THE KEY TO ENHANCING STUDENTS' MATHEMATICAL VOCABULARY KNOWLEDGE

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ABSTRACT

The importance of learning mathematical vocabulary is vital for the development of proficiency in mathematics. In an effort to improve students' mathematical performance, educators must use research-validated instructional methods to teach important mathematical vocabulary. Mnemonic instruction is a set of evidenced-based strategies used to improve achievement and attitudes toward learning by helping students connect new information to prior knowledge. One especially effective mnemonic instructional approach is the keyword strategy. Using a keyword strategy, students connect familiar words with new vocabulary words and an illustration to help learn the new vocabulary word meanings. The purpose of this article is to describe the instructional procedures required to implement the keyword strategy to improve learning of essential mathematical vocabulary.

Keywords: Instructional Strategy, Scaffolded instruction, Mathematics, Mathematical vocabulary, Mnemonics, Keyword strategy, Strategy instruction.

INTRODUCTION

Proficiency in mathematics depends on a continuous growth and blend of intricate combinations of critical component skills (e.g., concepts, procedures, algorithms, computation). The National Research Council (2001) explains proficiency in mathematics with five interconnected strands: (a) understanding mathematics, (b) computing fluently, (c) applying concepts to solve problems, (d) reasoning logically, and (e) engaging with mathematics. Within each strand numerous concepts, procedures, algorithms, and computations are important for students to learn, understand, and connect. But, mathematics is also a language (Miller, 1993; Raiker, 2002; Wakefield 2000); therefore, proficiency in mathematics also requires learners to develop the ability to communicate and comprehend the language used in mathematics.

Learning and using the language of mathematics, as with language in general, is essential and greatly dependent on vocabulary knowledge (Baker, Simmons, & Kame'enui, 1997). Technical vocabulary (e.g., congruent, vertex) and symbols (e.g., $\leq$, ¶, $\neq$) in mathematics are used early and continue throughout the course of study. It is estimated between 500 and 600 technical mathematics terms and symbols are introduced to students by the fourth grade (Wilmon, 1971). Considering the mathematics reforms over the last decade and heavy emphasis on mathematics as a language (Adams, 2003) the impact of vocabulary on student mathematical performance is potentially substantial.

Adding to the challenge of learning mathematics vocabulary, many terms are not frequently used in general conversations outside of math class. For example, *subtrahend* and *minuend* do not often appear in common conversation. When a mathematics term is used in common conversation, often the meaning associated with the term is very different than the mathematical meaning, further complicating the learning of mathematics. For example, *cone* in common conversation most likely refers to the sweet crunchy food that holds ice cream; but in mathematics, a *cone* is a solid shape with a circular base and a curved surface that tapers to a point. Considering the importance of communicating and comprehending the language of mathematics, it seems evident that limitations in student vocabulary capacity can negatively affect mathematical proficiency. Clearly, vocabulary recognition and knowledge are vital components for children to become mathematically proficient and mathematics instruction must include time devoted to vocabulary instruction.

1. The Importance of Learning Mathematics Vocabulary

Developing comprehensive vocabulary knowledge is essential to become a successful learner and user of mathematics. Students need to both understand and use mathematical words and phrases if they are to make good progress. Students lacking key vocabulary cannot communicate mathematical concepts and procedures correctly and will likely struggle to make important connections within and between concepts. If students lack fundamental vocabulary such as *parts*, *units*, or *numerical difference*, progress in understanding these and other future areas of mathematical knowledge may be slow and difficult. Proficient mathematicians have a thorough understanding of mathematical terminology and their connections to the other important mathematical concepts and procedures. Knowledge of mathematical vocabulary cannot be separated from overall conceptual understanding and helps to structure the foundation for students to communicate and fully comprehend the language of mathematics.

