Reading and Math: What is the Connection?
A Short Review of the Literature

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According to Ladson-Billings (1997), an important feature that should be in the reform of mathematics education is the expectation for students not merely to memorize formulas and rules and apply procedures but to engage in the processes of mathematical thinking. In short, they should be expected to do what mathematicians and other professional users of mathematics do. Such a mathematics education program is based on engaging students in posing and solving problems rather than on expecting rote memorization and convergent thinking.

These changes in mathematics education suggest that mathematics teaching must build on students’ learning and on their ability to pose and solve problems previously considered difficult for their age-grade levels. High expectations are critical. Because of the crucial role that algebra holds as a curricular gatekeeper, urban students cannot continue to be tracked out of it. In the current arrangement of the curriculum, access to higher level mathematics, beginning with algebra, can mean increased educational and economic opportunity for students.

U.S. school children continue to lag behind students in other highly technological nations in mathematics and science achievement. The reasons for this lag are multiple and include:

- teachers without adequate preparation in mathematics and science
- unimaginative approaches to teaching
- teacher misassignment
- poorly constructed textbooks and curriculum
- cultural bias toward the unimportance of math education and the myth that it is only for a select few to master.

It is more than what happens in the classrooms that contributes to the creation of a mathematically illiterate culture. Mathematics functions as a feared and revered subject in our culture. We fear it because we believe that it is too hard, and we revere it because we believe that it signals advanced thinking reserved only for “smart people.” Both these perceptions are a myth.

No one would readily admit to being unable to read, but many proclaim with pride their inability to perform even moderately complicated math problems. Not knowing how to read or write carries a stigma across race, class, and gender lines. On the contrary, poor math performance does not carry the same stigma. According to Ladson-Billings (1997), Asian parents attribute their students’ math failures to lack of effort, whereas most U.S. parents were more likely to suggest that their children’s poor performance was attributable to a lack of innate ability. These images do not prompt our children or their parents to embrace mathematics as a field of study or a necessary skill. This distortion and mystification of mathematics and its uses have contributed to our viewing it as unattainable, unnecessary, and undesirable.

In the traditional classroom of not too long ago, mathematics teachers were charged with using their subject area as a curriculum sieve, sifting and winnowing to select the top students to go on to higher mathematics. In our current highly technological, global economy, no student can afford to be left out of high-level mathematics. Thus, today’s mathematics teachers must conceive of their subject area not as a sieve but as a net that catches all students and teachers as a whole, but it has been particularly difficult for students and teachers in the urban core.

Mathematics teaching in our schools has traditionally emphasized repetition, drill, convergent right-answer thinking, and predictability. Students are asked to perform similar tasks over and over. They are rarely asked to challenge the “rules” of mathematics. They are rarely asked how their prior knowledge and experiences might support or conflict with school mathematics. Ladson-Billings (1997) contends that middle-class culture demands efficiency, consensus, abstraction, and rationality. Unfortunately, these features reflect the experiences and understandings of only one segment of our society. In addition, school mathematics is generally presented in ways that are divorced from the everyday experiences of most students. Thus, poor mathematics performance in the U.S. cuts across cultural groups.

Individuals do not learn things in a vacuum. Rather, learning occurs in a social context. As a result, for many students to experience success in mathematics, it needs to be deeply embedded in their everyday experiences. Instead of surface connections, teachers need to understand the deep structures of students’ experiences. In order to be successful at moving from students’ lives and interests to meaningful mathematics, teachers themselves, will have to be very knowledgeable in mathematics. A teacher who is struggling with their own
content knowledge will be hard pressed to instill confidence in the students entrusted to their care.

**LANGUAGE PROFICIENCY AND MATH PERFORMANCE**

According to MacGregor and Price (1999), the association between language proficiency and trends in math performance are difficult to disentangle from social and cultural factors. However, in an overview of the research on race, ethnicity, social class, language, and achievement in math, research that had been carried out in the US up to the early 90’s, Secada (1992) found sufficient evidence to conclude that "language proficiency, no matter how it is measured, is related to mathematics achievement" (pg 639).

Commins (1979, 1984), in studies of the language skills of bilinguals concluded that a certain level of linguistic proficiency seemed to be necessary for academic achievement. This is apparently because language competence allows one to use it as an organizer of knowledge and as a tool for reasoning. Dawe (1983) showed that bilingual students who performed poorly in mathematics tended to have low levels of competence in their native language. According to Dawe, this occurred because these students had learned their second language, (i.e. English) without an adequate foundation of first-language competence. They had not acquired in either language, the level of language proficiency that is a necessary foundation for academic learning.

MacGregor and Price (1999), contend that vocabulary, number and symbol sense, as well as the ability to read and comprehend word problems are important factors effecting achievement in math. However, they believe the connection is actually much deeper. They believe the cognitive ability that drives symbol processing is the connection between language and math. This symbol processing ability is the basis for both language proficiency and math achievement. It involves deriving meaning from symbols beyond the level of simple decoding.

