ELLevation: Literature Review

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WestEd is a nonpartisan, nonprofit research, development, and service agency that works with education and other communities throughout the United States and abroad to promote excellence, achieve equity, and improve learning for children, youth, and adults. WestEd has more than a dozen offices nationwide, from Massachusetts, Vermont, Georgia, and Washington, DC, to Arizona and California, with headquarters in San Francisco.

Overview of Literature Review Process

From September to October 2019, WestEd staff researched and drafted a literature review for ELLevation. WestEd collaborated with ELLevation to determine the focus areas for the literature review, as well as to identify any existing company resources or documents that could serve as the basis for the literature review.

The WestEd process entailed first identifying search strings based on the following focus areas:

- Mathematics and academic language
- STEM and academic language

The following search strings were then identified:

- Academic language and mathematics, academic language and English learners, vocabulary and mathematics, mathematics and English learners, or ELLs, or ELs

A WestEd researcher spent approximately two days searching these key words in academic databases, such as EBSCO Host (includes APA PsycARTICLES and ERIC), the SAGE Premier Journal Collection, and Google Scholar. When selecting references, the following factors were taken into account:

- Data of publication: Priority was given to references published in the past 10 years.
- Quality of publication: Priority was given to peer-referenced articles.
- Quality of research: Priority was given to the most rigorous study types, such as randomized controlled trials, quasi-experimental designs, correlational designs, descriptive analysis, mixed methods, and literature reviews. Other considerations included the target population and sample, including their relevance to the question, generalizability, and general quality.

All key search terms and references were recorded to draw themes on the focus areas. The literature review on the identified focus areas is presented below.

English Learners (ELs) need to be simultaneously engaged in rigorous, grade-level academic content with appropriately scaffolded instruction, while at the same time provided opportunities to develop their academic English language proficiency. In mathematics, understanding the interdependence between language and content is critical to the success of ELs (Great City Schools, 2016). Disciplinary practices in mathematics can be "cognitively demanding and language intensive" (p. 104) for ELs and students need opportunities to make meaning of these mathematical practices through productive discourse and appropriately structured interactions with others (The National Academy of Sciences, Engineering and Medicine, 2018).

Defining Academic Language in Mathematics

Gotleib and Ernst-Slavit (2013) describe academic language as a complex construct that includes language defined by specific linguistic features associated with different academic disciplines. These features cross discourse, sentence and word/phrase levels, and increase in complexity across the years and grade levels (Gottlieb & Ernst-Slavit, 2013). Specifically, in mathematics, there exists not only specialized vocabulary, but elements of specific types of discourse and register (i.e., the different levels of formality in language; Moschkovich, 2012). The Council of Great City Schools (2016) defines mathematical discourse as "communication that centers on making meaning of mathematical concepts" (p. 6). According to Biachini (2018) successful STEM teachers help to develop their students' academic language by including an instructional focus not just on vocabulary, but also on varying degrees levels of syntax and discourse. Moschkovich (2015) asserts that this definition of academic language, that encompasses a complex view of mathematical discourse and one of mathematical proficiency and practice, is "crucial for the education of ELs" (p. 3) and that separating language from mathematic thinking and practices can have "dire consequences for English learners" (p. 7).

Role of Vocabulary and Discourse in Mathematics

The importance of vocabulary instruction from early research (Stahl, 1986) shows that vocabulary instruction in general has significant effects on reading comprehension for native language speakers and more recent research specific to ELs and specific to mathematics highlights vocabulary as a critical piece in helping students to engage in mathematical thinking and learning (Gottlieb & Ernst-Slavit, 2013). According to Bay-Williams and Livers (2009), in order to simultaneously develop language and mathematical thinking, educators also need to consider the "when and how" (p. 239) of introducing vocabulary to maximize students' learning. Dunston and Tynmiski (2013) agree that mathematic vocabulary, with its discipline specific meanings, should be addressed deliberately, and that it is "inextricably bound to students' conceptual understanding of mathematics" (p.40).