The importance of learning vocabulary is well recognized in the area of reading and identified as a big idea by the National Reading Panel (2000). Unfortunately, the significance of students learning mathematical vocabulary is often underestimated and overlooked during math instruction (Garbe, 1985; Greenwood, 2002; Monroe & Orme, 2002). Access to important and new word meanings (e.g., numerator and denominator) used during instruction is essential for the learning and connection of new information (Baker et al., 1997). Vocabulary development is crucial to the mathematical proficiency of students; yet, many students struggle to learn even basic vocabulary required for success (Greenwood, 2002; Jones, 2002; Miller, 1993; Rubenstein & Thompson, 2002; Sanders, 2007).

While there are many plausible explanations and causes for poor mathematical performance, one explanation that is often overlooked, but particularly compelling, is the difficulties students experience when attempting to learn numerous and technical vocabulary terms. The development and implementation of evidence-based instructional activities that enrich essential and critical vocabulary knowledge necessary for mathematical proficiency is required to improve overall mathematical understanding and promotion for all students. The purpose of this article is to describe the instructional procedures for an evidence-based strategy used to improve essential mathematical vocabulary across varying types of learners.

2. Mnemonic Strategies

Mnemonic instruction refers to a number of different but related evidenced-based practices used to improve achievement and attitudes toward learning by helping students connect new information to their prior knowledge (Mastropieri & Scruggs, 2006). The various instructional practices used in mnemonic strategies are based on almost 30 years of educational research completed with diverse learners and across multiple content areas. In addition to enhancing the academic performance of low-performing as well as average and above average-achieving students, students with disabilities also benefit from mnemonic instruction (Kavale & Forness, 1999). Overwhelmingly positive evidence exists for using mnemonic instructional strategies to teach essential content vocabulary to students with disabilities in inclusive settings (e.g., Mastropieri, Scruggs, & Fulk, 1990; Scruggs & Mastropieri, 2000; Sanders, 2007); further necessitating the use of mnemonic instruction in mathematics classrooms.

Typically, mnemonic strategies help students to learn and remember new and important information (e.g., object characteristics, steps in a procedure, vocabulary) through a mnemonic device that purposefully connects the new information to information already familiar to the student. The letter, pegword, and keyword strategies are examples of specific instructional practices under the umbrella of mnemonics instruction. A commonly used letter strategy by mathematics teachers to help students to remember the order of operations when solving problems containing more than two arithmetic operations (e.g., +, -, x, ÷) is the phrase: *"Please Excuse My Dear Aunt Sally."* In this phrase, the first letter of each word represents an operation which could be explained as (a) *Parentheses* of brackets first (starting with the innermost), (b) *Exponents* or powers next, (c) *Multiplications* and *Divisions* next, and (d) *Additions* and *Subtractions* last.

A common pegword strategy to promote memorization of basic facts matches a rhyming word with a number and then forms a sentence to help students remember the answer. To practice, a student recites the math fact immediately followed by the corresponding word sentence. For example, to help students to remember the math fact 4 x 8 = 32, the words *door*, *gate,* and *dirty shoes* are matched with the numbers 4, 8, and 32, respectively. Then, the math fact, 4 x 8 = 32, is matched and read with the sentence: *Door in gate has dirty shoes* (see Mastropieri & Scruggs, 1991; Mastropieri & Scruggs, 2006). By linking the word phrase to the math fact, students are better able to remember the math fact in the future.

In one of the most effective and most powerful mnemonic instructional methods, the keyword strategy, students are taught meanings of new vocabulary terms by selecting a similar sounding word and a picture, drawing, or computer graphic that represents the essential information to learn (Atkinson, 1975; Kavale & Forness, 1999; Mastropieri & Scruggs, 2006). To date, numerous uses of the keyword strategy to learn vocabulary terms in foreign languages, social studies, history, and science have been included in the mnemonic research; unfortunately, few mathematics specific examples are available (Sanders, Riccomini, & Witzel, 2007). Therefore, the instructional procedures and specific examples of the keyword strategy developed with mathematics vocabulary are described next.

