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# How Early Mathematics Interventions Support Mathematics Vocabulary Learning: A Content Analysis

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**Abstract**

While there is a strong research base that supports intervening early in mathematics, research investigating the importance of mathematics vocabulary is still emerging. Practitioners and researchers may benefit from understanding how mathematics interventions support mathematics vocabulary acquisition, particularly for students who struggle with learning mathematics. Thus, the purpose of this study was to conduct a mathematics vocabulary content analysis across seven kindergarten and first-grade mathematics interventions. Across the intervention lessons, we recorded suggested teacher and student actions related to mathematics vocabulary instruction. The results indicated the most common instructional strategies used to teach mathematics vocabulary include: providing students with the opportunity to apply the meaning of the vocabulary term (94.7%), using representations (66.4%), and asking students to respond to teacher prompts using the term (44.7%). Overall, 29.7% of lessons clearly defined vocabulary terms, and 5.8% of lesson objectives addressed teaching the definition of the term. We discuss implications for researchers and practitioners to supplement interventions with opportunities for students to learn, practice, and apply mathematics vocabulary.

**Keywords:** early mathematics, vocabulary, intervention, content analysis

Vocabulary knowledge, or knowledge of terms and their meanings (Stahl, 2005), is one indicator of a student's understanding and abilities in various facets of academic success. Word knowledge is a component of academic language that includes knowing what terms (i.e., a single word or several related words such as *decimal number*) mean, as well as how they are used in academic contexts (Townsend et al., 2012). In other words, knowledge of a term includes both a definition and implications for how the term "fits into the world" (Stahl, 2005, p. 95). Texts include words that are strategically organized to form clauses and sentences; thus, students with extensive word knowledge are more likely to come across familiar words and more easily interpret the text. With the increasingly academic nature of texts that K-12 students are required to read and write in each discipline, vocabulary learning must be considered early in instruction and intervention (Larson et al., 2013; NGA & CCSSO, 2010). Children starting school with limited vocabulary often remain behind their peers later in elementary school (Chall & Jacobs, 2003) and even into high school. In a study of 11th and 12th grade students, measures of three dimensions of academic word knowledge explained significant variance in reading, writing, science and math (Townsend et al., 2020). The complexity of disciplinary texts, curricular materials, and tasks can mean that large numbers of new and unfamiliar words may prevent students from accessing content (Vukovic & Lesaux, 2013). In mathematics specifically, students' proficiency is often thought of as the use and application of numerals and symbols (e.g., computation) and the understanding and application of mathematics vocabulary (e.g., *less than*, *estimate*). Mathematics vocabulary allows students to describe their problem-solving processes, construct arguments, and communicate about mathematics. Thus, mathematics vocabulary plays a significant role in developing other mathematics knowledge and skills (Hornburg et al., 2018).

The importance of mathematics vocabulary and early mathematics intervention is accepted. When and how vocabulary is incorporated into mathematics interventions and introduced to students with learning difficulties are both important considerations because students who receive mathematics interventions are at an increased risk for lower understanding and application of mathematics vocabulary (Forsyth & Powell, 2017). The purpose of this study, then, was conducting a content analysis of instructional strategies used to teach mathematics vocabulary in kindergarten and first-grade early mathematics interventions. The research questions guiding this study were: 1. What instructional strategies are used in early mathematics intervention lessons to teach mathematics vocabulary terms? and 2. How do the intervention lessons present and define the mathematics vocabulary terms for teachers who implement the lessons? Below, we discuss previous research related to relationships between mathematics vocabulary and mathematics knowledge, recommendations for teaching mathematics vocabulary, and early mathematics interventions.

## Early Mathematics Interventions

In the United States, practitioners and researchers often implement interventions alongside students' core mathematics curriculum. Interventions, such as those reviewed by Nelson and McMaster (2019) are not intended to replace core mathematics instruction. Rather, interventions are intended to supplement core mathematics instruction, such as by increasing the amount of instructional time (Wanzek & Vaughn, 2007), and remediate students' difficulties with prerequisite skills that are necessary for them to access grade-level content (Powell et al., 2013). A strong research base that supports intervening early in mathematics with students who have learning difficulties, especially with foundational early mathematics skills, such as those that are taught in kindergarten and first grade (e.g., Dyson et al., 2013; Nelson & McMaster, 2019; Wilson et al., 2009).