According to MacGregor and Price (1999), the processes of language and math diverge above the level of symbol processing. Competence in one does not correlate with competence in the other at this higher level. This divergence is due in part to differences in syntax. The syntax of language and the syntax of math both evolve from the ability to process symbols. However, the syntax of language and the syntax of math are different. Both need to be taught and learned. Good reading, writing and grammatical skills do not in and of themselves translate into good arithmetic computational and problems solving skills. However, poor language skills do correlate with poor math skills, suggesting that both require a basic level of competency in symbol processing, i.e. deriving meaning from symbols.

For example, the concept of angular acceleration in physics is defined by a simple equation using the following Greek letters.

\[ T \] Symbol for Time in seconds

\[ \theta \] Symbol for angular displacement in radians (displacement of a point on an object rotating about an axis. A radian is about 57 degrees of displacement and there are 2 radians in one revolution. What is accurate to three digits?

Answer 3.14. How many radians would there be in one complete rotation of a point about the axis of a rotating object? Answer 2 X 3.14 = 6.28 radians per revolution.

\[ \omega \] Symbol for angular velocity or the number of radians of angular displacement per second.

\[ \alpha \] Symbol for the rate of angular acceleration that is represented by the change in angular velocity per second.

What does this mean? \[ \omega = \frac{\theta}{T} \]

What does this mean? \[ \alpha = \frac{\omega}{T} \]

To answer these questions requires the ability to process (comprehend) the symbols in each expression. Even with textbook definitions, this is difficult without something concrete or semi-concrete to use as a vehicle to understanding the meaning of the Greek letters in the expressions.

What does this mean? Answer the question using written narrative excluding any mathematical jargon.

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Symbols in math tend to be more precise than symbols in language, and operations in math tend to be more precise than operations in language. Multiple interpretations and ambiguity are not generally considered part of math computation until it is used as a tool in such things as statistical inference.

According to Ediger (1997), reading is a cognitive process that involves communicating, comprehending, and learning from written material. Is this definition different for mathematics? How? In reading, says
Ediger, students should be able to read and comprehend 95%-98% of the running words encountered without any previous practice. Comprehension goes down if this percent is less than 95%. Is there a parallel in reading math?

Whether students are reading for pleasure or reading to solve math word problems, teachers should identify and clarify unknown words at the beginning of a lesson or unit. They should be pronounced, defined, and made visible so students have the knowledge base to derive meaning from what they are attempting to decode and comprehend.

Hearing difficult passages read aloud may help students verbalize the printed word with correct pace, phrasing, and expression. In addition, having students define new items in their own words using concrete and semi-concrete examples is a good way for them to construct meaning for print. It is a mistake to confuse lack of experience with lack of ability. Using concrete and semi-concrete examples can help the reader connect meaning to abstract terms and symbols. For example, what does the term mean in your own words? What does mean in your own words? What is an exponent in your own words?

Using this strategy requires that teacher be good facilitators, allowing students to talk about a formal definition that is being put into their own words. Being able to "read" and assign meaning to abstract symbols is critical to comprehension. Can you "read" and assign meaning to these symbols?

\[ + \quad - \quad < \quad > \quad \Sigma \quad \alpha \quad \theta \quad \omega \]

Learning to think mathematically or mathematical maturity, has no concrete or semi-concrete conceptual meaning. The meaning is more intuitive and abstract and may be based on a set of complex behaviors that allow the student to demonstrate a deeper level of understanding.

Being able to think mathematically is reflected by the ability to read and comprehend mathematical symbolism in much the same way that we read words. However, the syntax is different and must be taught. There is little crossover between mathematical syntax and verbal syntax at levels above formal processing. For example, reading running narrative is linear and one dimensional, progressing always from left to right. On the other hand, "reading" math may be left to right, right to left, top to bottom, or even on the diagonal. A sentence has a subject and a predicate connected by a verb. A mathematical expression consists of variables that can have multiple or discrete meaning. Translating a mathematical expression into words could involve several sentences or even paragraphs.

We can assume that if students are unable to derive meaning from symbols, i.e., decode and comprehend running text, they will be unable to "do" math. However, we cannot assume that because students can read running narrative that they can read math. Although there are similarities at the fundamental level, the syntax of math and the syntax of running narrative are different and require different strategies for instruction and learning. Learning the language of math such as definitions, rules, algorithms, and proofs, should not be confused with thinking mathematically. Thinking mathematically is a more complex process that involves the meaningful application of definitions, rules, algorithms, and proofs. Students need to be able to move beyond rules and express real life experiences mathematically. Conversely, expressing things mathematically is difficult if students do not know or have not been taught the definitions, rules, algorithms, and proofs.

Mathematics should provide students with a sense of disciplined thinking. As they become more sophisticated in their understanding and application of mathematical principles, they should be able to demonstrate a sense of what math is and how it applies to the real world. Expression of mathematical thinking involves a focus on:
- seeking solutions, not just memorizing procedure
- exploring patterns, not just memorizing formulas
- predicting and evaluating answers, not just doing exercises.

The math teacher is a reading teacher...a reading teacher that teaches the student to read math.