Moschkovich (2013) highlights that while teaching vocabulary is critical, it is not by itself enough to enable students to communicate mathematically. Successful instruction includes opportunities for students to "actively use mathematical language to communicate about and negotiate meaning for mathematical situations" (Moschkovich, 2013; p. 3). In their *Framework for Re-envisioning Mathematics Instruction for English Language Learners*, the Council of Great City Schools (2016) encourages teachers to think about the role that both formal academic language and less formal language can be used to help guide students to deeper understanding of

mathematical reasoning. The National Academy of Sciences, Engineering and Medicine (2018) recommends that teachers provide opportunities for students to engage in learning with more than just individual words, and encourages educators to also teach students how to use the language of mathematics to develop claims and participate in disciplinary practices that allow for meaning making. Moschkovich (2012) adds that teachers should address and support ELs' participation in mathematical discussions as they learn and introduce targeted vocabulary in context and include activities that are rigorous and appropriately scaffolded for ELs.

Scaffolding Language in Mathematics

Providing scaffolds and supports help ELs access complex mathematical concepts and is critical to ensuring ELs make sense of their learning (Student Achievement Partners, 2018). According to August (2014), scaffolds support both receptive skills (listening and reading) and productive skills (speaking and writing) and can be used with ELs at any proficiency level. However, scaffolds should be carefully chosen and take into consideration not only the students' language proficiency level, but also their previous experience with mathematics instruction and their specific educational needs (Great City Schools, 2016; The National Academy of Sciences, Engineering and Medicine, 2018). Scaffolding provides opportunities for students to make meaning of their learning while simultaneously tackling the complex language of mathematics concepts and practices (Daniels, 2018). Doabler and colleagues (2016) suggest that in order for ELs to learn the academic vocabulary of mathematics they need frequent structured opportunities to engage and interact with the key vocabulary. According to Daniels (2018), the ultimate goal of scaffolding is to help students develop autonomy in their thinking and learning of these mathematical complex concepts and practices, which in turn will enable them to meet the articulated learning goal.

Practices in Teaching the Language of Mathematics

From research done on vocabulary instruction in general for native English speakers, vocabulary instruction that includes both definitional and contextual instruction, with opportunities for deeper processing and multiple exposures to words has been found to have significant effects on student comprehension (Stahl, 1986). Specifically for ELs, researchers have noted that instruction of mathematics vocabulary cannot be separated from its context (Gottlieb & Ernst-Slavit, 2013; Bay-Williams & Livers, 2009; Moschkovich, 2013; Zwiers, 2017). In the *Draft Guidelines for Improving Mathematics Materials for English Learners* (2017) the authors suggest that key vocabulary be strategically integrated and taught with the purpose of providing opportunities for students to engage in meaning-making and communication. Engaging students in meaning-making activities in STEM classrooms that include interaction with others, highly benefit ELs (National Academies for Sciences, Mathematics and Engineering, 2018).

According to August (2014), the teaching the academic vocabulary of mathematics should be "explicit and intentional" and students should be "provided with structures to practice their new vocabulary with peers and adults". According to Doabler (2016) strategies for identifying key vocabulary should help students make connections between new and unfamiliar words and provide opportunities for students to use the new vocabulary to communicate their mathematical thinking.

