imagine math

FOUNDATIONS PAPER

Imagine Math

Accelerating Math Achievement for English Learners:

Integrating Language Support in Mathematics Instruction

English learners (EL students) represent a growing segment of students in the United States. There are currently 5.1 million English learners with varying levels of English language proficiency enrolled in public schools, which represents 10.4% of all public school students.

While educators recognize the importance of providing additional supports as EL students learn to read and write, they may not consider how integral language is in acquiring mathematical proficiencies. Language is used in mathematics to solve problems, discuss computations, understand and process various symbolic representations, and explain mathematical reasoning. As Molina (2012) states, "[T]he phrase 'the problem with math is English' applies to all students. . . Language struggles are embedded in mathematics, which in many ways, is its own language."

Although many students may struggle with understanding the language of math, English learners are particularly challenged and need language support integrated in mathematics instruction to enable them to access rigorous, grade-level content. The Council of the Great City Schools (2016) states that "...in planning math instruction for a diverse array of learners, districts and states not only grapple with how to facilitate the development of conceptual understanding in mathematics, they must also address the specific needs of students who are simultaneously developing their English proficiency." Zahner, Velazques, Moschkovich, Vahey, and Lara-Meloy (2012) explain this recommendation:

> Mathematics teaching that promotes students' conceptual understanding has two central features: 1) teachers and students explicitly attend to mathematical concepts, and 2) students wrestle with and make connections among important mathematical ideas. All teachers face a considerable challenge in balancing both of these features in their teaching, and prior research reveals that teachers in schools with high numbers of Latinos/as and language minority students often focus on procedural content (Gándara & Contreras, 2009). In contrast, recommendations for effective environments for students from non-dominant linguistic backgrounds emphasize that instruction should provide "abundant and diverse opportunities for speaking, listening, reading, and writing" and "encourage students to take risks, construct meaning, and seek reinterpretations of knowledge."

Additionally, Judith Moschkovich (2010), a professor and education researcher in the field of EL students and mathematics states, "The language of mathematics does not mean a list of vocabulary or technical words with precise meanings, but the communicative competence necessary and sufficient for participation in mathematical discourse." EL students bring knowledge, skills, and language proficiency from their primary language to mathematics classrooms, which are assets to be leveraged and utilized in supporting their development of mathematical proficiency.

To become proficient in mathematics, EL students need access to robust instruction that aligns with grade-level mathematics standards and supports the acquisition of language necessary for understanding instructional content and becoming proficient in mathematics.

The National Research Council (2001) defined mathematics proficiency with the following strands:

- **conceptual understanding**—comprehension of mathematical concepts, operations, and relations
- **procedural fluency**—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- **strategic competence**—ability to formulate, represent, and solve mathematical problems
- **adaptive reasoning**—capacity for logical thought, reflection, explanation, and justification
- **productive disposition**—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's efficacy

Mathematics instruction for EL students should align with recommendations for effective mathematics instruction for all students in focusing on conceptual understanding and procedural fluency, using high cognitive demand for mathematical tasks and maintaining cognitive demand throughout lessons, and in engaging students in the practice of mathematics (Stanford University, 2013).

In considering the language demands of mathematics and EL students' need for language development, effective mathematics instruction should additionally:

- leverage students' background knowledge/experience,
- support the acquisition of academic language used in mathematics,
- teach mathematical vocabulary,
- include multiple modes of representation, and
- provide intentional scaffolding.

When needed, explicit, systematic instruction should be provided to EL students who have yet to master basic mathematics.

Adopt an Assets-Based Lens and Leverage Students' Background Knowledge and Experience

English learners enter school with varying backgrounds, experiences, and levels of English proficiency. They can engage with complex mathematical concepts and solve real-word problems (Council of the Great City Schools, 2016), and their unique backgrounds and knowledge are assets for learning that can be leveraged in classrooms (Council of the Great City Schools, 2016; Stanford University, 2013).

Teaching mathematics to EL students builds on the language and concepts students already have and understand in their primary language (Milyutin, 2018). It is therefore critical that EL students actively contribute to discussions and discourse, even if they use imprecise language when participating. Everyday language and academic language are interdependent and can be accessed to support math learning (Moschkovich, 2010).

Providing materials and instruction in a first language is one way that Imagine Math leverages students' strengths and springboards the learning of new concepts. Instruction in Imagine Math is provided in English and in Spanish. Bilingual access to rigorous content and precise translations ensure mastery of grade-level standards for EL students. This reduces the cognitive load associated with English-only instruction and facilitates learning for Spanish speakers. Accessing Spanish audio helps students learn new concepts in their native language and leverages vocabulary and language skills students already have in learning mathematics.

Spanish speaking students are also supported with academic language when they connect virtually with Imagine Math teachers. Bilingual, live, certified teachers engage in instructive interactions with students in Spanish and English (depending on the language requested by students). With live, certified teachers, students engage in mathematical discourse that teaches them how to utilize precise mathematical language to communicate their conceptual understanding in either Spanish or English.