In recent years, the number of empirical studies investigating the effects of early mathematics interventions has increased (e.g., Clarke et al., 2014; Dyson et al., 2015; Jordan et al., 2012), and results are encouraging for students who struggle to learn mathematics. In a meta-analysis of 34 studies of early math interventions for preschool through first-grade children, Nelson and McMaster (2019) reported a moderate average weighted summary effect ($g = 0.64$; 95% CI [0.52, 0.76]). The authors also reported that 10 treatment groups received interventions that included a focus on mathematics vocabulary as part of lesson content. Interventions that included mathematics vocabulary yielded a larger average effect ($g = 0.81$; 95% CI [0.53, 1.09]) than interventions that did not include mathematics vocabulary ($g = 0.59$; $SE = 0.06$); however, differences were not significant ($p = 0.16$). Despite recent advances in developing and testing the effectiveness of early mathematics intervention programs, researchers have yet to investigate how intervention programs incorporate specific instructional strategies for teaching mathematics vocabulary. Before researchers can test and identify the most effective vocabulary instructional strategies, we must first identify how mathematics programs currently support mathematics vocabulary acquisition. Such evidence is vital to guide and extend future research, as well as support teachers with enhancing instructional practices that promote students' immediate and long-term academic success (Marulis & Neuman, 2013).

## The Relationship Between Mathematics Vocabulary and Mathematics Knowledge

Academic vocabulary is vital to students' success in school (Cunningham & Moore, 1993; Townsend & Collins, 2009). While engaging in mathematical discourse requires knowledge and skills beyond mathematics vocabulary, targeted vocabulary instruction is an appropriate focus for ensuring that young students become equipped to engage with mathematics language. Additionally, the relation between early mathematics skills and literacy (which includes understanding and applying mathematics vocabulary) emerges early. Hornburg and colleagues (2018) examined the differences in mathematics specific language compared to general language knowledge in relation to numeracy skills for typically developing children. Mathematics-specific language was significantly related to several numeracy skills, such as counting, cardinality, and comparison. This relation was above and beyond the relation between general language knowledge.

Research also documents the relation between students' proficiency with mathematics skills and understanding specific mathematics vocabulary beyond preschool-aged children (Forsyth & Powell, 2017; Peng & Lin, 2019; Powell & Nelson, 2017). For example, Powell and Nelson (2017) reported that general vocabulary and computation were significant predictors of mathematics vocabulary knowledge in first grade students. Researchers have reported similar results among fifth-grade students with and without learning difficulties (Forsyth & Powell, 2017). Additionally, Peng and Lin (2019) found that even after controlling for general vocabulary knowledge and cognitive skills, mathematics vocabulary made direct and unique contributions to word problem solving skills. Collectively, the results of previous research underscore the important relation between mathematics achievement and students' understanding of mathematics vocabulary. By learning more about how current mathematics intervention programs support students' acquisition of vocabulary, researchers and practitioners may better support students who receive intervention.

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## Recommendations for Teaching Mathematics Vocabulary

Due to research that suggests an important connection between developing mathematics knowledge and skills and mathematics vocabulary, researchers and organizations have also provided recommendations for incorporating mathematics vocabulary into instruction (e.g., Fuchs et al., 2021; Pierce & Fontaine, 2009; Riccomini et al., 2015). Best practices for vocabulary instruction in the disciplines, and in mathematics specifically, include strategically choosing words and using a variety of instructional strategies.

Purposefully identifying terms when planning lessons is one key principle of effective vocabulary instruction (Fisher & Blachowicz, 2005). Strategically selecting words allows teachers to consider necessary scaffolding, predict possible misconceptions, and design instruction that will develop connections between prior knowledge and new concepts. This is particularly important with mathematics, as many mathematics terms have general, everyday meanings, as well as discipline-specific meanings (Rubenstein & Thompson, 2002; Shanahan & Shanahan, 2008), which can make teaching and learning mathematics vocabulary challenging. While some words may be completely unfamiliar to students and represent new mathematics concepts (e.g., *addend*, *quotient*), others may have common meanings that are different from how students see them used in mathematics contexts (e.g., *join*, *odd*, *volume*; Monroe & Panchyshyn, 1995). Because of this complexity around academic words, research cautions teachers about the number of academic words chosen, as well as when and how to introduce words (Bay-Williams & Livers, 2009; Townsend et al., 2012).

Mastering academic words is more complicated than simply learning definitions (Townsend et al., 2012); thus, teachers must employ a variety of instructional strategies to promote students' word knowledge (Hancioğlu et al., 2008). Researchers have recommended several instructional practices for teaching mathematics vocabulary to all students including: provide student-friendly definitions, use explicit instruction, organize vocabulary activities around known terms, model the appropriate use of the term, discuss real-world applications, and review terms frequently across lessons to allow for multiple exposures (Monroe & Panchyshyn, 1995; Pierce & Fontaine, 2009; Riccomini et al., 2015). Additionally, active academic vocabulary practice, such as word sorts, word walls, and word journals, promotes students' engagement with and use of academic language in the content areas (Larson et al., 2013). Other recommendations for active vocabulary practice in mathematics include brainstorming and semantic mapping to pre-teach terms, using concrete experiences and materials such as mathematics manipulatives, playing games and integrating technology, and giving students opportunities to talk about mathematics (Monroe & Panchyshyn, 1995; Pierce & Fontaine, 2009; Riccomini et al., 2015). Some of the recommended strategies for incorporating discipline-specific vocabulary, such as in mathematics, have not been empirically tested to determine who they work for and under what conditions (Riccomini et al., 2015). However, recent intervention studies indicate that evidence-based strategies for vocabulary development support students in building general academic word knowledge (Lesaux et al., 2010; Snow et al., 2009; Townsend & Collins, 2009).