According to Gregor, (1992) reading and math share common elements. The are both abstract, symbolic, cognitive processes, and they both require a working knowledge of the interaction of numerous discrete skills. Unfortunately, many students who score well on reading tests and tests of computational skills do not score well on tests of mathematical problem solving. This is due in part to the incorrect assumption that students transfer skills used in reading story selections to reading word problems. Such an assumption overlooks the different role that reading comprehension plays in math problems. In addition, many educators emphasize getting the "right" answer using the "correct algorithm", often ignoring the development of reading comprehension and thinking skills necessary to do real problem solving.

Before children can comprehend either oral or visual mathematics material, they must be allowed to recode it within their own language structure (Hollander, 1990). Such recoding facilitates the derivation and analysis of meaning. Students are more likely to be successful if familiar words are inserted into word problems, and if the
following guidelines are followed to assist them to read and solve math problems.

- Ability to read mathematical text does not necessarily lead to a successful strategy for solving word problems. Students must be taught how to a) recognize the problem, b) identify and apply appropriate strategies, and c) check and evaluate their answer.
- Students must be taught how to translate word problems into statements that mean something to them (comprehension must precede computation). Problems may need to be reworded into something more meaningful to the student.
- Having the student "reword" the problem can give clues to what is understood and to what is misunderstood.
- Rewording may also introduce error. This is not necessarily bad if the teacher uses the error as an opportunity for teaching and learning.

According to Hollander, solving word problems can be enhanced when the reader attempts to increase his/her comprehension through translating the language of the text into personal and meaningful vocabulary at their comprehension level. In short, success with math problems requires both reading for comprehension and computational skills.

Clarkson (1994) agrees that students reading ability as well as computational proficiency are factors important to success in mathematics including the ability to solve word problems. When students are taught how to read math, says Clarkson, their problem solving performance improves. In fact, even if students only improve their vocabulary in math their scores improve on verbal problem solving tasks.

The way in which math is written has a profound effect on students' math performance. In word problems, both math and non-math vocabulary can influence students' performance. There is little room for words the students do not comprehend or misinterpret based on different meanings in math versus running text. Examples include “mean”, “variable”, “equal”, etc. Something as simple as the number of words in a problem as well as the length of individual sentences can effect the difficulty level of problems. Difficulty is affected by grammar as well. Placing questions first appears to focus students on what is desired and tends to improve success rates. In addition, readability of math material is also influenced by the number of passive sentences as well as sentence length. Students must be taught how to read math material and how to use math texts as resources.

However, reading math material is different for reading running text. Knowing how to use procedures and algorithms as well as knowing when to use them are not the same skill. The way a mathematics task is worded will affect students’ success. In fact, many math exams test much more than math. Solving word problems in the language of math first requires a clear understanding of the language in which the problems are written, followed by the related, but different, ability to translate the verbal language into symbolic mathematical expressions, and visa versa. Words and the translation process may be the real "problem" in problem solving, not computational skills or the ability to read running text.

Ediger (1997) suggests that using the reading recovery method is appropriate in math recovery. Intense one-on-one structured tutoring involving comprehension of math content can have a dramatic effect on student performance in math providing the student can read. This tutoring can be provided by both adults and peers with equal effectiveness.

Ediger contends that reading and writing in mathematics are symbolic activities that should follow much modeling and talking about numbers and abstract symbols.

There is a danger, he says, in prematurely focusing on symbols. Symbols are abstract and in and of themselves have no meaning. The symbols that students read and write must have meaning to them. Starting with the abstract nature of symbols will almost assuredly lead to failure. Symbols become meaningful only through beginning with concrete and semi-concrete examples that can be attached to meaningful verbal comprehension. Learning and retention are improved when comprehension is attached to prior knowledge through the use of these concrete or semi-concrete examples and experiences. Some suggestions for improving learning and retention in math include:

- Having students make a mathematics glossary defining terms in their own words and including concrete and semi-concrete examples
- Having students write their own word problems and assist each other in the proofing of the final written product. Include correct spelling and grammar.
- Having students keep a diary of sequential days of instruction in math.

Reading, writing, and proofing test items is a powerful way to integrate reading, writing, and math. Developing multiple choice items should require that each response is plausible. Essay questions should elicit a clear-cut answer.

Reading to solve word problems with a purpose and plan is essential. Students must be taught how to do this.
- Calculators and computers should be used as a tool, not as an end in themselves.
SUMMARY

Two very important things can be concluded from this short review of the literature concerning the connection between reading and math.

Reading and math require very similar cognitive skills at the symbol processing level. Symbol processing involves the ability to derive meaning (comprehension) from symbols whether they be letters, words, numbers, or equations. If the student lacks the ability to process symbols, then he or she cannot read nor can they “do” math. In short, the student must be able to read before they can be successful at any other academic endeavor. Trying to improve math performance for a student who cannot read will be ineffective.

Students who can read fluently can do anything academically. Their only barriers are motivation, expectations, instruction, and other things that are not dependent on some vague, phantom, innate ability. However, they must be taught how to be successful in other academic domains. Our first priority is to be sure the student can read. Our second should be to provide them with the skills necessary to be successful in all other academic areas.

BIBLIOGRAPHY


