How children learn mathematics has been the focus of research for many years. The research base has developed with theories from mathematics education, educational psychology and cognitive psychology (e.g. Geary, 1990; Ginsburg, 1997; Rousselle and Noel, 2007; Wright, 1994). Math educators have used this research to help guide instructional practices and to help them make sound instructional decisions. Recently, brain-imaging technology has brought the field of neuroscience into the study of teaching and learning mathematics. Imaging technologies have allowed scientists to determine which areas of the brain are active when the mind is engaged in mathematics. This technology has given researchers and educators a new piece of the learning puzzle. It is now possible to compare learning theories in mathematics to neurological analyses of how the brain physically functions while it is doing mathematics. In this book David Sousa links research and theory in mathematics teaching and learning to emerging research in neuropsychology. He reviews knowledge of the human brain’s evolution and physiology, as well as current theories about teaching and learning and merges that knowledge with new information from brain imaging.

In the first two chapters of *How the Brain Learns Mathematics*, Sousa traces a genetic history of number sense using research from cognitive science and psychology. He begins with the assertion that people have an innate number sense (p.9). He cites experiments, such as infant gaze studies that suggest a basic and innate sense of number. In these gaze studies, babies are shown images of sets of two objects and sets of three objects. The babies consistently look for longer periods of time at the sets of three objects. This finding indicates that babies can detect differences in quantity at very early ages. Mathematics may be viewed as a subject learned in school but this
research suggests that number sense may be hardwired in our brains.

Sousa also uses research on brain function to further support the notion that humans may have innate mathematics ability. Brain imaging has shown that the region of the brain that controls finger movement is the same as the region attached to counting (p.15). While Sousa concedes that it is not known if the proximity of the two brain functions is purely a coincidence, it is still interesting that finger movement and counting are such close neurological neighbors.

After developing a genetic foundation for mathematical thinking, Sousa moves to a brain imaging based explanation of memory and learning. He organizes the chapters according to three age bands; kindergarten, preadolescence and adolescence in order to highlight the differences in the developing brain and the impact of those differences on students’ ability to learn mathematics. Sousa approaches the study of each of the age bands through the lens of cognitive and educational theory. He skillfully layers information from brain scans to show the parts of the brain that are active during different mathematics activities. This section of the book is particularly relevant to classroom teachers who are interested in tailoring mathematics instruction to children’s cognitive and neurological development.

From an instructional perspective, Sousa emphasizes meaning based teaching for all age bands. He makes a case for meaning based instruction by drawing primarily on memory research. He advocates using mathematical reasoning and meaning based activities because new learning that is meaning based has been linked to long-term retention in memory (p.56). As an advocate for meaning based learning, Sousa argues that a topic like the division of fractions is best taught through the use of models that help students construct the meaning of the operation and the quantities. He discourages the use of tricks in teaching topics like the division of fractions. “Just invert and multiply” may help students store the procedure for the division of fractions but it is unlikely to help them connect the division of fractions to larger mathematical ideas.

Sousa also advocates that teachers attend to research on memory when planning lessons. Teachers who plan with knowledge of working memory understand that students can only hold about five or six new pieces of information in their working memory. Teachers who limit the number of objectives per lesson increase the likelihood that their students will remember more of the information in the lesson (p.201).

Sousa dedicates a chapter to recognizing and addressing mathematics difficulties. The chapter addresses environmental, neurological and other factors that may contribute to these difficulties and even disabilities. Sousa argues that a teacher’s perceptions about how children should be taught and assessed can influence how a disability is perceived or diagnosed (p.164). A child who struggles with rote memorization, for example, might be diagnosed as learning disabled by an instructor who relies heavily on memory-based instruction. That same child might have strengths in problem solving and would not be diagnosed as learning disabled by a teacher who attends to problem solving over rote memorization.

Environmental and instructional settings that make a child feel anxious may also contribute to mathematics difficulties. Sousa documents some of the physiological effects of stress and anxiety on memory and cognitive function (p.172) and offers
suggestions for teachers who are interested in developing mathematics learning environments that mitigate anxiety.

Sousa also explores physiological aspects of mathematics learning disabilities. The use of functional magnetic resonance images (fMRI) to diagnose and monitor learning disabilities is an emerging field in neuroscience. Scientists are using fMRI to compare the brains of children with learning disabilities to those of children who are functioning normally in school. Sousa includes images from fMRI to compare students with dyscalculia, a mathematics disability, to the brains of typically functioning children (p.181). The images suggest that the brains of students with learning disabilities are physiologically different from students who do not have learning disabilities.

Sousa draws attention to a promising new avenue for educational research. Brain imaging is potentially promising as an additional lens to define and diagnose mathematics learning disability- but the field is still new. On one hand, some researchers (e.g. Temple et al., 2003) have used brain imaging to measure differences in the brains of learning disabled and non learning disabled children and then measure the changes in the learning disabled brains as a result of instruction. On the other hand, a shortcoming of this book is that Sousa does not point out the relative newness of the use of brain imaging in diagnosing disability in children. In other fields, there is criticism of the use of brain imaging for clinical diagnoses. The American Psychological Association, for example, does not support the use of brain imaging for the clinical diagnosis of mental illness in adolescents (Council on Children Adolescents and their Families, 2005) because they argue that there are as many differences within the categories of normal and abnormal brains as there are across categories.

In the final chapters, Sousa offers many instructional suggestions and activities that teachers can use in the classroom. Some of the suggestions, such as organizing the class period to correspond with the most attentive periods for children (p. 205), correspond directly to research. A weakness of the book is that some of the suggestions for classroom practice do not seem consistent with the research. For example, Sousa suggests that students use a mnemonic to help them memorize the procedure for multiplying fractions. This suggestion is contrary to the arguments for meaning based instruction that he develops throughout the book.

In spite of its weaknesses, this book can support classroom teachers who are interested in using research-based approaches to design brain compatible instruction. The book may also appeal to a broader audience of non-educators who are interested in the popular topics of brain imaging and brain based learning. Sousa’s book is an enjoyable and informative read that makes research from mathematics education, cognitive science, psychology and neuro-psychology accessible to a broad audience.
References