# Method

We used a content analysis methodology to investigate how early mathematics intervention programs incorporated mathematics vocabulary. A content analysis is "a research technique for making replicable and valid inferences from texts to the contexts of their use" (Krippendorff, 2004, p. 18). A content analysis allows researchers to sift through text in a systematic manner to identify patterns among the features of the text (Stemler, 2000). Kripendorff (2004) outlined six components of conducting a content analysis: (a) identify the segment or unit of the text that will be considered; (b) develop a sampling plan; (c) create a reliable coding scheme; (d) use the coding scheme to reduce data and efficiently represent the texts; (e) rely on the data to make inferences; and (f) respond to the research questions and explaining the implications of the results (pp. 83-87).

## Intervention Selection Criteria

We used the following inclusion and exclusion criteria for this content analysis.

1. Intervention programs were identified as effective early mathematics interventions in a previously conducted meta-analysis on early mathematics programs (Nelson & McMaster, 2019). Nelson and McMaster (2019) conducted an exhaustive search of the literature on early numeracy interventions. The authors reported searching published literature between 1980 and 2016 using electronic databases (Academic Search Premier, Education Source, ERIC, ProQuest Digital Dissertation, and PsycINFO). To

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conduct the search of the electronic databases, the authors reporting using several relevant search terms, including " early childhood, early intervention, instruction, intervention, first grade, kindergarten, math*, num*, preschool, remed*, and training (p. XX, Nelson & McMaster, 2019). Finally, Nelson and McMaster (2019) also reported searching reference lists of relevant reviews and contacting authors of previously published studies to identify other intervention programs.

2. Interventions focused on early mathematics content, specifically on early number skills including: counting, comparison, quantity, simple addition and subtraction, number line sequences, number identification, number relations, and place value.
3. Interventions were specifically designed for kindergarten and first-grade students.
4. Programs were developed by researchers in the United States.
5. Intervention programs needed to be available for purchase. We excluded intervention programs that were not widely available (i.e., they were not available for purchase; e.g., Hassinger-Das et al., 2015) to teachers or researchers. The reason for this inclusion criteria was that we needed to access all lesson plans to complete the coding for the content analysis.
6. Programs were available in English.

Based on these selection criteria, we identified three kindergarten and four first-grade early mathematics intervention programs for this content analysis, which are briefly described below. Please see Supplementary files for additional information about each of the included intervention programs.

## Kindergarten Interventions

The *Number Sense Interventions* program (Jordan & Dyson, 2014) focused on whole number concepts related to counting, comparing, and manipulating sets. The *Peer-Assisted Learning Strategies – Kindergarten (PALS-K)* program (Fuchs et al., 2011b) focused on numeral recognition, number concepts, and the mental number line. The *Whole Number Foundations Level K*™ (*WNF-K*) program (Davis & Jungjohann, 2014) focused on whole number procedural fluency and conceptual understanding.

## First Grade Interventions

The *Early Numeracy Intervention-Level 1 (ENI)* program (ENI; Bryant et al., 2015) focused on number knowledge and relationships, operations, and problem solving. The *Number Rockets* program (Fuchs et al., 2018) focused on identifying and writing numerals, identifying quantities that are more and less, number sequencing, counting, place value, and addition and subtraction. The *Peer-Assisted Learning Strategies – First Grade (PALS-1)* program (Fuchs et al., 2011a) emphasized place value, number concepts, and addition and subtraction. The *Whole Number Foundations Level 1*™ (*WNF-1*) program (Jungjohann & Doabler, 2014) focused on number combinations, place value, computation, and word problem-solving.

## Coding Procedures

We purchased each intervention program in order to have access to the full sequence of lesson plans and accompanying student materials. To conduct the content analysis, we coded each individual lesson for all intervention programs. All intervention programs include academic language specific to the early mathematics content; therefore, we coded all lessons for potential teacher and student actions related to mathematics vocabulary instruction and application (as outlined in the lesson scripts). We recorded if lessons explicitly or implicitly identified vocabulary terms.

Throughout the coding procedures, results, and discussion of this study, we refer to lessons with an *explicit* or *implicit* focus on vocabulary terms. We did not make the decision to differentiate between implicit and explicit vocabulary until we received all programs. Not all programs matched their descriptions in the literature related to mathematics vocabulary (i.e., a program described as teaching mathematics vocabulary did not have a vocabulary list, and programs that had vocabulary lists did not specify this in research publications under the description of the intervention). Upon reviewing the materials, we noticed that some programs included specific vocabulary lists (which we refer to hereafter as *explicit* vocabulary lessons), while other programs did not (which we refer to as *implicit* vocabulary lessons). The purpose of this content analysis was to provide an overview of instructional strategies used to teach mathematics vocabulary, regardless of whether the programs listed vocabulary terms.