Instruction that promotes ELs engagement in mathematical language use can be supported by frameworks designed to be used in the development of curriculum and instruction (Council of Great City Schools, 2016; English Learner Success Forum, 2017), Student Achievement Partners, 2017; Zwiers, 2017;). In the Council of Great City Schools (2016) a key instructional practice includes supporting academic language and conversations that emphasizes the need for ELs to be able to not only to learn to reason mathematically, but to also express their mathematical reasoning orally. According to the Council examples of this practice in the classroom include teacher modeling what mathematical reasoning and academic language looks like and suggests that allowing for productive struggle to happen with appropriate scaffolds in place can encourage more formal mathematical communication on the part of the students. The English Learner Success Forum (2017) also provides guidance focused on key areas of language development they recommend being utilized in curriculum design. One example includes "strategic opportunities to use and refine both language and mathematics over time" (p. 10) with an emphasis on materials and practices that support ELs learning of the mathematical language through sustained activities and experiences that support the connections between the students home language, English, and mathematical concepts. Student Achievement Partners (2018) also highlights the necessity of ELs learning mathematical language in context and suggests that explicit language instruction be limited "to the occasions when the necessary terminology is a prerequisite for engaging with the content" (p. 30). The authors suggest words with multiple meanings should be identified and taught using their mathematical definitions and suggest that students need opportunities to engage in mathematical language through the four language domains of reading, writing, speaking and listening. According to Zwiers (2017) with Understanding Language/Stanford University, engaging students in learning by using mathematical language routines, can promote mathematical language, practices and content at the same time. The authors define mathematical language routines as "a structured but adaptable format for amplifying, assessing, and developing students' language" (p. 9).

For more information about each of the frameworks or guidelines mentioned above see below.

- Council of Great City Schools (2016): *Framework for Re-envisioning Mathematics Instruction for English Leaners: Supporting Academic Language and Conversation and Strategic Scaffolding*
  This framework was designed to define a new vision for mathematics instruction that "explicitly attends to the needs of ELLs, addressing the interdependence of language and mathematics" (p. 8). The guide provides
  - Key Instructional Principles and Practices
  - Criteria for Mathematics Instructional materials
- English Learner Success Forum (2017) *Guidelines for Improving Math Materials for English Learners* provide "specific guidance to developers of mathematics content on key areas of English language development that must be embedded across the curricula, in units, and in lessons" (p. 3). The document provide five areas of focus with 15 guidelines that include examples of models, explanations, practices, strategies, and supports.
  - Area of Focus I: Interdependence of Mathematical Content, Practices, and Language

    - Area of Focus II: Scaffolding and Supports for Simultaneous Development
    - Area of Focus III: Mathematical Rigor Through Language
    - Area of Focus IV: Leveraging Students Assets
    - Area of Focus V: Assessment of Mathematical Content, Practices and Language
- Student Achievement Partners (2018) developed the *Selected Research on Providing English Language learners Access to College and Career Ready, Grade Level Instruction in Core Academic Classes* which offers evidenced-based resources and tools that can support ELs in accessing college and career ready, grade-level instruction in core academic classes. Objectives are provided that support mathematical learning for ELs
    - Objective 1: Support the majority of mathematical language acquisition within the context of the mathematical learning. Limit explicit language instruction to the occasions when the necessary terminology is a prerequisite for engaging with the content. (p. 30)
    - Objective 2: Provide supports to allow all English Language Learners access to mathematical concepts being introduced. (p. 34)
    - Objective 3: Write tasks with care to allow English Language Learners to engage with mathematical concepts. (p. 39)
- Understanding Language/Stanford Center for Assessment, Learning and Equity with Zwiers, et. al. (2017) in *Principles for the Design of Mathematics Curricula: Promoting Language and Content Development* presents a framework with four design principles supported by mathematical language routines. The mathematical language routines are a "structured but adaptable format for amplifying, assessing, and developing students' language," (pg. 9) and support students in learning mathematical content, practices, and language.
    - Design Principles:
        - Support Sense-Making
        - Optimize output
        - Cultivate conversation
        - Maximize linguistic and cognitive meta-awareness

The challenge of navigating how to support ELs in their academic language development, while at the same time engaging them in rigorous, complex mathematical thinking is a complex one. As stated above, instruction must utilize appropriate scaffolds and supports to ensure ELs are engaged in meaningful opportunities of interaction and discourse focused on mathematical practices. The vocabulary of mathematics is a critical piece of students' learning. There is also a strong emphasis on examining the different levels of register of mathematical discourse and the role that both formal and informal language can play in helping students communicate mathematically.

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