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IMAGERY

A Sensory-Cognitive Connection for Math

Why can't everyone think with numbers? Why do some children learn math readily, handle money and time concepts with ease, retain information from year to year, and think with numbers effortlessly? What cognitive processes do some have that others do not?

Some people are able to understand the concepts underlying math processes easily. They can perform math calculations quickly, either mentally or on paper, and have an innate sense of whether or not an answer is correct. Math is their friend, dependable and logical. But for others, math is an enemy, illogical and filled with random memorization. It's a dragon, ready to embarrass or diminish them in the eyes of others. For the people who "get" math, the language of numbers turns into imagery. They use internal language and imagery that lets them calculate and verify mathematics; they "see" its logic.

Mathematics is cognitive process-thinking-that requires the dual coding of imagery and language. Imagery is fundamental to the process of thinking with numbers. Albert Einstein, whose theories of relativity helped explain our universe, used imagery as the base for his mental processing and problem solving. Perhaps he summarized the importance of imagery best when he said, "If I can't picture it, I can't understand it."

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Imaging is the basis for thinking with numbers and conceptualizing their functions and their logic. The Greek philosopher Plato said, "And do you not know also that although they [mathematicians] make use of the visible forms and reason about them, they are thinking not of these, but of the ideals which they resemble... they are really seeking to behold the things themselves, which can be seen only with the eye of the mind?"

The relationship of imagery to the ability to think is one of the preeminent theories of human cognition. Allan Paivio, author of the Dual Coding Theory (DCT) and a cognitive psychologist, stated, "Cognition is proportional to the extent that mental representations (imagery) and language are integrated." Research from the 1970s and into the 1990s has validated Dr. Paivio's work as a viable model of human cognition and its practical, as well as theoretical, application to the comprehension of language (Bell, 1991). Dr. Paivio believes that in order to think and understand, humans must be able to simultaneously generate imagery and corresponding language to describe that imagery.

Mathematics is the essence of cognition. It is thinking (dual coding) with numbers, imagery and language; reading/spelling is thinking with letters, imagery and language. Both processes, often mirror images of each other, require the integration of language and imagery to understand the fundamentals and then apply them. Dual coding in math, just as in reading, requires two aspects of imagery: symbol/numeral imagery (parts/details) and concept imagery (whole/gestalt).

NUMERAL IMAGERY

Visualizing *numerals* is one of the basic cognitive processes necessary for understanding math. For example, we image the numeral "2" for the concept of two. When we see the numeral "3," we know that it represents the concept of three of something: three pennies, three apples, three horses, three dots. If someone gives us two pennies for the numeral three, we have a discrepancy between our numeral-image for three and the reality (concept) of three. The first imagery needed for math is the symbolic (or numeral) imagery that represents the reality of a number concept.

What does numeral imagery look like? Here's one example. Cecil was very good in math. He could think with numbers, arrive at answers in his head, and mentally check for mathematical discrepancies in finance or life situations easily.

He explained this ability, "I just visualize numbers and their relationships. Certain numbers are in certain colors, and the number-line in my head goes specific directions." Not only could Cecil visualize numerals and concepts, both types of imagery, but he also had an unusual talent for color imagery. He assigned colors to specific numbers!

"What color is the number 14?" he was asked.

His eyes went up, and in all seriousness, he said, "Light blue."

Similarly, number 3 was reddish pink and the number 88 "kind of a purple." Quizzed again months later, Cecil assigned the same colors to the same numbers.

Chronological relationships appear in our minds on a number line, the days of the week, the months in the year. *Imagery is our sensory systems' way of making the abstract real.* It is a means to experience math.

CONCEPT IMAGERY

While imaging numerals is important to mathematical computation, another aspect of imagery is equally important: concept imagery. Understanding, problem solving and computing in mathematics require another form of imagery—the ability to process the gestalt (the whole). Sometimes children or adults can visualize the numerals, the parts, but cannot bring those parts to a whole, just as they can sometimes visualize individual words but cannot bring those words to a whole to form concepts. Mathematical skill requires the ability to get the gestalt, see the big picture, in order to understand the process underlying mathematical logic.

"Concept imagery is the ability to image the gestalt (whole)," Bell (1991). Concept imagery is basic to the process involved in oral and written language comprehension, language expression, critical reasoning and math. It is the sensory information that connects us to language and thought. In "On Memory and Recollection," Aristotle wrote, "It is impossible even to think without a mental picture." Much later, Thomas Aquinas wrote, "Man's mind cannot understand thoughts without images of them."

