WHITE PAPER

Supporting Struggling Readers in Mathematics Education

with Apex Learning Digital Curriculum

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What unique literacy challenges are faced by adolescents in high school mathematics?

Mathematics requires students to understand numbers, abstract symbols, and the mathematical context of words. Mathematical literacy is attained only when students can decipher the numbers, apply abstract symbols, and use words to construct mathematical meaning (Mayer & Hegarty, 1996; Schoenfeld, 1992).

When definitions, theorems, or mathematical sentences are read, they often cannot be read simply from left to right or word by word; rather, readers need to consider the words, numbers, symbols, equations, and graphs, diagrams, charts, or other types of visual information, often in a non-linear order (Barton, Heidema, & Jordan, 2002). For example, consider the mathematical definition for an acute angle: "an angle whose angle measure is less than (‹) 90°." Students must understand the words *angle measure,* know what a 90° angle looks like and why it is significant, and understand the meaning and symbol for *less than.*

Also, students need to have a command of the specific academic meanings of many vocabulary words in mathematics. For instance, the word *function* has a very specific meaning in mathematics, whereas *function* outside the mathematics classroom may mean something else entirely. Communicating mathematically requires that students fluently recall the mathematical definitions of words. Without this fluency, the process of reading and understanding mathematics is more difficult.

Problem solving, an essential process in mathematics, is defined by the National Council of Teachers of Mathematics as "engaging in a task for which the solution is not known in advance" (2000, ¶ 2). Thus, problem solving, particularly in word problems, can present unique challenges for adolescents who struggle with reading. Problem solving requires students to analyze the data, read to understand the problem, make choices on how to apply mathematics to solve the problem, develop a solution, and then express reasonable answers that are mathematically sound (Polya, 1962). Students who have difficulty with vocabulary or have other reading problems may get lost in the words and be unable to make sense of the problem in ways that would allow them to begin working through the mathematics.

Mathematics textbooks are another potential literacy challenge for struggling readers. Mathematics textbooks are organized very differently from many other textbooks in secondary classrooms. Students' understanding of a mathematics textbook depends on their understanding of mathematical concepts and their ability to decipher associated diagrams. Students must simultaneously read explanatory text from right to left, examine associated diagrams or equations that are located outside of the words, and vertically follow mathematical equations that prove or support the words of the definition (Franz & Hopper, 2007). Many students do not consider a mathematics textbook anything more than a collection of problems. Associated text is often ignored; therefore, students do not develop expertise in either mathematical knowledge or in reading a mathematics textbook.

What does current research tell us about best practices for supporting struggling readers in mathematics?

Results from the National Assessment of Educational Progress (NAEP) indicate that mathematics scores for students in the United States have increased since 1991 (National Center for Education Statistics, 2013). However, closer investigation of the scores reveals that student achievement is far from acceptable. Data from 2007 indicate that 66% of eighth graders scored at the basic level or below, 26% scored proficient, and only 8% attained an advanced rating. Mathematics education researchers continue to investigate methods for improving instructional strategies for secondary students.

Mathematical literacy may be one key to improving mathematics achievement. Mathematicians define mathematical literacy as a student's ability to understand and work with numbers flexibly (Principles and Standards of School Mathematics, 2000). Communication is one of the ten standards of the National Council of Teachers of Mathematics (2000). In defining the standard of communication, the National Council of Teachers of Mathematics states that students should be able to

- organize and consolidate their mathematical thinking through communication;
- communicate their mathematical thinking coherently and clearly to peers, teachers,and others;
- analyze and evaluate the mathematical thinking and strategies of others;
- use the language of mathematics to express mathematical ideas precisely. (¶ 1)

While reading, writing, and speaking are inherent to mathematics instruction, the emphasis is on teaching students mathematics—algebra, geometry, trigonometry, statistics, and calculus. Research on supporting struggling readers in mathematics is limited, but emerging research is pointing to the importance of mathematical literacy instruction. In mathematics, it is important for students to think flexibly about numbers and concepts. For instance, the idea of "the whole" could mean one object or multiple members that make a whole. Students need to have many experiences reading and writing about concepts to build their knowledge. Therefore, explicit instruction that allows students to investigate multiple solutions, to communicate using mathematically correct academic vocabulary, and to deepen their understanding of mathematics is imperative.

Researchers have found that students who are directly taught strategies for reading mathematics improve their comprehension of mathematical problems (Donahue, 2003; Ostler, 1997). Reading strategies help students read, comprehend, and apply the text so that they may solve mathematical problems. Strategies that help students organize materials seem to have the most wide-ranging application for mathematics. For instance, a graphic organizer that charts the word, definition, and associated equations is useful for helping students understand mathematical concepts such as conic sections (circles, parabolas, ellipses, and hyperbolas). This strategy helps students organize material that is similar but requires specific approaches to find solutions.