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### *Suggested Teacher Actions Related to Vocabulary Instruction*

Best practices for vocabulary instruction in the disciplines include using a variety of instructional strategies, and previous research reports a significant difference across curriculum programs according to the number of instructional strategies used to teach mathematics vocabulary (Barnes & Stephens, 2019). Thus, we coded interventions for how lessons suggested that teachers support student learning of mathematics vocabulary terms, as well as how the lessons instructed the teachers to use the mathematics terms. Variables were chosen based on recommendations for teaching vocabulary (Fisher & Blachowicz, 2005; Monroe & Panchyshyn, 1995; Pierce & Fontaine, 2009; Riccomini et al., 2015; Vukovic & Lesaux, 2013).

We coded each lesson for how teachers may support student learning of the explicit and implicit mathematics vocabulary terms we identified in the programs. To do this, we reviewed the scripted portion of the lessons, as well as sections of the lessons that may have outlined suggested actions for the teachers (e.g., "show count sequence on fingers as you count verbally"). Table 1 provides a summary of each suggested teacher action we coded.

### *Student Opportunities for Vocabulary*

Our coding also included the type of student opportunities for vocabulary use in each intervention program. We coded for student opportunities based on recommendations from previous researchers (Monroe & Panchyshyn, 1995; Pierce & Fontaine, 2009; Riccomini et al., 2015). Student opportunities were coded as assumptions of students' responses or actions in reference to the directions the teachers gave. For example, if the lesson read as, "Today we are focusing on addition. Turn to your partner and tell them what you think the definition of addition is," we coded "yes" for the student opportunity, "students have the opportunity to write/state their own definition" because the lesson implied students would have the opportunity to engage in this practice. Table 2 provides a summary of the types of student opportunities to use mathematics vocabulary terms that we identified from the programs in this study.

### *Instructional Tools for Vocabulary Introduction and Practice*

We were also interested in the types of instructional tools that intervention programs included to introduce and practice mathematics vocabulary. We coded these instructional tools for teaching vocabulary based on guidelines from previous researchers (Monroe & Panchyshyn, 1995; Pierce & Fontaine, 2009; Riccomini et al., 2015). We coded each lesson for the presence of the following activities specifically related to teaching mathematics vocabulary: writing activities, dictionary consultations, concrete or physical manipulatives, pictorial representations, prompts for students to draw pictures, picture to term matching, and mnemonics.

## Conducting the Content Analysis

To conduct this content analysis we followed the steps outlined by Krippendorff (2004) by (a) identifying intervention lessons as our unit of text analysis; (b) selecting intervention selection criteria that would be easily replicated by other researchers and allow for appropriate generalization of the results (see Intervention Selection Criteria); and (c) creating a reliable coding scheme based on features of effective vocabulary instruction (see Coding Procedures). Based on the coding scheme and coding of the lesson plans, we identified features of vocabulary instruction that were present in each of the lessons. We coded the lessons using a database in Excel. Each variable for every lesson (see Tables 1 and 2) received a code of 0 for not present (e.g., no instance of lesson providing a definition of mathematics vocabulary terms), and 1 for present (e.g., at least one instance of the lesson providing a definition of a mathematics vocabulary term). By coding the lessons with scores of 0 and 1 we were able to (d) efficiently identify patterns of instructional features of the lesson plans. For all research questions, we calculated frequencies (present, not present), means, and standard deviations for the different teacher and student vocabulary variables we coded in this study. Based on the frequency with which patterns in the lesson plans were present, we then (e, f) made inferences that allowed us to answer research questions about how early mathematics interventions support learning of mathematics vocabulary.

## Coder Training and Coder Agreement

The first author trained five research assistants (RAs) to assist with the coding. Four RAs were college juniors or seniors majoring in psychology; all had previous research experience working on psychology research projects with human subjects. The fifth RA was a third-grade teacher pursuing a master's degree in literacy and did not have previous research experience. The training included requiring the RAs to read and discuss two journal articles that

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were focused on early mathematics interventions, reviewing the coding protocol, and reviewing an additional supporting document that provided explanations and definitions of concepts (e.g., examples of how a script may suggest students use the term while communicating with peers). After the 2-hour initial training, each RA completed between 15 and 20 practice lessons. The first author compared each RA's codes to her own codes and then met individually with the RA to discuss the discrepancies. Each RA met at least 90% agreement on the practice lessons before independently coding. Then, 20% of randomly selected lessons were double-coded to determine interrater agreement of the coding protocol, which was calculated as: [agreements ÷ (agreements + disagreements) × 100]. The first author and RAs held in-person meetings to discuss discrepancies and to determine the final code prior to analyses. For example, the most commonly disagreed upon code was for the student action "students have the opportunity to apply or practice the meaning of the term." During the meetings to discuss the discrepancies, the coder who selected "yes" for this code identified the part of the lesson that they used to determine that this opportunity was present. The coders reviewed the section together and referred to the definition and examples in the code book to determine if the lesson should receive a code of "yes." The average interrater agreement was 85.5%.