3. Using the Keyword Strategy to Teach Mathematics Vocabulary

The keyword mnemonic strategy is an evidenced-based instructional strategy to supplement and enhance traditional vocabulary instruction on essential and often difficult to learn vocabulary in math. There are four main steps to consider when supplementing mathematics instruction with the keyword strategy: (a) select important and difficult to learn vocabulary, (b) create the keyword mnemonics, (c) incorporate into math instruction, and (d) plan systematic and spaced review using the developed keyword mnemonics.

3.1 Select important vocabulary

Teachers can develop a list of important vocabulary that students must learn throughout the year. Given the volume of terms at any given grade level, teachers are better served to organize key terms either by unit or category. To help teachers with this daunting task, many states now have vocabulary word lists arranged by grade level. After developing the initial list based on state standards or state created lists, teachers must then review their mathematics curriculum to examine consistency of the textbooks. A good match may or may not exist. Regardless of the correspondence, teachers must decide which are the most important terms as well as which terms will cause the most difficulty. It is from this scaled down list that teachers can begin to develop the keyword mnemonics for each term.

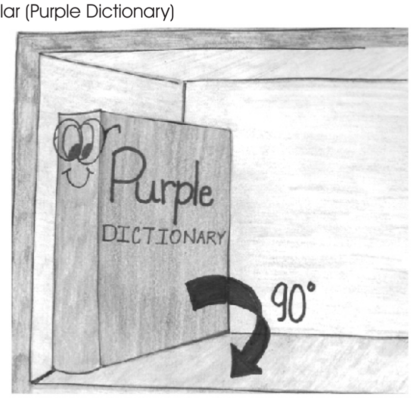
3.2 Create keyword mnemonics

Creating the keyword mnemonics is the most challenging aspect of using the strategy. Using the identified list of essential math vocabulary for students to learn, a three step process is used to create a mnemonic strategy for each word: (a) Recode, (b) Relate, and (c) Retrieve (see & Scruggs & Mastropieri, 2002). The first step is to recode the target word to an acoustically similar, but familiar word or keyword. For example, the word *perpendicular* is linked to the keyword or phrase *purple dictionary.* The keyword phrase is composed of two words that are familiar to the students. The next step is to relate the keyword phrase in an interactive picture with the important information (e.g., definition) targeted for learning. In this case, students must learn that perpendicular means two lines intersecting at a 90 degree angle. The final step is to help the students to retrieve the important information by describing the picture in a sentence to help strengthen the connection to the picture and definition of the target vocabulary. In this example the descriptive sentence was *The purple dictionary is sitting on the shelf at a 90 degree angle. It is perpendicular to the bookshelf.* Figure 1 refers to the keyword mnemonic for 'perpendicular'.

The three step process is again illustrated for the mathematical term *ray.* First, recode the target term to the keyword phrase *run away.* Next, an interactive picture is created to link the target vocabulary word, *ray,* with the keyword phrase *run away*. The picture in Figure 2 depicts a boy running above the symbol of a ray. The connection between the target word, keyword phrase, and picture is further strengthened with a descriptive sentence, *Run away Ray! Ray started running at point A and never stopped running. He is a ray.* This keyword mnemonic is designed to help students remember that a ray is a line with a starting point and no endpoint which is usually depicted with the symbol of a line with a point on one end and an arrow on the opposite end. The three step process of recoding, relating, and retrieving allows students to connect the new and unknown word with a more familiar word or phrase increasing the likelihood for recall. A keyword mnemonic is also presented in Figure 3, for the term *parallel.*

Regardless of the vocabulary selected, the steps for creating a keyword mnemonic are the same. Teachers can create and provide the keyword mnemonics for the students or students can create their own. However,

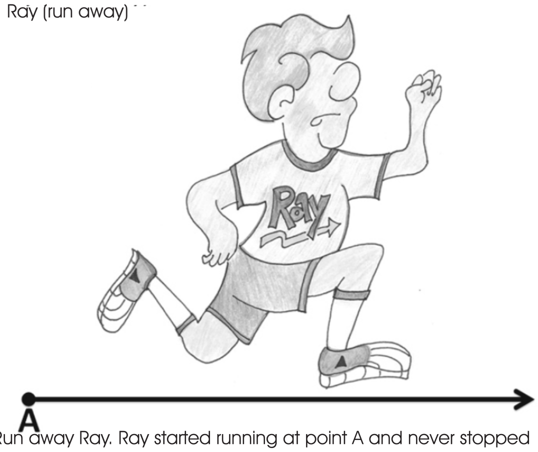
Perpendicular (Purple Dictionary)



The purple dictionary is sitting on the shelf at a 90 degree angle.
It is perpendicular to the bookshelf.