Active reading strategies can also support struggling readers in learning mathematics. Reading research points to concrete cognitive strategies that active readers use to comprehend the text, including accessing prior knowledge, making and revising predictions, using visual cues and text features, making inferences, asking questions, making mental images, monitoring for comprehension and fixing up when needed, and summarizing (Brenner, 2009; Kamil, Borman, Dole, Kral, Salinger, & Torgeson, 2008; NICHD, 2000; Pressley, 2000).

One powerful reading strategy that can support reading in mathematics is asking questions (Kamil, Borman, Dole, Kral, Salinger, & Torgeson, 2008). Proficient readers ask themselves questions about the content as they read to help clarify the information and consider the author's purpose. In particular, considering Question Answer Relationships (QAR) (Raphael, 1986) can help students focus on the reasonableness of their answers. In considering QAR, readers ask themselves about the relationship between the text and the question or mathematical problem being asked, and determine whether the answer to the problem is evident on the page, based entirely on background knowledge (or "in my head"), or a combination of both (Raphael, 1986). Proficient readers in mathematics also consider questions of reasonableness. Reasonableness is an important concept in mathematics. Students must develop a sense that their solution is plausible given the problem.

The active reading strategy of using visual cues can also support students in reading mathematical text. Because of the interplay between text, graphics, and vertical equations and mathematical problems, explicit instruction regarding visual cues can support comprehension (Kerper, 1998). Visual cues include text features such as bolding items, italics, headers and sub-headers, and captions.

The active reading strategy of accessing prior knowledge can also support the development of mathematical literacy. Proficient readers access prior knowledge by considering what they already know about a topic before and during reading. Explicit instruction and modeling of this strategy have been shown to support reading comprehension (Hansen & Pearson, 1983; Tovani, 2000). Because mathematics builds from one concept to the next, from one way of working with numbers to the next, accessing prior knowledge can support mathematics achievement.

Research has also investigated the importance of specific vocabulary development using reading strategies (Adam, 2003; Kersaint, Thompson, & Petkova, 2008). Many words in mathematics have specific meanings that are far different from meanings used in casual conversations. In fact, mathematics may need to be considered a second language (Adams, 2003; Wakefield, 2000). Therefore, strategies of language acquisition should be applied in the mathematics classroom. Students must have frequent opportunities to read and speak using precise mathematical language to develop fluency. Teachers should consider the need for translation and interpretation just as a reading teacher would when helping students with difficult or new text. Supported practice in reading mathematical text is essential to developing understanding.

How is Apex Learning adopting those best practices in its digital curriculum?

Apex Learning recognizes the interaction between words, symbols, and numbers in mathematics. Its digital curriculum has adopted several strategies to aid students in becoming mathematically literate. Two key components of the instruction are vocabulary development and active reading strategies to support students in mastering the unique requirements of reading mathematical text.

In each mathematics Comprehensive Course and Tutorial, students are provided with scaffolding that uses active reading strategies, which are modeled and practiced with mathematics content. In the Algebra I curriculum, for example, students use text features and visual cues to support comprehension of the text and diagrams, graphs, and other visuals; connect the material to previous content by accessing their prior knowledge; and are prompted to ask questions during reading and to consider Question Answer Relationships. Interactive graphic organizers guide students to different parts of the page as a mathematical concept is developed. Reading Support Cards remind students to ask questions, make mental images, make predictions as they encounter new materials, and apply the active reading strategies as appropriate, providing scaffolding for learning both the mathematics content and the reading strategies.

Another unique feature of the digital curriculum is explicit instruction in mathematics vocabulary. Students are taught how to read mathematical terms in context. Students are also presented with words that have multiple meanings or meanings specific to mathematics. Students review the mathematical meaning and compare this with more casual uses of the word. As students encounter these words later in the material, they are able to review the meanings by using vocabulary rollovers. This serves to heighten a student's awareness of mathematical vocabulary. This intentional, specific development of word knowledge is meant to provide struggling readers with strategies to help them develop the capacity to recall the mathematical meanings of words and to persevere and problem solve when faced with challenging academic vocabulary.

Finally, real-world applications in the mathematics curriculum give students meaningful opportunities to practice the active reading and vocabulary strategies they have learned. Students must read and decipher the mathematical situation, use multiple data sources to plan a solution strategy, and then decide if the solution makes sense for the problem. This sophisticated text handling requires that students apply many literacy strategies to make sense of the mathematics. Intentional, explicit strategy instruction helps the students learn to act like "real mathematicians" in an engaging, meaningful way and supports them to be successful with rigorous mathematical study.

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Our digital curriculum is designed to actively engage students in learning—combining embedded supports and scaffolds to meet diverse student needs, actionable data to inform instruction, and success management, to ensure you get the outcomes you're expecting.

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