## Results

In this section, we present the results of the content analysis of mathematics vocabulary included in kindergarten and first-grade mathematics intervention programs. Across programs, we coded a total of 360 lessons. There were 90 kindergarten lessons and 270 first-grade lessons. The programs varied in the total number of lessons, ranging from 16 lessons to 138 total lessons.

### Research Question 1: Instructional Strategies Used to Teach Mathematics Vocabulary

We were interested in exploring how early mathematics intervention programs suggested that teachers use actions and verbalizations for teaching mathematics vocabulary terms, how the programs provided student opportunities for practice, and which instructional tools.

Table 3 shows the results focused on suggested teacher actions and verbalizations for all lessons, as well as differentiated by program type. Fewer than 50 total lessons (13.3%) included instructions for teachers to activate prior knowledge regarding a mathematics vocabulary term before teaching the term. Only one of these instances was in an implicit vocabulary program. Few lessons (1.4%) included student-friendly non-examples while introducing a mathematics vocabulary term, and none of lessons prompted teachers to teach students the root word of a mathematics vocabulary term.

We were also interested in investigating how programs incorporated student opportunities to engage with mathematics vocabulary terms (also presented in Table 3). Results were mostly similar across explicit and implicit vocabulary programs. One difference that emerged related to requiring students' responses to questions to incorporate the vocabulary terms. Nearly half (44.7%) of all lessons required this student action, while more explicit vocabulary programs (51.2%) required students to verbally respond with the mathematics term than did implicit vocabulary programs (31.3%). Nearly all lessons (94.7%) required students to apply the meaning of the mathematics terms, usually through practice opportunities within the lesson that were unrelated to focusing on vocabulary (e.g., "find the set that has the *greatest* number of blocks"). For the other potential student actions that we coded, none occurred in more than 11% of lessons, regardless of the program type.

Finally, we investigated the instructional tools that were incorporated into the lessons to provide students with practice opportunities. Many lessons included either concrete or pictorial representations while introducing or applying mathematics vocabulary terms (66.4%). In contrast, all other instructional tools were present in fewer than 3.3% of all lessons.

### Research Question 2: How Mathematics Vocabulary Terms are Defined

We investigated if terms were listed for interventionists, were included in intervention lesson objectives, were clearly defined within the lesson or passively introduced to students, and were student-friendly. Three of the seven programs, including 248 of the 360 total lessons, plainly listed terms for interventionists as part of the lesson content (*Early Numeracy Intervention*; *WNF-K*; *WNF-1*). The remaining 112 lessons represented the four implicit vocabulary programs that did not specifically list mathematics.

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Although many lesson objectives included mathematics vocabulary words (e.g., "teach *plus 1* strategy"), few lesson objectives (5.8%) specifically mentioned teaching the *definition* of the mathematics vocabulary terms (e.g., "students will define *plus*"). In other words, lessons used mathematics vocabulary terms in the objectives to describe teaching mathematics knowledge and skills, but lesson objectives were generally not directly focused on teaching mathematics vocabulary. Of the 248 lessons that listed mathematics vocabulary terms for the teacher, 32.3% clearly defined mathematics vocabulary terms within the script. Of the 112 lessons that did not list mathematics vocabulary terms, 24.1% clearly defined mathematics vocabulary terms as part of the teacher script (for an approximate total of 29.7% of all lessons). Approximately 25.8% of all lessons included *student-friendly* definitions; meaning that not all lessons that provided an explicit definition were student-friendly. Thus, the majority of lessons only passively used mathematics vocabulary terms within the teacher script, regardless of whether the lessons listed mathematics vocabulary as part of the lesson content.

## Discussion

The purpose of this study was to investigate how early mathematics content interventions support mathematics vocabulary acquisition and identify practices that teachers may use to provide support for vocabulary. The results of this study add to the evidence base related to mathematics vocabulary instruction and contribute recommendations for teachers regarding how to enhance vocabulary learning opportunities within mathematics interventions and beyond. More specifically, our results indicate that some instructional approaches recommended from previous research are evidenced in readily available intervention programs. However, some are not, thus offering useful information to teachers and researchers about ways that mathematics vocabulary instruction may be enhanced.

### How Intervention Programs Support Mathematics Vocabulary

We identified how early mathematics intervention programs suggested teacher actions and verbalizations. Riccomini e t al. (2015) recommend that teachers use explicit instruction to teach mathematics vocabulary terms, and one of the components of explicit instruction that the authors recommend is to connect new words with prior knowledge. Yet, the results of our content analysis indicate that about 13.3% of lessons in explicit mathematics vocabulary programs prompted teachers to activate students' prior knowledge. Another component of explicit instruction involves using non-examples to teach students concepts; though only 5 total lessons (1.4%) in our content analysis included non-examples.

