UNDERSTANDING THE COGNITIVE PROCESSES AND METACOGNITIVE STRATEGIES THAT WORK WITH MATHEMATICAL LEARNING DISABILITIES

By

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Suzie gets the assignment "wrong" because sloppy writing led to misspelling and misalignment of numbers. Jeff has not yet memorized the multiplication tables, Juan reverses numbers when copying from the book or the chalkboard. Ashley cannot decide "what to do" when solving math word problems. Alfredo cannot "remember" algebraic formulas. Gerard cannot remember the procedural sequence for division computation.

ABSTRACT

The reality is that approximately 5-8% of school-age students have memory or other cognitive deficits that interfere with their ability to acquire, master, and apply mathematical concepts and skills (Geary, 2004). These students with Mathematical Learning Disabilities (MLD) are at risk for failure in middle school mathematics because they generally are unprepared for the rigor of the middle school mathematics curriculum. This article not only seeks to explore why students with MLD are such poor mathematical problems solvers, but it seeks to explore and illuminate the mystery behind the cognitive processes and metacognitive strategies that are used to solve mathematical problems.

Keywords: Mathematical Learning Disabilities, Metacognitive Strategies, Constructivism, Middle School Mathematics.

INTRODUCTION

Reality

The reality is that approximately 5-8% of school-age students have memory or other cognitive deficits, which interfere with their ability to acquire, master and apply mathematical concepts and skills (Geary, 2004). These students, like the ones mentioned above, have mathematical learning disabilities (MLD) and are at particular risk for failure in school mathematics because they generally are unprepared for the rigor of the school mathematics curriculum. A recent report published in October 2008 by the British government claimed that mathematical learning disabilities cut a student's chances of obtaining good exam results at age 16 by a factor of 7 or more and often wipe out a significant amount of money from their lifetime earnings (Government Office for Science, 2008).

Students with mathematical learning disabilities can be highly intelligent and articulate, theirs is not a general learning problem. Instead, they have a selection deficit with numerical sets (Spinney, 2009). Put simply, they fail to see the connection between a set of objects and the numerical symbol that represents it. Similarly, difficulties are presented in counting, giving and receiving change; tipping, learning abstract concepts of time and direction, telling and keeping track of time and the sequence of past and future events (Vaidya, 2004). Essentially, students with mathematical learning disabilities are unable to function with these mathematical milestones characteristic of their age group.

Learning Disabilities in Mathematics Defined

Mathematical Learning disabilities are characterized by a poor understanding of the number concept and the number system. Students with a mathematical learning disability find learning and recalling number facts difficult. They often lack confidence even when they produce the correct answer. They also fail to use rules and procedures to build on known facts. Additionally, in word problems, they often don't understand which type of arithmetical operation is asked for. Similarly, there may be exaggerated difficulties with intensive numbers such as speed, temperature, averages and proportional measures. Some students with mathematical learning disabilities also have spatial problems, which affect understanding of position and direction. Lastly, students with mathematical learning disabilities can usually learn the sequence of counting words, but they may have difficulty navigating back and forth

There are two types of mathematical learning disabilities, Quantitative and Qualitative. Quantitative mathematical learning disabilities are characterized by deficits in the skills of counting and calculating and often refer to deficits in the areas of following sequential direction, lacking a keen sense of directionality, of ones position in space, and of spatial orientation and organization. Qualitative mathematical learning disabilities are characterized by difficulties in comprehension of instructions or the failure to master the skills required for an operation. Specifically, difficulty in the areas of pattern recognition and extension, visualization, estimation, deductive reasoning, and inductive reasoning are often specific deficits associated with a qualitative mathematical learning disability.

Current Trends

Relative to research on reading disabilities, research on mathematical learning disabilities is very much at the infancy stage. In fact, math researchers are still working to define the concept of mathematical learning disability and to identify underlying cognitive or genetic attributes (Vaidya, 2004). While the definition of learning disabilities has been the subject of controversy for decades, the current federal classification system identifies three specific areas of deficit: reading, written language and mathematics and maintains the presumption that the disabilities are a result of central nervous system dysfunction (Augustyniak, Murphy & Phillips, 2005).

