Mathematical Skills

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Mathematical Skills are essential for understanding how the world works and for solving problems that are important to human survival and prosperity. They are used in everyday living in societies across the world. The most basic mathematical skills involve estimating the amount of small sets of items without using symbols, called *number sense*, and tracking a small number of individual objects through space and time, called *parallel individuation*. These skills are thought to be present at birth or early in life and to increase in precision into adulthood.

Number sense serves as the foundation for counting and simple arithmetic and geometry skills that are developed during infancy and early childhood through social interactions and children's play and exploration of environments. During the toddler and preschool years, children develop understanding of several principles of counting, including that each item being counted is associated with one number name, called *one-to-one correspondence*; number names always have the same order, called *stable-order*; the final number counted represents the quantity of the set, called *cardinality*; any set of items can be counted, called *abstraction*; and the order that things are counted does not matter, called *order-irrelevance*.

More complex mathematical skills, including advanced arithmetic, algebra, and geometry, are typically taught within the context of formal schooling and require extensive practice. Mathematical skills taught in school focus on learning symbol systems, concepts, and procedures for solving complex problems across settings. During the elementary years, children develop a conceptual understanding that the quantity of a set does not change when it is

rearranged, called *conservation of number*, which is important for learning arithmetic skills, such as addition, subtraction, multiplication, and division. Children also learn problem solving strategies, including fact retrieval, decomposition, and formulas. A variety of tools makes learning mathematical skills more engaging and contextualized, including manipulatives, such as counters, ten frames, cubes, number lines, and fraction strips, and card, dice, and online games and apps. Calculators and computers afford students with opportunities for performing more complex mathematical operations, including modeling and graphing. The Common Core State Standards for Mathematics emphasize the following domains: Counting and Cardinality, Operations and Algebraic Thinking, Number and Operations in Base Ten and Fractions, Measurement and Data, Geometry, Ratios and Proportional Relationships, The Number System and Quantity, Expressions and Equations, Functions, Modeling, and Statistics and Probability. These skills are used in a variety of trades and careers, especially in highly industrialized and technological societies emphasizing Science, Technology, Engineering, and Mathematics (STEM).

Three major neurocognitive systems are theorized to support mathematical skills. The *quantity system*, or number sense, may be used to meaningfully represent size and distance relations between quantities. It is used during tasks such as numerosity estimation, number comparison, approximate addition, and subtraction and engages a horizontal segment of the intraparietal sulcus (HIPS) brain region. The *verbal system* represents and manipulates number words during counting, retrieval of memorized addition and multiplication facts, and exact calculation, and engages general-purpose language modules and a region of the left angular gyrus. The *visual system* represents and spatially manipulates numbers using a visual symbol system, which is commonly Arabic numerals, to perform arithmetic when memorized facts

cannot be retrieved, and engages the posterior superior parietal lobe. Visuospatial skills, such as visual attention and search, pattern processing, visual imagery, mental rotation, and visuospatial working memory, as well as domain-general cognitive processes, such as executive function, are used in conjunction with mathematical skills.

Individuals can experience difficulties in any of the systems that support mathematical skills. Research suggests several instructional strategies for students who experience mathematical difficulties, including using formative assessment to plan instruction, allowing students to think aloud during problem solving, using explicit instruction with visual representations, and arranging peer-assisted activities. A variety of interventions with scientific evidence are available for individuals who experience mathematical difficulties.

Further Readings

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