Connecting words to prior knowledge and discussing non-examples are particularly important practices related to mathematics vocabulary instruction. Many mathematics terms have both everyday meanings and meanings that are specific to the mathematics contexts (Shanahan & Shanahan, 2008). This means that activating students' prior knowledge of words can support their understanding of new concepts, as well as provide teachers with opportunities to discuss misconceptions. Non-examples of mathematics vocabulary terms, then, will also enhance a student's ability to apply new terms. Previous research highlights the effectiveness of components of explicit instruction (e.g. use of prior knowledge and non-examples) for students who struggle to learn mathematics (Fuchs et al., 2021); therefore, teachers may need to identify moments within mathematics intervention lessons to provide students with opportunities to make connections between new terms and known concepts and chances to work with non-examples.

We also identified how early mathematics intervention programs allow students to engage with mathematics vocabulary terms. An encouraging result is that almost all lessons provided students with opportunities to apply the meaning of the mathematics term, usually through practice opportunities related to mathematics knowledge and skills (e.g., solving word problems, computation, number comparison, number knowledge). However, we discussed previously that only 29.7% of lessons actually defined mathematics terms as part of the teacher script. So, even though most lessons provided students with opportunities to practice or apply their understanding of a term, students who do not receive explicit instruction on the definition of the term may not be practicing or applying the term to their full potential. In other words, we are left wondering if a student can appropriately apply the meaning of a term without knowing first if the student understands the definition of the term. The varying dimensions of word knowledge (Nagy & Scott, 2000) are impacted by the way teachers instruct students on and have them practice with words. When considering knowing mathematics words in depth, or having a rich semantic representation of the word, the level at which students are able to apply their knowledge of the word corresponds to the depth of knowledge they have around the word. However, it is also important to mention that the results of our content analysis refer only to the scripts as they are written, not necessarily what happens in practice as lessons are implemented.

Regarding instructional tools, none of the lessons used mnemonics, and only one lesson required students to consult a glossary. Although previous researchers have recommended both strategies (Monroe & Panchyshyn, 1995; Riccomini et al., 2015), perhaps these strategies were not as prevalent given that research indicates that *active processing* is typically more beneficial than looking up the definition of target words (Wright & Cervetti, 2016). It is promising that more than half of all lessons used either concrete or pictorial representations while students had opportunities to practice or apply the meaning of vocabulary terms. Active vocabulary practice supports students in both understanding and applying new words (Larson et al., 2013). Unfortunately, active practice discussing terms with peers, which aids students in personalizing word meanings, was minimal in the interventions we reviewed. Providing multiple and varied opportunities to work with words, both alone and with peers, is essential to learning new words (Fisher & Blachowicz, 2005).

## Ways in Which Mathematics Interventions Define Mathematics Vocabulary

With our second research question, we identified how mathematics intervention lessons defined mathematics vocabulary terms. Although 248 lessons clearly listed mathematics vocabulary terms as part of the lesson, less than a third of these lessons defined the mathematics vocabulary terms as part of the lesson. Our results also indicated that only 25.8% of all lessons included student-friendly definitions.

When considering teacher preparation for and implementation of research-based vocabulary instruction, we found this result concerning for several reasons. First, although mathematics interventions list vocabulary terms as part of the lessons, teachers may also need guidance on when and how to introduce or define the terms (i.e. the lessons may have a specific time or specific language that will be most impactful). In one study on academic language in the disciplines, secondary teachers showed only general understandings of academic language (Carter et al., 2016). After a full year of professional learning on supporting students' academic language development in the disciplines, teachers' understanding of academic language deepened and the importance they placed on academic language across the disciplines increased. It is unlikely that each early childhood or elementary teacher has been involved in this type of professional learning initiative, and it is unreasonable to assume they are ready to employ research-based vocabulary practices without it.

Second, if the lessons do not contain a script for teachers to introduce or practice the mathematics vocabulary term, the chance that the teacher will introduce the term may be lowered (e.g., the teacher may not realize the term is important or needs to be defined). Thus, the chances the students will learn and apply those terms accurately (or at all) may also be lowered. This concern is reinforced by the finding that fewer than 6% of all lessons included a learning objective for students related to defining the mathematics vocabulary terms. Research on vocabulary instruction notes the importance of when and how to introduce new and unfamiliar words to students (Bay-Williams & Livers, 2009; Townsend et al., 2012). As the majority of lessons only passively used mathematics vocabulary terms within the lesson, the action of supplying teachers with a list of the mathematics vocabulary terms may not be adequate in terms of providing students with opportunities to learn and apply correct mathematics vocabulary. Future development of mathematics intervention programs may consider revising how mathematics vocabulary terms are defined within lessons, as well what information is provided for teachers on introducing these terms.