Teach Academic Language Used in Mathematics

Mathematics has its own language and representational systems that can be challenging for EL students to understand while they are acquiring English language proficiency. The syntax, symbols, and terminology used in mathematics are distinct and can be confusing for EL students when terms are used differently than in conversational English. Word problems can be particularly challenging for EL students who are still learning English (Deussen, Autio, Miller, Lockwood, & Stewart, 2008).

Classroom instruction should support students in understanding complex mathematical texts as they appear in grade-level curriculum (Stanford University, 2013). Providing explicit instruction in how to read mathematical equations, terms, and symbols help EL students learn how to process the language of mathematics.

Imagine Math utilizes academic mathematical language to present new concepts. Throughout Imagine Math lessons, students engage with content with varying levels of text and language complexity such as word problems, visual representations of mathematics (e.g., tables and charts), and symbolic representations of equations. Supports are provided to enable students to understand academic language and mathematical concepts. For example, students can access mini-lessons that provide visual illustrations of concepts to facilitate access to rigorous content.

Part of learning math is making connections across mathematical ideas and concepts. To support students in utilizing language to deepen conceptual understanding, Imagine Math includes journaling protocols and templates that students use to organize their thinking and explain their reasoning. This infusion of language production into mathematical processes reinforces the idea that mathematics is as much about reasoning and discourse as it is about computation.

Use and Teach Rigorous Mathematics Vocabulary

Understanding mathematical vocabulary is essential to learning math. EL students need to not only learn math-specific terms, they need to understand how mathematical definitions are different than other definitions of words (Robertson, n.d.). In teaching math vocabulary, "vocabulary need not be pre-taught or introduced in isolation but instead should be included in activities that involve high cognitive demand mathematical work: reasoning, sense making, explaining, comparing solutions, etc." (Stanford University, 2013). When introducing new vocabulary, EL students benefit from engaging experiences that facilitate conceptual understanding and use vocabulary for labeling, discussing, and grounding meaning in language (Stanford University, 2013).

Imagine Math programs contextualize vocabulary instruction. Vocabulary is taught within lessons as EL students are learning new concepts and skills. For early learners, math vocabulary instruction is intentionally introduced through play to engage students in meaning-making, then learning is reinforced through song for long-term recall. For older students, academic vocabulary is integrated into all lessons to support students in learning the language of mathematics. Additionally, students can access models, diagrams, and visualizations of terms to facilitate comprehension and learning. Within the program, dictionaries can be accessed on-demand that explain vocabulary in student-friendly terms.

Multiple Representations

Many students encounter difficulty understanding relationships between visual representations of math and mathematic symbols (Gersten et al., 2009). Mathematics has its own language and representational systems that is challenging for most learners and particularly challenging for EL students as they are acquiring language skills. (Deussen et al., 2008). The systematic use of visual representations and manipulatives in learning math may lead to significant and positive gains in math proficiency (Gersten et al., 2009), and supports the development of EL students' conceptual understanding (Milyutin, 2018).

Multiple representations in each Imagine Math lesson makes abstract concepts simultaneously concrete and flexible for all students, helping to bridge language development and mathematics. EL students

encounter a variety of representations in each Imagine Math lesson via models, symbols, and diagrams to assist with learning and deepen understanding. For early learners, students learn math with computerized manipulatives, such as base ten blocks. As students advance in elementary grades, concepts are presented visually and spiraled to build mastery toward symbolic processing.

Imagine Math includes a full suite of digital tools including number lines, graphics, diagrams, and graphs that can be used to generate multiple representations of mathematics. The math tools give EL students another way to concretely represent their mathematical thinking. Learning is further reinforced with visual representations of concepts after students answer problems. Finally, multiple representations are also included throughout Imagine Math Application Tasks to help students connect mathematical concepts and procedures.

Scaffolding and Live Teachers

Instructional scaffolding refers to supports or assistance provided to students that enable them to complete tasks with high rates of success that they may not otherwise complete independently. Mathematical scaffolding refers to providing instructional support for procedural skills, conceptual understanding, metacognitive strategies, and mathematical practices (Moschkovich, 2015). EL students benefit from instructional scaffolding that enables them to process language associated with mathematics and learn new mathematical concepts.

Imagine Math programs integrate instructional scaffolding within rigorous, grade-level lessons. As EL students progress in learning mathematics, a progressive system of intentional scaffolds support successful learning within Imagine Math. These intentional scaffolds include visual representation of concepts, vocabulary instruction necessary for learning math concepts, verbal directions and instruction, and spiraled practice that supports students in mastering concepts before gradually increasing the difficulty of practice items.

As EL students engage with lessons and need help completing problems or understanding concepts, students can access rigorous real-time instruction by live, on-demand, certified bilingual teachers. Live teachers chat with students and provide instructions and visual models and illustrations via a two-way interactive whiteboard to help students successfully engage with math problems.

Conclusion

EL students need language support integrated in mathematics instruction so they may access rigorous, grade-level content. Effective mathematics instruction for EL students leverages their background knowledge and experience, addresses the use of academic language and vocabulary in mathematics, includes multiple modes of representation of mathematical concepts and expressions, and provides intentional scaffolding for skill acquisition. Imagine Math is intentionally designed to support learning for EL students and integrates these effective practices in all lessons and instructional sequences.

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imaginelearning.com
877-725-4257 • solutions@imaginelearning.com

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