repeated mechanically, teachers should first focus on key ideas and later succinctly teach the terms used to refer to those interrelated ideas. For instance, the lesson *A Less Slippery Slope* helps students develop a conceptual understanding of slope as a unit rate of change (Hamburger & Chu, 2019).

Students are invited into the discussion by being asked to share about how to climb something and reflect on what made it easy or hard to climb. In the class discussion, the teacher advances the idea of the vertical and horizontal components common to the related stories. Students then compare and order staircases and, in whole-class discussion, the teacher introduces or highlights notions of "rise" and "run." Students read collaboratively to connect stairs with ramps, which more closely resemble the lines they will explore in subsequent tasks.

Next, in groups of four, students coordinate tables with graphs of linear functions to describe the horizontal and vertical changes between points. Afterward, there is a class discussion in which the teacher and class co-construct the concept of slope as the unit rate of change. This discussion culminates with students stating, "As x increases by ... y changes by ..." These uses of language articulate how x and y covary across representations, including tables and graphs (Hamburger & Chu, 2019).

Throughout the lesson, students develop the concept of slope using tables, graphs, and numerical values (with units). The arc of the lesson allows students to connect their prior knowledge to new language as it is developed in the context of the mathematical concept. This approach allows students to conceptually understand slope well before developing a formula. By embedding language within meaningful tasks, students are better equipped to develop conceptual understanding. Rather than providing students with terms and definitions, allowing students to develop a working definition within a task will make concepts immediately accessible (Chu et al., 2022; Hamburger & Chu, 2019).

Offer Generative Formulaic Expressions to Connect Multiple Ideas

Another common practice to support English Learners is giving sentence starters. Typical sentence starters, however, limit language choice for students (Grapin et al., 2021). They generally offer little room for students to go beyond the script to express their own ideas. Sentence starters are often questions in disguise (e.g., "The square of 5 is ...").

Instead of these limiting sentence starters, we recommend using formulaic expressions, which are swatches of language that can connect multiple ideas. Formulaic expressions engage students to do mathematics and have flexible uses. One of these uses is enabling students to connect multiple ideas. For example, being able to complete the sentence "I think ... is steeper than ..." requires more than just knowing the individual words. Completing this formulaic expression is a way for English Learners to connect broader ideas and express the relationship between two ideas.

Sample Classroom Lesson on the Concept of Slope

In the lesson *A Less Slippery Slope*, as students interact with the concept of slope, they participate in a *Read and Do*. During this task, students in groups of four use formulaic expressions to identify horizontal and vertical changes between two points. After naming points on a table or graph, students work in their groups, and one student identifies a starting point. From there, each student in the group uses the following formulaic expression:

> *"Starting from the point ...,*
> *to get to the point ...,*
> *there is a horizontal change in the* x *of ...,*
> *and a vertical change in the* y *of ..."*

This formulaic expression is a temporary support to connect multiple mathematical objects: a starting point, an end point, the horizontal change, and the vertical change (Hamburger & Chu, 2019). Students are not required to use the formulaic expression verbatim, and they often naturally drop pieces of it. For example, they may drop "in the *x*" or "horizontal." The purpose of the offered formulaic expression was not to predetermine how students must use language but rather to draw their attention to the key elements of the task at hand.

Indeed, a more generative formulaic expression is

> *"As* x *increases by ...* y *changes by ..."*

With this formulaic expression, students can connect multiple ideas. For example, if *x* increases by 2, *y* increases by 6, which corresponds to a slope of 3 because when *x* increases by 1, *y* increases by 3. Formulaic expressions are fundamentally generative, and because they have broader application, engaging English Learners with formulaic expressions rather than rigid scripts builds their linguistic autonomy over time.

Integrate Oracy and Literacy in Meaningful Activities

Although prevalent practice treats reading, writing, speaking, and listening as separate domains, our approach is to integrate oracy and literacy into meaningful activity. Teachers should create lessons that allow students to read, write, listen, and speak to each other in order to deepen their mathematical practices.

Sample Classroom Lesson on the Concepts of Distance and Time

An example of interweaving literacy and oracy happens in the *Reading in Four Voices* task during the lesson *You've Crossed a Line*. During *Reading in Four Voices*, a group of four students reads a fable about the race between the tortoise and the hare that describes the 10-mile journey each animal took to cross the finish line.

In groups of four, students take turns reading the text out loud. The text has been carefully segmented into meaningful swatches using four different styles of font. On students' first reading, they read for the overall plot of the story. On the second reading, they pause after each student's turn to decide how to contribute to a collective drawing of what is happening in the story. Typically, students draw pictures of the animals and a long line to show the course of the race. Then they draw different moments from the story. These inscriptions can be connected to the more standard representations of double number lines but do not efficiently show the covariation of distance and time.

Students read the text a third time, and they are provided with a distance–time graph that juxtaposes the tortoise's slow and steady rate of motion with the hare's piecewise linear journey. In the third read, students read the parts of the story and coordinate each moment of the animals' journey with their rate of motion along the coordinate plane in relation to distance and time. Students speak about the tortoise's slow and steady pace and the moment in the story in which the hare takes a nap along the course, which is denoted by a horizontal line. In the third reading and its related activity, students engage in both literacy and oracy to connect the specific values in the story with the values shown in the graph.

Indeed, the example illustrates and reiterates the multimodal nature of mathematics learning. That is, students are reading graphs, comparing values, finding rates of change, and coordinating with the events in the story. As they do so, they are truly speaking, listening, reading, and writing in mathematically specific ways that are harmoniously integrated.

Next Steps for Educators: Guidance for Planning High-Quality Learning Opportunities

As secondary mathematics teachers plan high-quality learning opportunities for their students, including English Learners, they will need to attend to the ideas in this brief around concepts, language, and participation. In Table 3, we offer some questions that teachers can reflect on in their design process, along with some concrete actions that they can take.

Table 3. What Can Educators Do? Questions to Ask and Actions to Take

Category	Questions to ask	Actions to take
Conceptual and Linguistic Development	▪ What is the conceptual focus? ▪ What language will students need to talk about the concept? ▪ How will language develop alongside concepts? ▪ How are students offered opportunities to develop working definitions?	▪ Use working definitions to launch students' exploration of a cluster of mathematical ideas. ▪ Invite students to formulate and refine definitions once they have explored a concept.
Language to Connect Ideas	▪ How are language opportunities provided throughout the lesson? ▪ What language supports need to be offered to connect ideas? ▪ What language supports need to be offered to engage in disciplinary practices?	▪ Offer formulaic expressions that allow students to connect ideas. ▪ Create activities that are significantly open-ended and allow multiple approaches and perspectives.
Multimodal Communication	▪ Where are students reading, writing, listening, or speaking? How can communication be integrated?	▪ Provide opportunities for students to read, write, listen, and speak to deepen mathematical ideas. ▪ Explicitly plan possible flows, such as writing before speaking about and sharing ideas.

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