Finally, the result indicating that not all lessons provided definitions that were student-friendly definitions was contradictory to recommendations for practice (Pierce & Fontaine, 2009; Townsend & Collins, 2009). For students who receive intervention, definitions provided in language that is friendly may be necessary for them to access the term's meaning and how to apply it. If teachers recognize that the definitions provided to them in the lesson scripts are unfriendly, teachers may consider rephrasing definitions to allow all students to access the content.

## Implications for Practice

The results of this study provide several implications for practitioners who use or design mathematics intervention programs. First, teachers should be aware that even if mathematics intervention programs *list* mathematics vocabulary terms as part of the targeted skills within the lesson, this does not ensure that the teacher scripts adequately provide students with opportunities to learn student-friendly definitions, communicate using the vocabulary terms, identify similar and unlike terms, and so on. Teachers may need to evaluate the degree to which programs and individual lessons support students' learning and understanding of mathematics vocabulary. This is also true for those classroom teachers who may supervise other staff (e.g., paraprofessionals) in their implementation of interventions. Staff who have less training in mathematics may need additional support to identify methods to enhance learning opportunities.

Second, teachers may also need to supplement intervention sessions by adding brief vocabulary instructional activities for students, while maintaining fidelity to the lesson. For example, teachers may start each lesson with a short game that pre-teaches vocabulary for that lesson, coordinate vocabulary terms and instruction across classroom and intervention settings (i.e., with general education teachers who teach regular mathematics class), and create more opportunities within the lesson for students to communicate about mathematics (Nelson et al., 2020). Finally, teachers may want to consider monitoring student understanding of mathematics vocabulary terms through formative assessment (e.g., exit tickets). Teachers can use this information to re-teach or provide additional practice opportunities with mathematics vocabulary terms that may hinder a student's progress in mastering the mathematics intervention lesson content, as well as student performance on classroom and high-stakes tests.

It is also important to note that each of the programs we selected for this content review has previously been identified as an effective program for promoting mathematics knowledge and skills for kindergarten and first-grade students; some intervention studies have reported large effects for students with mathematics difficulty. The purpose of this content analysis was to determine the types of instructional strategies present in these programs; yet, more research needs to be conducted to further examine how incorporating more (or different) mathematics vocabulary instructional strategies enhances students' learning during intervention. More specifically, design-based research projects might offer teachers a systematic way to plan, implement, and track their instruction and student progress, as related to exploring specific ways vocabulary can be more explicitly highlighted in interventions.

## Limitations and Future Research

There are some limitations of this study that may be addressed by future research. First, we only considered kindergarten and first-grade mathematics programs; second, we did not code every possible kindergarten and first-grade early mathematics program available to teachers. For both these reasons, the results of this study may be difficult to generalize to other mathematics programs, including mathematics intervention programs that are teacher-developed, are printed in languages other than English, and were developed by researchers in countries other than the United States. Future research may address this limitation by including other programs, as well as focusing on different grade levels. Researchers may also consider broadening the research focus on academic vocabulary and explore the use of vocabulary in other content areas such as reading and science, and consider investigating other programs that were not easily accessible for this review.

Third, because our coding scheme was primarily based on recommendations for teaching academic vocabulary, our coding scheme may not have accurately captured the instructional strategies used in the four programs that did not have an explicit focus on mathematics vocabulary (i.e., *PALS-K*, *PALS-1*, *Number Rockets*, *Number Sense Interventions*). Future research may consider coding for other components of vocabulary instruction in intervention programs that we did not consider in this content analysis, such as, synonyms to teach new terms (Barnes & Stephens, 2019), explicit procedures for introducing terms, and games (Riccomini et al., 2015).

Finally, the results of our coding may be limited by the fact that the RAs were not experts in mathematics intervention. Although the first author (a) trained the RAs to use the coding coding protocol, (b) conducted a reliability check of 20% of the lessons, and (c) met with the RAs regularly, the coding process could have been strengthened by using RAs with specific mathematics intervention expertise.

Future researchers may also consider examining instructional strategies and tools according to the technical difficulty of vocabulary terms (Rubenstein & Thompson, 2002). We used the vocabulary lists from the explicit programs as a reference for mathematics vocabulary terms; therefore, our results should be interpreted with caution as they may not generalize to other mathematics terms, such as informal terms that may not have been identified in the programs as mathematics vocabulary terms. Future researchers may consider conducting content analyses that also focus on identifying informal mathematics terms, as well as the instructional strategies used to introduce and practice those terms.

## Conclusion

The results of this study add to the growing body of research on the importance of mathematics vocabulary in learning mathematics knowledge. Teachers should consider how scripted lessons support, or do not support, students' understanding of mathematics vocabulary. Mastering mathematics content includes being proficient in communicating about mathematics, which requires an understanding of how to use and apply common mathematics vocabulary terms.