Figure 1. Keyword Mnemonic for 'Perpendicular'

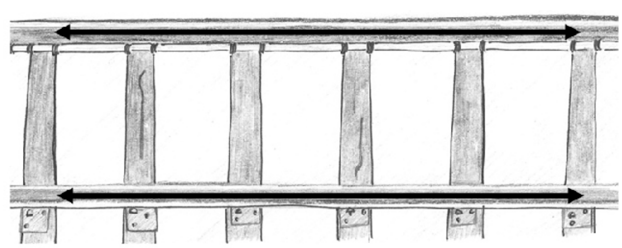
Ray (run away)



Run away Ray. Ray started running at point A and never stopped running. He is a Ray!

Figure 2. Keyword Mnemonic for 'Ray'

Parallel (pair of rails)



The pair of rails on railroad tracks will never intersect because they are the same distance apart. They are parallel.

Figure 3. Keyword Mnemonic for 'Parallel'

students will require a great deal of practice before they are able to create their own keyword mnemonics. Although this step is time consuming, once the keyword mnemonic is created, it can be used again and again. This allows teachers to build a collection of important vocabulary for use in subsequent schools years. The next and most important step requires the teacher to infuse the keyword mnemonics into daily math instruction.

3.3 Incorporate into mathematics instruction

Simply creating and sharing the keyword mnemonics strategy with students is not necessarily sufficient to promote the learning of important vocabulary terms. Since the keyword mnemonic strategy is a method to help students connect new information to prior knowledge and acts as a memory enhancement device, teachers must provide students numerous opportunities during math instruction to use the keyword mnemonic strategy. Initially, teachers must explicitly model the process of how to effectively use the keyword mnemonics strategy to remember important information. As students become more familiar with the process, teachers can begin to allow students independent opportunities to practice using the strategy.

3.4 Plan for systematic and spaced review

Students must not only learn the concepts and definitions of new vocabulary terms, it is also essential that the new terms are kept in their repertoire. It is inefficient to introduce and teach important vocabulary terms if students ultimately forget the important concepts and definitions. Effective teachers help students to remember important information by providing systematic and spaced learning opportunities throughout the year (Pashler, Bain, Bottge, Graesser, Koedinger, McDaniel, et al., 2007). By arranging instructional activities that re-expose students to the important vocabulary 3-4 weeks after initial instruction, teachers are promoting better recall of essential vocabulary concepts and definitions. The keyword mnemonic strategy naturally lends itself to systematic and spaced instructional activities because once created, each student has a hard copy of the keyword mnemonic strategy that can be revisited at various times during the year. The activities used to revisit essential vocabulary concepts and definitions include a variety of activities such as the use of teacher-directed or peer-assisted activities during regular instructional time to discuss the keyword mnemonics. Teachers can include vocabulary focused questions on homework assignments, quizzes, and tests. The more teachers include vocabulary in regular instructional activities paired with the keyword mnemonic strategy, the more likely students will remember those important concepts and definitions.

Conclusion

Often, students struggle to learn important mathematical vocabulary and do not make vital contextual connections. The keyword strategy is a method to help students connect new and difficult word meanings to the mathematical context necessary for understanding and proficiency. As seen with the specific mathematics vocabulary examples described, the keyword strategy is a contextually relevant set of strategies that can be implemented easily and with relatively little professional development. The keyword strategy offers teachers an evidenced-based instructional methodology to promote essential mathematics vocabulary development for all students, helping educators to close the gap in mathematical performance among diverse learners.

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