The task of defining mathematics learning disability is a challenging one, owing in part to the lack of consensus in defining and measuring learning disability (LD) per se. Current LD definitions are based on relatively poor achievement in reading, spelling, writing, or math. Despite inclusion of math achievement in these definitions, the LD literature is dominated by work on reading disability and the terms reading disability and learning disability are often inappropriately treated as synonymous. Interestingly, however, the prevalence of math disability parallels or exceeds the reported frequency of reading disability. The disproportionate amount of research devoted to reading disability may reflect the more apparent societal concern with literacy than with numeracy (Fleishner, 1994). However, recent trends include greater research attention to and funding for math and science education than in the past (National Center for Educational Statistics, 1998). Still, our understanding of a mathematical learning disability is limited and research on the genetic bases of a mathematical learning disability is even more limited (Geary, 1993).

The prevalence of formally classified learning disabilities (LD) has been increasing throughout the last two decades. As a result, there is a greater need for teachers to possess an extensive array of teaching techniques to address the needs of these students. In fact, according to the National Council of Teacher's of Mathematics, "students with special educational needs must have the opportunities and support they require to attain a substantial understanding of important mathematics (NCTM, 2000 p.5).

The need for more systematic research and unified theory surrounding mathematical learning disabilities is highlighted by a major funding initiative through the National Institute of Health and the Education Department (Special Education Report, 2003) to propagate research in the areas of math cognition, learning and mathematical learning disabilities. A seminal component of the literature base, which remains lacking, is an empirically-based identification of core deficits, and thus, a consensus operational definition for math disability (Augustyniak, Murphy & Phillips, 2005). Thus, the present article seeks to not only explore why students with Mathematical learning disabilities are such poor problem solvers, but it seeks to explore and illuminate the mystery behind the cognitive processes and metacogntive strategies that are used to solve problems.

Math as a Second Language

Mathematics is often referred to as a language. However, it is considered as a second language to most students and should be taught as such. The conceptual aspect of mathematics learning is connected to language. It is exclusively bound to symbolic representation of ideas (Vaidya, 2004). Most of the difficulties seen in mathematics results from the underdevelopment of the language of mathematics. Teaching of the linguistic elements of math language is sorely neglected. The syntax, terminology, and the translation from English to math language and from math language to English must be directly and deliberately taught (Sharma, 2001).

Specifically, when students have the ability to understand the language found in word problems, their proficiency in solving them is greatly influenced. In addition to understanding the meaning of specific words and sentences, students are expected to understand textbook explanations and teacher instruction. Thus, students with a disability in this area are at a significant disadvantage because they need to be able to concentrate on two difficult concepts at the same time.

Math vocabulary may also pose problem for students with mathematical learning disabilities. Specifically, they may find it confusing to use several different words, such as add, plus, combine, that have the same meaning. Other terms, such as to factor, do not occur in everyday conversations and must be learned specifically for mathematics. Additionally, sometimes a student understands the underlying concept clearly but does not recall a specific term correctly.

Relating Cognitive Theories to Mathematics

From the psychological perspective of cognitive behaviorism, both emotions and behaviors (Poor problem solving strategies, low frustration tolerance, lack of motivation to persevere, etc) are expressions of beliefs which often develop in a biased or dysfunctional, manner and over time become automatic core beliefs (Beck, 1995; Ellis & Dryden, 1997). Vygotskian theory informs us that student beliefs and knowledge are inextricably determined by the socio-cultural environment (mathematics classroom) with language and social modeling being the vehicles of shared knowledge. For example, while the pedagogical mainstays of direct instruction, modeling and guided practice are often adequate in building procedural proficiency and increase fact retrieval, they have generally been found to be insufficient to promote transfer of independent strategy performance to new/novel tasks among a significant percentage of students (Augustyniak, Murphy & Phillips, 2005). In fact, Augustyniak et al continue to suggest that many theorists and researchers assert that traditional models of teaching mathematics have produced an inhibitory effect on mathematics learning by promoting self-limiting belief systems. Schoenfeld (1988) and Decorte, Op't Eynde and Verschaffel (2000, 2002) provide heuristic categorizations of mathematical related, socially shared belief systems and their respective influence. The following beliefs (Augustyniak, Murphy & Phillips, 2005) about mathematics, beliefs about self and beliefs about the social context of mathematics learning and problem solving have implications for development or inhibition of self-regulated mathematic learning:

- Mathematics learning is memorization
- There is only one correct way to solve any mathematics problem
- All math problems can be solved in a few minutes
- Goal Beliefs: I have to learn enough- enough to pass the exam
- Task Value Beliefs: the material in this class has nothing to do with the real world
- Locus-of-Control Beliefs- I will do well on the exam by chance
- The teacher will point out everything I need to know
- I succeed in math by doing the problems exactly how the teacher wants
- Math knowledge is passed down from above

In order to develop student independence, emerging models for instructional strategies have become increasingly constructivist. The goal would be to have students think math, not just do math. A constructivist approach to math provides students with opportunities to think through a math problem and learn how to represent their thinking in mathematical symbolism. One of the important aspects that they learn from this process is to learn the language of mathematics and the need to have math language to express mathematical concepts (Augustyniak, Murphy, Phillips, 2005).

Educational Implications/Recommendations

There are several constructivist instructional strategies that should be implemented when assisting students with mathematical learning disabilities who have difficulty with the following metacogntive process strategies related to mathematical problems:

- Rereading the problem or parts of the problem
- Identifying the important information
- Asking themselves questions
- Putting the problem in their own words
- Visualizing or drawing a picture or diagram of the problem
- Telling themselves what to do
- Estimating the outcome
- Checking that the process and product are correct

These strategies may be applied to any mathematics class at any grade level and are critical components of the constructivist theoretical approach to mathematics.

First, using verbal rehearsal or acronym RPH-HECC

- R Read for Understanding
- P Paraphrase- in your own words
- V Visualize- draw a picture or diagram
- H Hypothesize- make a plan
- E Estimate- predict the answer
- C Compute- conduct the arithmetic
- C Check- make sure everything is right

is a very powerful learning strategy that benefits students with mathematical learning disabilities. It allows students to use a very clearly defined step-by step process providing them with the opportunity to think about math (constructivism) as they work through each step. Similarly, this process allows students to think aloud while demonstrating an activity. Again, this thinking aloud strategy provides students with the necessary feedback needed to think about and internalize what is being asked rather than what needs to be done.

Second, another invaluable instructional strategy is that of visualization. Visualization is a constructivist approach that suggests that students with mathematical learning disabilities need to be taught to select important information in the mathematical problem and then develop a schematic representation. However, the strategy continues to suggest that drawing a picture is not enough; students must be able to visualize the relationships among the pieces of information in the problem. The ability to visualize as a teacher talks about geometric forms or proportion, for example, can help students store information in long-term memory and can help them anchor abstract concepts. Again, this strategy allows students to think about mathematical concepts rather than just do the mathematical concepts.

Third, using the strategy of role reversal is often a very powerful constructivist tool that allows students to think about math rather than just do math. Specifically, the strategy suggests that students "change places" and become the teacher. This may be accomplished at any given time and all students should be able to play this role when they feel successful with any given topic. This strategy fosters student independence rather than dependence.

Fourth, peer coaching is yet another very powerful constructivist approach that allows student to think about math rather than just do math. Specifically, this strategy gives students the opportunity to see how other students approach mathematical problems differently, how they use cognitive processes and self-regulation strategies differently and how they represent and solve problem differently.

Fifth, allowing students to develop their own math problems is still another constructivist strategy that allows student to think about math rather than just do math. Specifically, this strategy suggests that when students identify with the information in the problem, they take ownership of the problem.

Conclusion-Final Thoughts

Little is known about the developmental and corrective trajectories associated with learning disabilities in mathematics (Lyon & Cutting, 1998). To date, there has been insufficient research to link specialized instruction modalities with specifically defined impairments in mathematics learning. However, students with mathematical learning disabilities have a heightened need for a flexible educational environment, consistent application of appropriate pedagogical principles, and the attention of experienced, sensitive teachers (Lyon & Cutting, 1998).

Essentially, a teacher is limited only by his or her own perceived limitations in finding reasonable, creative approaches in instruction and ability to gather valid and applicable information about student needs. When teachers begin to think outside the box and use strategies such as the ones presented in this article, they become partners with their students, and allow students to learn at different paces. Similarly, student interest is tapped, retention is likely to be greater and the choices provided are generally motivating.

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