Researchers may also want to consider how to enhance mathematics intervention programs to increase opportunities for students who receive intervention to learn and practice important vocabulary terms. Success with mathematics in the school-age years has several implications for adulthood outcomes; thus, it is critical that researchers and practitioners understand how to improve students' performance in all areas of mathematics.

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**Table 1**

*Coding Protocol: Suggested Teacher Actions Used to Teach Mathematics Vocabulary Terms*

| Suggested Teacher Actions | Definition and Example(s) |
|---|---|
| Use student-friendly definitions to introduce terms. | Lesson script asks teachers to explain the meaning of the word in everyday language or depict how the word is typically used. |
| Teach the root words. | The lesson script asks teachers to teach the meaning of “tri” and “angle” prior to teaching the term “triangle.” |
| Use student-friendly non-examples when defining the term. | When introducing the term, teachers provide counterexamples or non-examples for comparison. |
| Activate students’ prior knowledge to teach terms. | The lesson script includes teachers encouraging the use of brainstorming or semantic mapping. |
| Scripts repeat mathematics vocabulary terms across several lessons. | Mathematics terms are used across multiple lessons. |

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**Table 2**

*Coding Protocol: Student Opportunities to Use Mathematics Vocabulary*

| Potential Student Actions or Opportunities | Definition or Example(s) |
|---|---|
| Respond to the intervention script. | Based on the wording of the intervention script, student responses required students to verbally state the vocabulary term. |
| Use the term with other students. | Students use the term when communicating with other students (e.g., turn to your partner and say the word "addition"). |
| Make a real-world connection or example. | Students make an authentic connection to the term (e.g., when asked, "what is a real-world example of a number line?" students have the opportunity to respond, "calendar, thermometer, etc."). |
| Write/state their own definition. | Students create their own definitions (e.g., written, stating orally, with pictures) before the teacher gives the definition. |
| Identify similar examples of terms or alternate definitions. | Students create alternate or similar definitions based on the definition provided by the teacher. |
| Identify non-examples. | Students identify counter-examples and non-examples of the term or the definition. |
| Apply/practice the meaning of the term. | Lesson activities or materials (e.g., worksheets) require students to use, apply, or practice mathematics terms and definitions (e.g., extended opportunity to use the term). |
| Engage in brainstorming, making estimates about terms, or activating prior knowledge. | Students engage in activating prior knowledge about the mathematics term, prior to the term being introduced or defined. |

**Table 3**

*Results for Potential Teacher and Student Actions and Instructional Tools According to Program Type*

| | All Lessons (max = 360) | | Explicit Vocab (max = 248) | | Implicit Vocab (max = 112) | |
|---|---|---|---|---|---|---|
| | *N* | % | *N* | %[a] | *N* | %[a] |
| **Suggested Teacher Actions** | | | | | | |
| Provide student-friendly definitions | 93 | 25.8% | 73 | 29.4% | 20 | 17.9% |
| Activate prior knowledge | 48 | 13.3% | 47 | 18.9% | 1 | < 1% |
| Include student-friendly non-examples | 5 | 1.4% | 5 | 2.0% | 0 | 0% |
| Teach the root words | 0 | 0% | 0 | 0% | 0 | 0% |
| **Potential Student Actions** | | | | | | |
| Apply/practice the meaning of the term | 341 | 94.7% | 242 | 97.6% | 100 | 89.3% |
| Respond using the term | 161 | 44.7% | 127 | 51.2% | 35 | 31.3% |
| Write/state their own definition | 38 | 10.6% | 26 | 10.5% | 12 | 10.7% |
| Use the term with other students | 37 | 10.3% | 25 | 10.1% | 12 | 10.7% |
| Identify similar examples of terms, or alternate definitions | 15 | 4.2% | 13 | 5.2% | 2 | 1.8% |
| Identify counter examples, or opposite terms | 6 | 1.7% | 4 | 1.6% | 2 | 1.8% |
| Brainstorm, make estimates about terms | 6 | 1.67% | 6 | 2.4% | 0 | 0% |
| **Instructional Tools** | | | | | | |
| Pictorial representations | 158 | 43.9% | 100 | 40.3% | 58 | 51.8% |
| Concrete representations | 136 | 43.9% | 45 | 40.2% | 92 | 37.1% |
| Pictorial or concrete representations | 239 | 66.4% | 160 | 64.5% | 79 | 70.5% |
| Drawings and pictures | 12 | 3.3% | 6 | 2.4% | 6 | 5.4% |
| Journal or writing activities | 12 | 3.3% | 11 | 4.4% | 1 | < 1% |
| Picture and word matching | 3 | < 1% | 3 | 1.2% | 0 | 0% |
| Dictionary or glossary consultation | 1 | < 1% | 1 | < 1% | 0 | 0% |
| Mnemonics | 0 | 0% | 0 | 0% | 0 | 0% |

Note. Vocab = vocabulary.

[a] Percentages calculated based on the total number of lessons per program type (vocabulary terms explicitly listed in intervention lessons; no vocabulary terms listed in intervention scripts)