The ability to create mental representations for mathematical concepts is directly related to success in mathematical reasoning and computation. However, because some children do not have this imaging ability, they are often mislabeled as not trying, unable to retain information, or having dyscalculia (the inability to perform arithmetic operations).

MANIPULATIVES MAY NOT BE ENOUGH

Manipulatives don't guarantee that children learn mathematical concepts or retain how to do mathematical computation. For example, Joanie's second grade class had focused on using manipulatives for understanding and computing addition and subtraction, and had even moved into some multiplication. Joanie appeared to be doing well at the end of the year. But when she reached third grade, her teacher complained that Joanie didn't seem to understand math and couldn't do simple computation.

Concrete experiences-manipulatives - have been used for many years in teaching math (Stern, 1971). However, like Joanie, many children and adults have often experienced success with manipu-latives, but failure in the world of computation (NCTM, 1989; Moore, 1990; Papert, 1993). They have what has often been described as "application problems."

Joanie's second grade class had spent a lot of time with manipulatives. Some of the children moving on to third grade continued to "think with numbers." Their experience with manipulatives became part of their mental deposit of imagery. Like a bank deposit, these images could be drawn upon at will. However, not all children create mental imagery as they work with concrete manipulatives. For these children, the process of turning the concrete experience into imagery must be consciously stimulated.

ON CLOUD NINE® MATH CONCRETE TO IMAGERY TO COMPUTATION

Arnheim (1966) wrote, "Thinking is concerned with the objects and events of the world we know…When the objects are not physically present, they are represented indirectly by what we remember and know about them…Experiences deposit images."

Numbers can be experienced and the relationships between them can be made concrete by using manipulatives. What appears abstract can be experienced *and imaged* to concreteness. Math's roots are in the realm of the concrete, and imagery is the link to mathematical processing, retention, and application.

To develop concept and numeral imagery, the *On Cloud Nine®* math program (developed by the authors) integrates and consciously applies imagery to the cognitive process of computing and conceptualizing math and mathematical principles. As individuals become familiar with the concrete manipulatives, they are *questioned* and *directed* to consciously transfer the experienced to the imaged. They image the concrete and attach language to their imagery. The integration of imagery and language is then applied to computation. Individuals develop the sensory-cognitive processing to understand and use the logic of mathematics.

The program moves through three basic steps to develop mathematical reasoning and computation using: 1) manipulatives to experience the reality of math, 2) imagery and language to concretize that reality in the sensory system, and 3) computation to apply math to problem solving. *On Cloud Nine®* manipulatives serve two purposes: 1) to concretize numbers and mathematical concepts, and 2) to serve as a base for establishing imagery.

When asked to add the numbers 3 + 2, children who are drawing on their vault of images may see 3 apples and 2 more oranges to show 5 pieces of fruit. Others may draw on an image of a number line and place their mental finger on the 3 as a starting point. The "+" tells them to move forward and the "2" indicates how many places. They know the answer because they can "see it" in their mind's eye. These children may look up as they access their images (defocusing).

Children who don't seem to have a vault of images may say things like "I don't remember that one." They need explicit instruction in imaging the concrete and applying that imagery to the computation.

How does imaging as a conscious process work? The *On Cloud Nine®* math program begins with numbers in isolation—numeral imagery. A student is asked to view the written numeral, and then it is taken away. The student must demonstrate the "number" underlying the numeral by showing how many cubes represent that number. The student sees, says, and writes the number in the air. The goal is for the student, when she sees the numeral, to immediately create an image of the formation of that number and the value behind it.

The process continues with experiencing the number line, first as a concrete manipulative, then as a flexible mental image. "Show me where you see the number 15?" "What's the number one step up from that?" "Is the 3 close to the 15 or quite far away?" "What number is closer to the 15 – the 10 or the 5?" Students develop a number line they carry with them in their vault of images. These students can access their vault of images at will. Conscious imagery and the ability to simultaneously create images and verbalize these imaging—dual coding—are continued as children are taught addition, subtraction, word problems, multiplication, division and more advanced math.

On Cloud Nine® math integrates and consciously applies imagery to the cognitive process of computing and conceptualizing math and mathematical principles. Children image the concrete and attach language to their imagery. The integration of imagery and language is then applied to every aspect of mathematical computation.

All children can develop the sensory-cognitive processing to understand and use the logic of mathematics. In every aspect of math, children can have access to what becomes an innate bank vault of imagery for memory and computation.

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